COMPREHENDING THE

2026

NATIONAL ELECTRICAL CODE®

VOLUME 1

ARTICLES 90–480

The Essential Guide to
Electrical Safety, Compliance, and Industry Standards

NEC®

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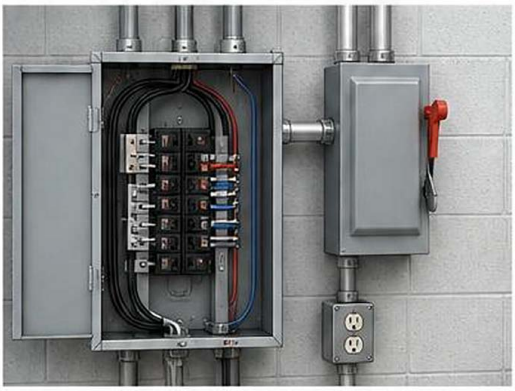

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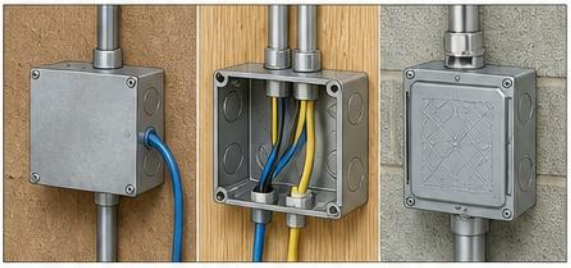

Boxes and conduit bodies enclose and protect splices, terminations, and devices while providing access for future maintenance.

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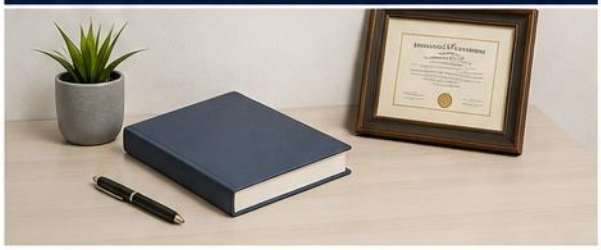

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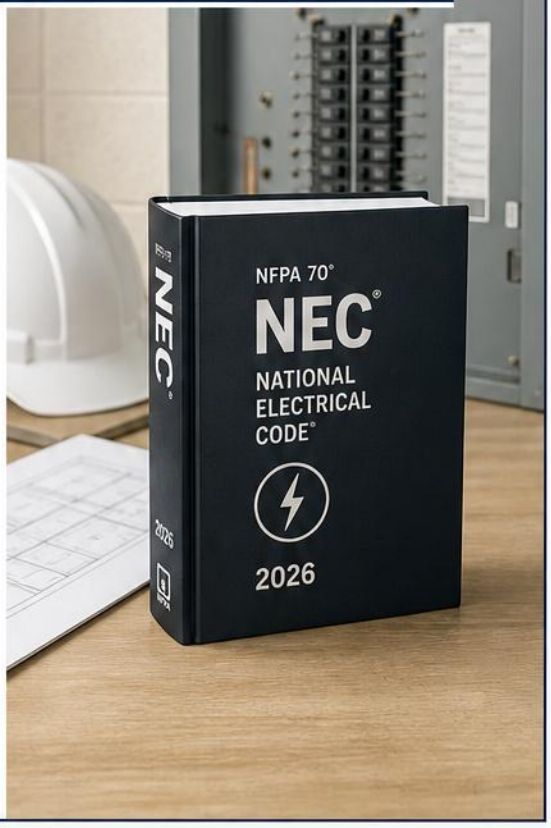
HOW TO USE THE *NATIONAL ELECTRICAL CODE*

Introduction to How to Use the *National Electrical Code*

The original *NEC* document was developed in 1897 as a result of the united efforts of various insurance, electrical, architectural, and other cooperative interests. 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 your 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 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 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, assist you in what you're trying to 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 contains the definitions of terms used throughout the *Code*. For example, the term "Dwelling Unit" is found in many articles. If you don't know the *NEC* definition for a "dwelling unit" you can't properly identify its *Code* requirements. Another example worth mentioning is the term "Outlet." For many people, it has always meant a receptacle—not so in the *NEC*!

Where a definition is unique to a specific article, the article number is indicated at the end of the definition in parentheses (xxx). For example, the definition of "Pool" is specific to Article 680 and ends with (680) because it applies ONLY to that article. Definitions of standard terms, such as volt, voltage drop, ampere, impedance, and resistance, are not contained in Article 100. If the *NEC* does not define a term, then *Merriam-Webster's Collegiate Dictionary*, 11th edition, or the applicable building code acceptable to the authority having jurisdiction should be consulted.

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 that 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.

The meaning of a rule is heavily influenced by both grammar and punctuation. Where a comma is placed can completely change what a rule requires. For instance, in 250.28(A), the statement requires that a main bonding jumper be a wire, bus, screw, or other comparable conductor. If the comma between "bus" and "screw" is removed, then only a "bus screw" would be an acceptable option. That small comma significantly changes the requirement for the rule.

Slang Terms or Technical Jargon

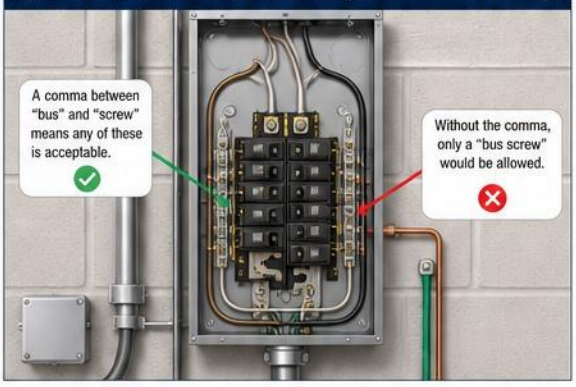
Professionals in the construction trades across the country often use local "slang" terms that aren't universally understood. This can make communication challenging if you don't know what those terms mean. Before using them, take time to look up their definitions and proper applications. For example, the word "pigtail" commonly refers to a short length of conductor used to connect a device to a splice, but it is also used to describe a rubberized light socket with pre-terminated conductors. Although both uses involve the same word, they refer to very different things and can easily cause confusion. Likewise, terms such as "splice" and "tap" are frequently used interchangeably in the field, yet they describe two distinct concepts. The consistent use of the terminology defined in the *Code* helps ensure that every person understands exactly the same thing, no matter where they are located.

NEC Style and Layout

Understanding the structure and writing style of the *Code* is essential for using it effectively. The *National Electrical Code* is organized using twelve major components.

1. Table of Contents
2. Chapters—Chapters 1 through 9 (major categories)
3. Articles—Chapter subdivisions that cover specific subjects
4. Parts—Divisions used to organize article subject matter
5. Sections—Divisions used to further organize article subject matter
6. Tables and Figures—Represent the mandatory requirements of a rule
7. Exceptions—Alternatives to the main *Code* rule
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

Figure 1 Correct Use of Commas Can Change a Requirement NEC 250.28(A)



Punctuation, such as a comma, can completely change the intent and requirements of a rule.

1. TABLE OF CONTENTS

The Table of Contents shows how the *Code* is organized—listing chapters, articles, parts, and the page numbers where they begin. It's an excellent tool that can be referenced regularly to see how the different *NEC* components relate to one another. When you need rules for a specific situation, checking the Table of Contents helps you quickly locate the exact *NEC* rule that applies.

2. CHAPTERS

The *Code* consists of nine chapters, each broken down into articles. Articles are grouped into four main categories: 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—Specific Occupancies and Locations
Chapter 6—Specific Equipment
Chapter 7—Specific Conditions and Systems
Chapter 8—Communications Systems Outside and Entering Buildings (Telephone, Data, Satellite, Cable TV, and Broadband)
Chapter 9—Tables—Conductor and Raceway Specifications

3. ARTICLES

The *NEC* includes approximately 160 articles, each addressing a specific subject. It starts with Article 90, Introduction to the *Code*, which explains the purpose of the *NEC*, what is covered and what is not covered, and how the *Code* is organized. It also provides guidance on enforcement, the writing of mandatory and permissive rules, and the inclusion of explanatory material. Article 90 further offers information on formal interpretations, equipment testing for safety, wiring design planning, and formatting requirements for measurement units. Here are some additional examples of articles found in the *NEC*.

Article 110—General Requirements for Electrical Installations
Article 210—Load Calculations
Article 210—Branch Circuits
Article 250—Grounding and Bonding
Article 300—General Requirements for Wiring Methods and Materials
Article 334—Nonmetallic-Sheathed Cable
Article 406—Wiring Devices
Article 430—Motors, Motor Circuits, and Motor Controllers
Article 500—Hazardous (Classified) Locations
Article 555—Marinas, Boatyards, and Docking Facilities
Article 680—Swimming Pools, Fountains, and Similar Installations
Article 690—Solar Photovoltaic (PV) Systems
Article 705—Interconnected Electric Power Production Sources
Article 720—Limited-Energy Systems

4 Parts. Longer articles are divided into parts. Each part of a *Code* article is identified in the section numbers, which help you remember the "part" in an *NEC* rule related to a specific topic. For example, Table 110.34(A) provides working space clearances for electrical equipment. If we are not careful, we might assume this table applies to every electrical installation, but Table 110.34(A) appears in Part III, which includes only requirements for "Over 1,000 Volts, Nominal" installations. Rules for working clearances for electrical equipment systems of 1,000V, 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 organized as a "Code Section." A *Code* section can be divided into subdivisions: first level subdivisions are shown in parentheses like (A), (B),…, the next level are second level subdivisions in parentheses like (1), (2),…, and the third level subdivisions use lowercase letters such as (a), (b), and continue in that pattern.

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

Note: According to the *NEC Style Manual*, first and second level subdivisions must have titles. A title for a third level subdivision is permitted but not required.

Many in the industry incorrectly use the term "Article" when referring to a *Code* section. For example, they may say "Article 210.8," when they should say "Section 210.8." Section numbers in this textbook are shown without the word "Section," unless they start a sentence. For example, Section 210.8(A) is shown as simply 210.8(A).

6 Tables and Figures. A large number of *NEC* requirements are presented in tables that list *Code* rules in a systematic sequence. Table titles are extremely important; read them carefully so you understand the scope, applications, and limitations of each one. Notes are sometimes provided inside a table or just below it; be sure to read these as they are also part of the requirement.

For example, Note 1 for Table 300.7(A) describes how to measure the cover when burying cables and raceways, and Note 5 explains what must not be encountered in soil.

7 Exceptions. Exceptions are *NEC* requirements or permissions that offer an alternative approach to a specific rule. There are two kinds of exceptions: mandatory and permissive. When a rule includes several exceptions, those with mandatory requirements are listed before the permissive exceptions.

Figure 1 Working Space in Front of Electrical Equipment 110.34(A)

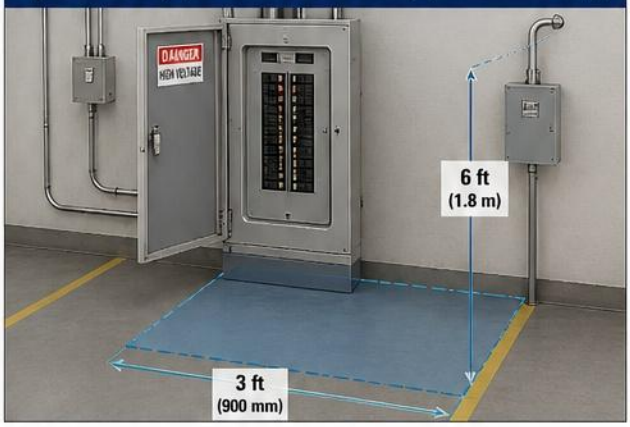


Table 110.34(A) specifies minimum working space clearances in front of electrical equipment.

Mandatory Exceptions. A mandatory exception uses the words "shall" or "shall not." The term "shall" in an exception indicates that if you meet the exception, you must do it in that specific manner. The phrase "shall not" means the action is not allowed.

Permissive Exceptions. A permissive exception uses wording such as "shall be permitted," meaning the action is acceptable (but not required) in that situation.

8 Informational Notes. An Informational Note offers explanatory material intended to clarify a rule or offer guidance, but it is not a *Code* requirement.

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

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

Annex A.	Informational References
Annex B.	Application Information for Ampacity Calculation
Annex C.	Conduit, Tubing, and Cable Tray Fill Tables for Conductors and Fixture Wires of the Same Size
Annex D.	Examples
Annex E.	Reserved
Annex F.	Availability and Reliability for Critical Operations Power Systems (COPS), and Development and Implementation of Functional Performance Tests (FPTs) for Critical Operations Power Systems
Annex G.	Supervisory Control and Data Acquisition (SCADA)
Annex H.	Administration and Enforcement
Annex I.	Recommended Tightening Torque Tables from UL Standard 486A-486B
Annex J.	Reserved
Annex K.	Use of Medical Electrical Equipment in Dwellings and Residential Board-and-Care Occupancies
Annex L.	Proposed Organization of the 2029 *National Electrical Code*

11 Index. The Index at the back of the *NEC* helps you locate a particular rule by using relevant keywords.

12 Changes to the Code. Updates in the *NEC* are shown as follows:

- New or modified rules since the last edition are identified by shading the revised text.
- Brand-new rules are not shaded; instead, a shaded "N" appears in the left margin beside the section number.

- Relocated rules are treated like new rules with a shaded "N" in the left margin by the section number.
- Deleted rules are indicated by a bullet symbol " • " located in the left margin where the rule was in the previous edition. Unlike older editions, the bullet symbol is only used where one or more complete paragraphs have been deleted.
- A "Δ" represents partial text deletions and or figure/table revisions somewhere in the text. There's no specific indication of which word, group of words, or sentence was deleted.

How to Locate a Specific Requirement

How to go about finding what you're looking for in the *Code* book depends, to some degree, on your experience with the *NEC*. Experts typically know the requirements so well that they just go to the correct rule. Very experienced people might only need the Table of Contents to locate the requirement they're looking for. On the other hand, average users should use all the tools at their disposal, including the Table of Contents, the Index, and the search feature on electronic versions of the *Code* book.

Let's work through a simple example: What *NEC* rule specifies the maximum number of disconnects permitted for a service?

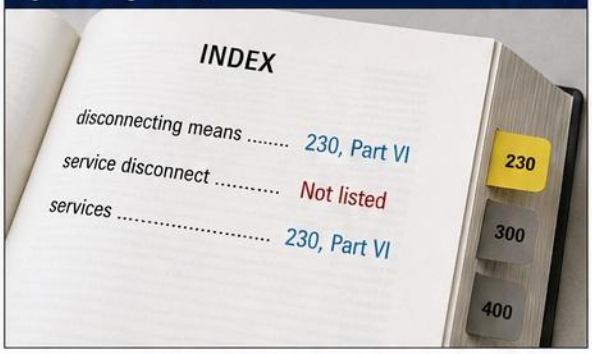
Using the Table of Contents. If you're an experienced *Code* user, you might use the Table of Contents. You'll know Article 230 applies to "Services," and because this article is so large, it's divided up into multiple parts (eight parts to be exact). With this knowledge, you can quickly go to the Table of Contents and see that it lists the Service Equipment Disconnecting Means requirements in Part VI.

Author's Comment:

The number "70" precedes all page numbers in this standard because the *NEC* is *NFPA Standard Number 70.*

Using the Index. If you use the Index (which lists subjects in alphabetical order) to look up the term "service disconnect," you'll see there's no listing. If you try "disconnecting means," then "services," you'll find that the Index indicates the rule is in Article 230, Part VI. Because the *NEC* doesn't give a page number in the Index, you'll need to use the Table of Contents to find it, or flip through the *Code* book to Article 230, then continue to flip through pages until you find Part VI.

Figure 1 Using the Index — *NEC* – Index



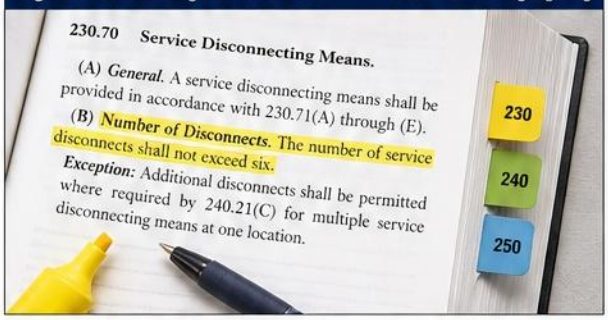
The Index is an alphabetical list of subjects. Use related terms if your first search term isn't listed.

With enough exposure to the use of the *NEC*, you'll discover that some words and terms are often specific to certain articles. The word "solar," for example, will immediately send experienced *Code* book users to Article 690—Solar Photovoltaic (PV) Systems. The word "marina" suggests that what you seek might be in Article 555. There are times when a main article will send you to a specific requirement in another one in which compliance is required, in which case it will say (for example), "in accordance with 230.xx." Don't think of these situations as a "circle," but rather a map directing you to exactly where you need to be.

Customizing Your *Code* Book

One way to increase your comfort level with your *Code* book is to customize it to meet your needs. You can do this by highlighting and underlining important *NEC* requirements. Preprinted adhesive tabs are also an excellent aid to quickly find important articles and sections that are regularly referenced. However, understand that if you're using your *Code* book to prepare to take an exam, some exam centers don't allow markings of any type. For more information about tabs for your *Code* book, visit MichaelHayes.com/tabs.

Figure 2 Customizing Your *Code* Book — *NEC* – Tabs & Highlighting



Highlight and underline key requirements. Use tabs to quickly access frequently used articles and sections.

Highlighting. As you read through or find answers to your questions, be sure you highlight those requirements in the *NEC* that are the most important or relevant to you. Use one color, like yellow, for general interest and a different one for important requirements you want to find quickly. Be sure to highlight terms in the Index and the Table of Contents as you use them.

Underlining. Underline or circle key words and phrases in the *Code* with a red or blue pen (not a lead pencil) using a short ruler or other straightedge to keep lines straight and neat. This is a very handy way to make important requirements stand out. A short ruler or other straightedge also comes in handy for locating the correct information in a table.

Interpretations

Industry professionals often enjoy the challenge of discussing, and at times debating, the *Code* requirements. These types of discussions are important to the process of better understanding the *NEC* requirements and applications. However, if you decide you're going to participate in one of these discussions, don't spout out what you think without having the actual *Code* book in your hand. The professional way of discussing a requirement is by referring to a specific section rather than talking in vague generalities. This will help everyone involved clearly understand the point and become better educated.

In fact, you may become so well educated about the *NEC* that you might even decide to participate in the change process and help to make it even better!

BECOME INVOLVED IN THE *NEC* PROCESS

The actual process of changing the *Code* takes about two years and involves hundreds of individuals working to make the *NEC* as current and accurate as possible. As you advance in your studies and understanding of the *Code*, you might begin to find it very interesting, enjoy it more, and realize that you can also be a part of the process. Rather than sitting back and allowing others to take the lead, you can participate by making proposals and being a part of its development. For the 2026 cycle, there were over 3,933 Public Inputs and 1,800 Public Comments. This resulted in several new articles and a wide array of revised rules to keep the *NEC* up to date with new technologies and pave the way to a safer and more efficient electrical future.

Here's how the process works:

STEP 1—PUBLIC INPUT STAGE

Public Input. The revision cycle begins with the acceptance of Public Input (PI), which is the public notice asking for anyone interested to submit input on an existing standard or a committee-approved new draft standard. Following the closing date, the committee conducts a First Draft Meeting to respond to all Public Inputs.

Figure 1 First Draft Meeting 1.1.2

At the First Draft (FD) Meeting, the Technical Committee considers all Public Input and provides a response. The committee may use the input to develop First Revisions to the standard. The First Draft documents consist of the initial meeting consensus of the committee by simple majority. However, the final position of the Technical Committee must be established by a ballot which follows.

Committee Ballot on First Draft. The First Draft developed at the First Draft Meeting is balloted. In order to appear in the First Draft, a revision must be approved by at least two-thirds of the Technical Committee.

First Draft Report Posted. First revisions which pass ballot are ultimately compiled and published as the First Draft Report on the document's NFPA web page. This report serves as documentation for the Input Stage and is published for review and comment. The public may review the First Draft Report to determine whether to submit Public Comments on the First Draft.

STEP 2—PUBLIC COMMENT STAGE

Public Comment. Once the First Draft Report becomes available, there's a Public Comment period during which anyone can submit a Public Comment on the First Draft. After the Public Comment closing date, the Technical Committee conducts/holds their Second Draft Meeting.

Second Draft Meeting. After the Public Comment closing date, if Public Comments are received or the committee has additional proposed revisions, a Second Draft Meeting is held. At the Second Draft Meeting, the Technical Committee reviews the First Draft and may make additional revisions to the draft Standard. All Public 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 that 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.

Figure 2 Second Draft Report Posted 1.1.3

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 assuring 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.

Figure 3 Standards Council Meeting 1.1.4

Once all appeals concerning a standard have been reviewed and a decision has been made by the Standards Council—whether it is appropriate or not—the Standards Council may then issue the Standard as an official NFPA Standard. However, this decision is final and is subject only to a limited review by the NFPA Board of Directors. After that action, the new NFPA Standard becomes effective twenty days following the Standards Council's issuance.

TEMPORARY INTERIM AMENDMENT—(TIA)

Occasionally, a change to the *NEC* arises due to an emergency situation. An editing error may occur that could impact the safety of electrical installations—to the point that it might create a hazard. It could also be the result of a condition in the field that must be addressed right away and cannot wait for the standard *Code* cycle or the next edition of the standard.

When such circumstances exist, a TIA, or "Temporary Interim Amendment," can be submitted for consideration. The NFPA classifies a TIA as "tentative" because it has not been developed through the full standards-making process. It is considered interim since it is effective only between editions of the standard. A TIA automatically becomes part of the Public Input of the proposal for the next edition of the standard; therefore, it is subject to all steps in the standards-making process.

AUTHOR'S COMMENT:

- Proposals, comments, and TIAs can be submitted for consideration online at the NFPA website, **www.nfpa.org**. From the homepage, look for "Codes & Standards," then select "Standards Development," and click on "How the Process Works." If you'd like to see something changed in the *Code*, you are encouraged to participate in the process. Visit ***www.nfpa.org/process*** to view helpful videos about the process, the various stages, and how to get involved.

FIGURE 1 Standards Development Process — *NEC* Article 90

The *National Electrical Code* (*NEC*) is developed through a transparent, consensus-based process that includes public input, committee review, Standards Council approval, and final ratification by the NFPA Board of Directors.

ARTICLE 90 Introduction to the *National Electrical Code*

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

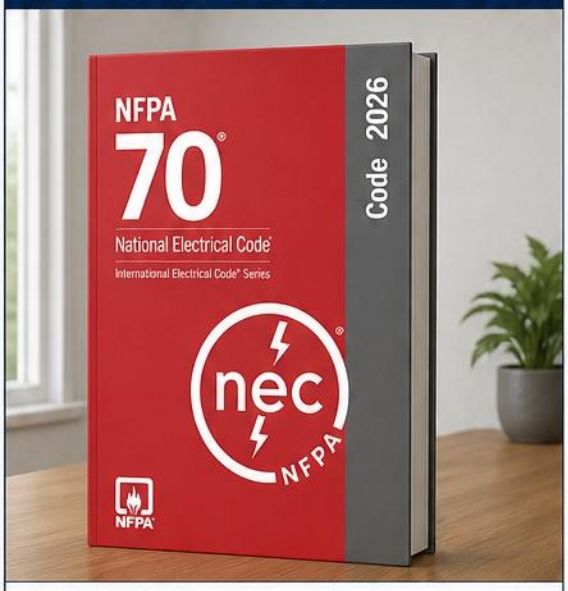
Article 90 describes the purpose of the *National Electrical Code* (*NEC*), when it applies, when it does not apply, who enforces the *NEC*, and the arrangement of the different chapters. Although the information is valuable, this article contains no actual requirements. It serves to provide the reader with only the scope and application of the *NEC*.

This article stands alone outside of the chapter structure of the rest of the *Code*, and it has no parts because it contains no requirements. Take the time to become familiar with the information contained in Article 90 before you begin diving into the *NEC*. Doing so will help you better understand when and how to apply the *NEC*.

90.1 Scope

Article 90 covers the use, application, arrangement, and enforcement of the *National Electrical Code*. Figure 90–1

Figure 90–1 Scope of Article 90 *NEC* 90.1



Article 90 addresses the use, application, arrangement, and enforcement of the National Electrical Code.

It also covers how mandatory, permissive, and nonmandatory text is expressed, provides guidance on the examination of equipment and wiring planning.

Author's Comment:

- The *NEC* is revised every three years through the NFPA Standards Development Process. It is overseen by the *National Electrical Code* Committee, which consists of a Correlating Committee and 18 Code-Making Panels. The responsibility of the committee is to ensure that the *Code* document minimizes the risk of electricity as a source of electric shock, and also as a potential ignition source of fires and explosions due to electrical installations.

90.2 Scope and Application of the *NEC*

(A) Scope of NEC.

(1) **Covered by the *NEC*.** The *Code* covers the installation and removal of electrical and limited-energy conductors, equipment, and raceways for the following areas:

(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. ▶Figure 90–2

Figure 90–2 Connection to the Serving Electric Utility *NEC* 90.2(A)(1)(3)

Conductors and equipment connected to the serving electric utility are included.

Figure 90–2 | Installations Covered *NEC 90.2(A)(1)*

The Code applies to the installation and removal of electrical conductors and limited-energy conductors, and to these systems:

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

(2) Yards, lots, parking areas, carports, and industrial sites.

(3) Conductors and equipment that are connected to the supply of electricity.

Author's Comment:
The *NEC* addresses removal of equipment and conductors because abandoned conductors and cables can increase the fire loading in a building.

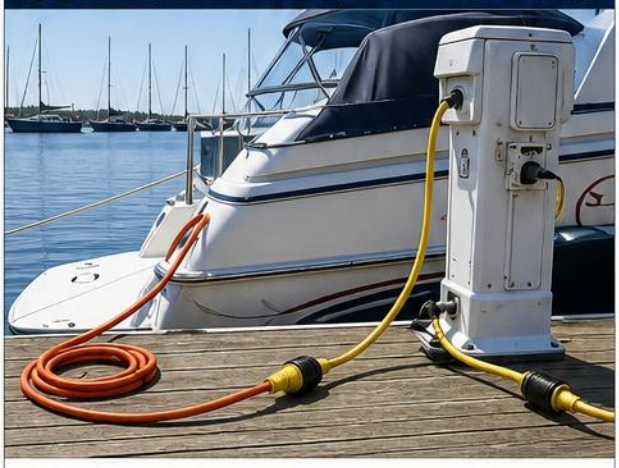
(4) Office buildings, warehouses, garages, machine shops, and recreational buildings used by the electric utility that are not an integral part of a utility's generating plant, substation, or control center.

Figure 90–3 | Installations in Utility Buildings *NEC 90.2(A)(1)(4)*

The Code applies to installations in office buildings, warehouses, garages, machine shops, and recreational buildings used by the electric utility that are not an integral part of a utility's generating plant, substation, or control center.

(5) Shore power to ships and watercraft in marinas and boatyards.

Figure 90–4 | Shore Power Installations *NEC 90.2(A)(1)(5)*



The Code covers installations of shore power to ships and watercraft in marinas and boatyards.

(6) Installations used to export power from vehicles to premises wiring or for bidirectional current flow.

Figure 90–5 | Vehicle-to-Premises Power Export *NEC 90.2(A)(1)(6)*

The Code covers installations used to export power from vehicles to premises wiring or for bidirectional current flow.

Author's Comment:
The battery power supply of some electric vehicles can be used bidirectionally, which means it can be used as an optional standby power source. The rules for this application are found in Article 625.

(2) Not Covered by the *NEC*. The Code does not cover installations of electrical or limited-energy systems for:

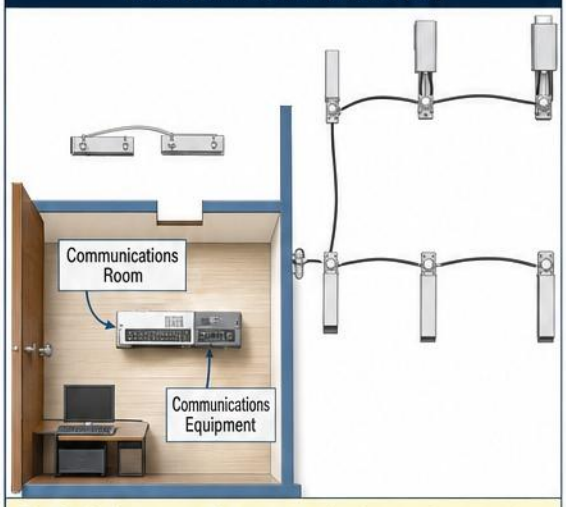
(1) The Code does not cover ships, watercraft (other than floating buildings), aircraft, or automotive vehicles.

(2) The *Code* does not apply to underground mines or to self-propelled mobile surface-mining equipment and the attendant electrical trailing cables.

(3) The *Code* does not apply to railway power, energy storage, or communications wiring.

(4) The *Code* does not apply to communications equipment under the exclusive control of the communications utility that is located outdoors or in building spaces used exclusively for those purposes. See Figure 90–6.

Figure 90–6 Communications Equipment Under Exclusive Control of Communications Utility 90.2(A)(2)(4)



The *Code* does not apply to communications equipment under the exclusive control of the communications utility located outdoors or in spaces used exclusively for those purposes.

Author's Comment:

- The *Code* continues to apply to electrical equipment (such as receptacles, switches, and luminaires) installed in areas used exclusively for utility communications equipment.

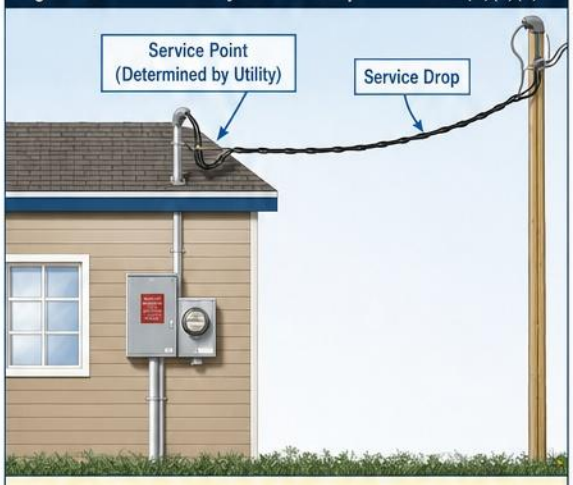
(5) The *Code* does not apply to installations under the exclusive control of a serving electric utility where those installations:

a. Include utility *service drops* or utility *service laterals* and associated metering. See Figure 90–7 and Figure 90–8.

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 electrical energy. See Figure 90–9.

c. Are in legally established easements or rights-of-way. See Figure 90–10.

Figure 90–7 Utility Service Drops 90.2(A)(2)(5)a.



The *Code* does not apply to installations under the exclusive control of a serving electric utility where they include service drops and associated metering.

Figure 90–8 Utility Service Laterals 90.2(A)(2)(5)a.

The *Code* does not apply to installations under the exclusive control of a serving electric utility where they include service laterals and associated metering.

Figure 90–9 Utility Installations on Utility Property 90.2(A)(2)(5)b.

The *Code* does not apply to installations on property owned or leased by the utility for purposes including communications, metering, generation, control, transformation, transmission, energy storage, or distribution of electrical energy.

Figure 90–10 Not Covered by the *NEC* Electric Utility Easements 90.2(A)(2)(5)c.

The *Code* does not cover installations on property that are located within legally established easements or rights-of-way.

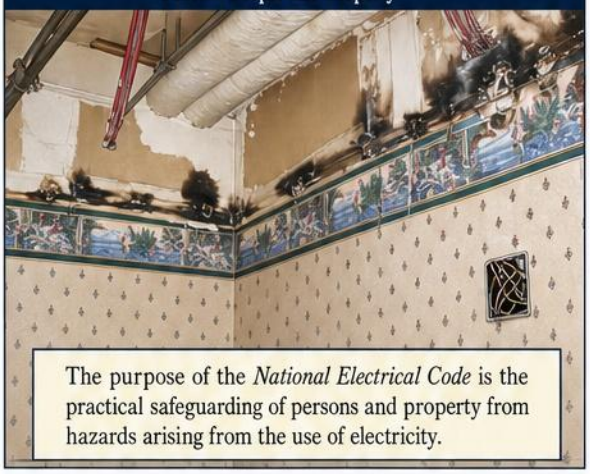
Author's Comment:

The electric utility industry uses *ANSI C2, National Electrical Safety Code (NESC)*, for safety requirements in the generation, transmission, distribution, and metering of electric energy—not the *NEC*.

(B) Purpose of the *NEC*.

Protect People and Property. The purpose of the *National Electrical Code* is the practical safeguarding of persons and property from hazards arising from the use of electricity. ▸Figure 90–11

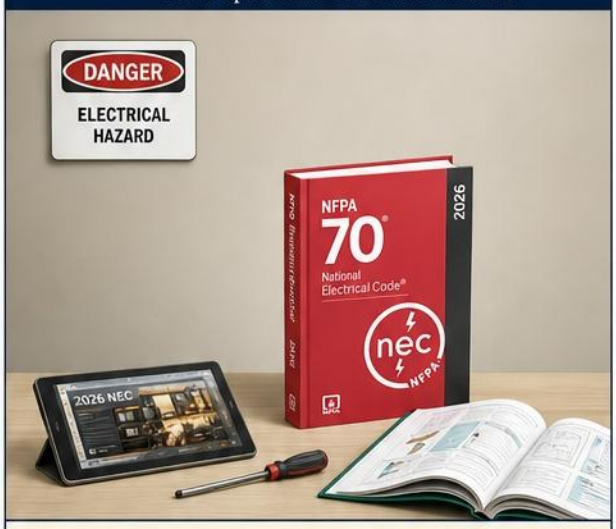
Figure 90–11 Purpose of the *NEC* Protect People and Property 90.2(B)



The purpose of the *National Electrical Code* is the practical safeguarding of persons and property from hazards arising from the use of electricity.

Not a Specification or Instruction Manual. The *NEC* is not a design specification or instruction manual for the untrained. ▸Figure 90–12

Figure 90–12 Purpose of the *NEC* Not a Specification or Instruction Manual 90.2(B)



The *NEC* is not a design specification or an instruction manual for the untrained.

Author's Comment:

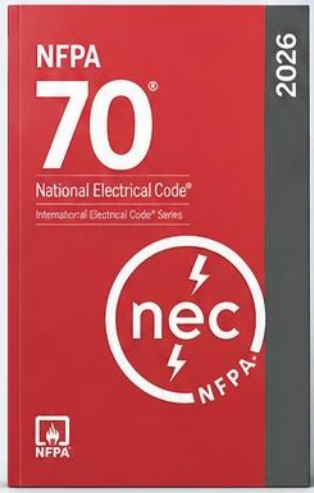
The *Code* is intended to be used by those who are skilled and knowledgeable in electrical theory, electrical systems, building/electrical construction, and installation/operation of electrical equipment.

(C) Essentially Safe Installation.

Considered Safe. The *NEC* contains requirements that are considered necessary for electrical safety.

Essentially Free from Hazards. Installations complying with the *Code* and properly maintained are considered essentially free from electrical hazards. ▸Figure 90–13

Figure 90–13 Essentially Free From Hazard 90.2(C)



The *NEC* contains requirements that are considered necessary for electrical safety. Installations complying with the *Code* and properly maintained are considered essentially free from electrical hazards.

NEC Rules Not Intended. The *NEC* provisions are not intended to ensure that every electrical installation will be efficient, convenient, adequate for good service, or appropriate for future growth.

Figure 90–14 NEC Rules Not Intended 90.2(C)

The *NEC* provisions are not intended to ensure that every electrical installation will be efficient, convenient, adequate for good service, or appropriate for future growth.

Note: Hazards frequently arise because the initial wiring did not allow for anticipated increases in electrical use, which can cause wiring systems to become overloaded.

Figure 90–15 Why Hazards Occur 90.2(C) Note

Hazards often occur because the initial wiring did not provide for increases in the use of electricity, resulting in wiring systems becoming overloaded.

Author's Comment:

The *NEC* does not require electrical systems to be designed or installed to accommodate future loads. However, consideration should be given not only to ensuring electrical safety (Code compliance), but also to meeting the customers' needs—both today and in the coming years.

(D) Relation to Other International Standards. The requirements in the *NEC* address the fundamental principles of protection for safety contained in the *International Electrotechnical Commission Standard 60364-1*.

Note: Fundamentals of protection for safety includes protection against electric shock, thermal effects, overcurrent, fault currents, and overvoltage.

90.3 Code Arrangement

The *NEC* consists of an Introduction (Article 90) and nine chapters, followed by informative annexes.

General Requirements, Chapters 1 through 4. The requirements contained in Chapters 1 through 4 apply generally to all electrical installations.

Specific Requirements, Chapters 5 through 8. The requirements in Chapters 5 through 8 are permitted to supplement or modify the requirements contained in Chapters 1 through 8.

Figure 90–16 Code Arrangement 90.3

Code Arrangement 90.3

The *NEC* consists of an introduction and nine chapters followed by informative annexes.

General Requirements	Specific Requirements
• Ch 1 - General • Ch 2 - Wiring and Protection • Ch 3 - Wiring Methods & Materials • Ch 4 - Equipment for General Use	• Ch 5 - Specific Occupancies and Locations • Ch 6 - Specific Equipment • Ch 7 - Specific Conditions and Systems • Ch 8 - Communication Systems, Outdoor and Entering Buildings
Chapters 1 through 4 apply generally to all electrical installations.	Chapters 5 through 8 may supplement or modify the requirements in Chapters 1 through 8.
• Chapter 9 - Tables Ch 9 tables are applicable as referenced in the *NEC*.	**• Annexes A through L** Annexes are for information only and are not enforceable.

Author's Comment:

In this textbook, Chapter 8 is not included because it only covers communication cables outside and where they enter buildings. The general requirements for communication cables are now covered in Article 720.

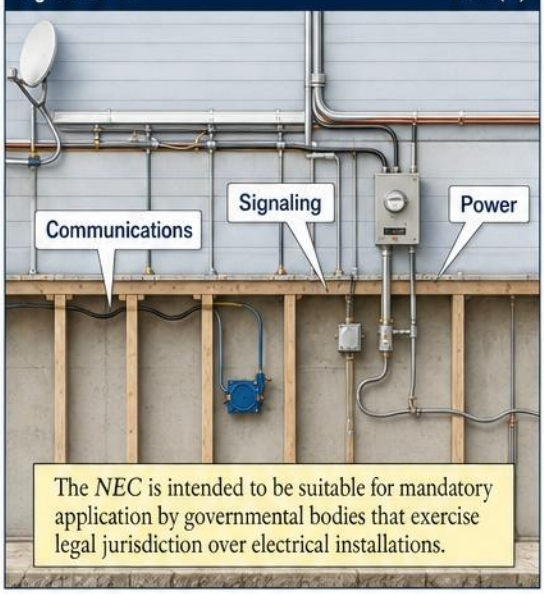
Tables, Chapter 9. Chapter 9 consists of tables that are referenced throughout the *NEC*. The tables are used to calculate raceway sizing, conductor fill, radius of raceway bends, and conductor voltage drop.

Informative Annexes. Annexes found in the back of the *NEC* are not part of the *Code* requirements but are included for informational purposes only.

90.4 *NEC* Enforcement

(A) Application. The *NEC* is intended to be suitable for mandatory application by governmental bodies that exercise legal jurisdiction over electrical installations. Figure 90–17

Figure 90–17 90.4(A)



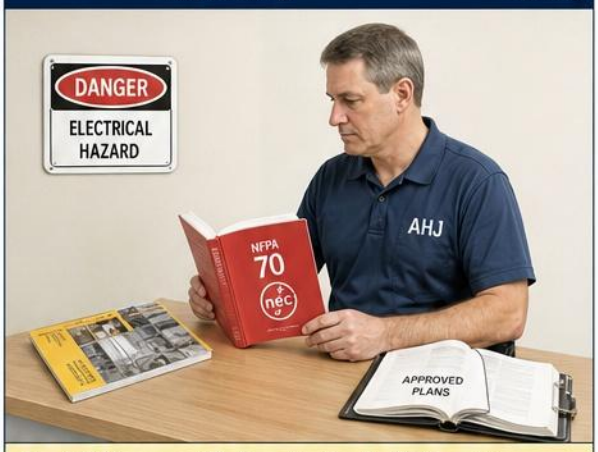
The *NEC* is intended to be suitable for mandatory application by governmental bodies that exercise legal jurisdiction over electrical installations.

Author's Comment:
Once the *NEC* has been adopted (in part, wholly, or amended), the *National Electrical Code* becomes statutory law for the adopting jurisdiction and is thereby considered a legal document.

(B) AHJ Responsibility. The *authority having jurisdiction (AHJ)* is responsible for enforcing the *NEC*, making interpretation of the rules, approving equipment and materials, and granting special permission. Figure 90–18

Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible for enforcing the *NEC* requirements and approving equipment, materials, or an installation. Figure 90–19

Figure 90–18 Authority Having Jurisdiction (AHJ) Responsibility 90.4(B)



The AHJ is responsible for enforcing the *NEC*, making interpretation of the rules, approving equipment and materials, and granting special permission.

Figure 90–19 Authority Having Jurisdiction (AHJ) *Article 100 Definition*

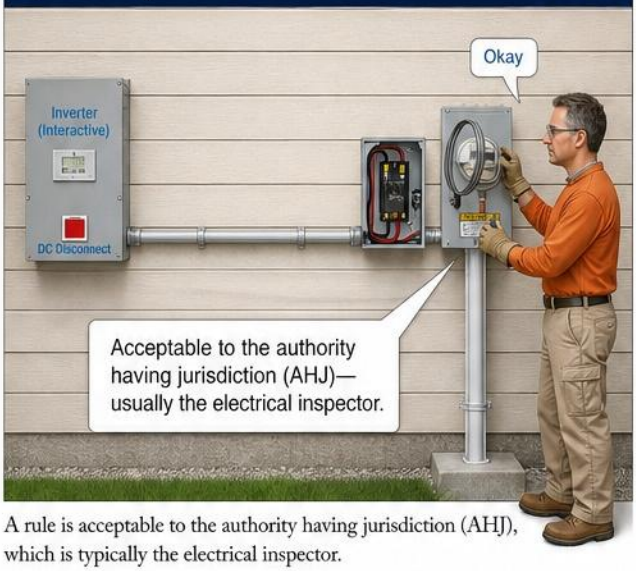
The organization, office, or individual responsible for enforcing the *NEC* requirements and approving equipment, materials, or an installation.

Approved. Acceptable to the authority having jurisdiction (AHJ)—usually the electrical inspector. Figure 90–20

Special Permission. Written consent of the authority having jurisdiction (AHJ).

(C) Waiving Requirements and Alternate Methods. By special permission, the authority having jurisdiction (AHJ) may waive *NEC* requirements or approve alternate methods where equivalent safety can be achieved and maintained. Figure 90–21

Figure 90–20 Approved Article 100 Definition — **Article 100**



A rule is acceptable to the authority having jurisdiction (AHJ), which is typically the electrical inspector.

Figure 90–21 Authority Having Jurisdiction (AHJ) Waiving Requirements and Alternate Methods — **90.4(C)**

With special permission, the AHJ can waive *NEC* requirements or approve alternate methods when equivalent safety is provided and maintained.

(D) Waiver of Product Requirements. If the *Code* requires products, constructions, or materials that are not available at the time the *NEC* is adopted, the authority having jurisdiction (*AHJ*) can allow products that were acceptable in the previous *Code*.

Author's Comment:

- Sometimes it takes years for testing laboratories to establish product standards for new *NEC* product requirements. It takes time before manufacturers can design, manufacture, and distribute those products to the marketplace.

90.5 Mandatory and Permissive Rules, and Explanatory Material

(A) Mandatory Rules. The words "shall" or "shall not" used in the *NEC* indicate that a rule is a mandatory requirement.

Author's Comment:

- For greater ease in reading this material, we will use the word "must" instead of "shall," and "must not" will be used instead of "shall not."

(B) Permissive Rules. The phrases "shall be permitted" or "shall not be required" used in the *NEC* indicate the rule application is optional.

Author's Comment:

- For greater ease in reading this material, the phrase "shall be permitted" (as used in the *NEC*) has been replaced with "is permitted" or "are permitted."

(C) Explanatory Material. Explanatory material referencing other publications, related *NEC* sections, or providing information related to a rule, is included in this *Code* in the form of informational notes or informative annexes. Informational notes and informative annexes are not enforceable as a requirement of the *NEC*.

Author's Comment:

- For convenience and ease in reading this material, "Informational Notes" will simply be identified as "Note."

(D) Informative Annexes. Nonmandatory information related to the use of the *NEC* is provided in informative annexes. Informative annexes are included for information purposes only and are not part of the enforceable requirements of the *NEC*.

90.7 Examination of Equipment for Safety

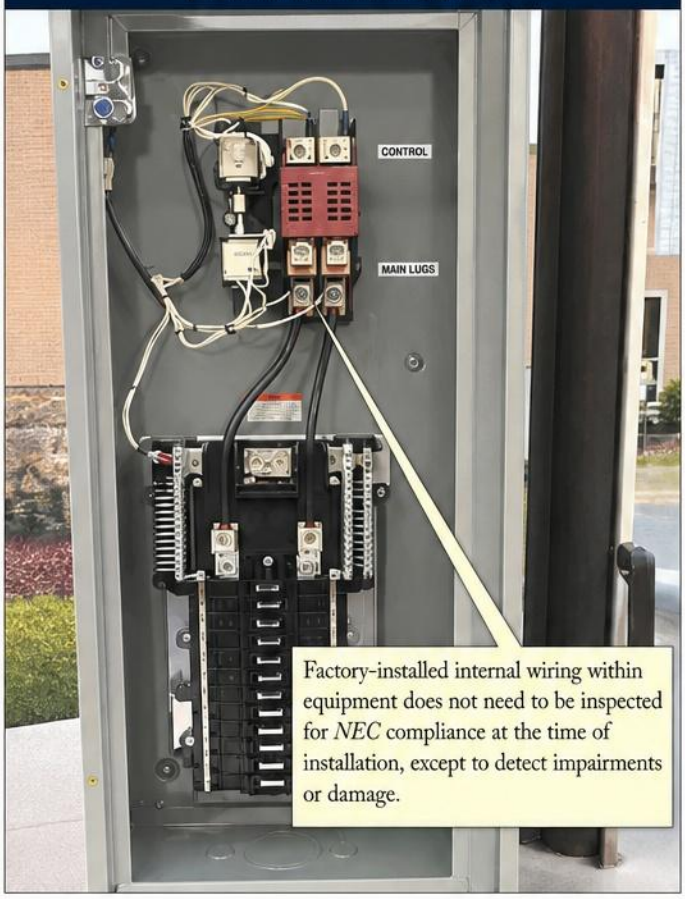
For specific equipment and materials referred to in this *Code*, examinations for safety are made under standard conditions. This provides a basis for approval where the record is made generally available through announcements by organizations, properly equipped/qualified for experimental testing, inspections of the run of goods at factories, and service-value determination through field inspections.

Performance evaluation of products for compliance, listing, and safety is commonly conducted by a Qualified Electrical Testing Laboratory (QETL) in accordance with the listing standards.

Except to detect impairments or damage, internal wiring that is factory installed within equipment does not have to be examined for *NEC* compliance during the time of installation.

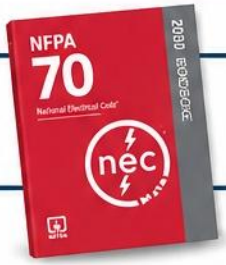
Listed. Equipment and materials included in a catalogue maintained by a product testing laboratory that is accepted by the authority having jurisdiction. The listing entity periodically inspects the production of that equipment or material to confirm it meets applicable designated standards and is appropriate for the intended use.

Figure 90–22 | Internal Wiring of Equipment Examination Not Required **90.7**



Internal wiring that is factory-installed in electrical equipment is not required to be examined for *NEC* compliance during installation, except to find impairments or damage.

ARTICLE 90 REVIEW QUESTIONS



Please use the 2026 *Code* book to answer the following questions.

1. The *NEC* does not apply to installations in _____ mines.

(a) above-ground
(b) underground
(c) overhead
(d) aerial

2. The *NEC* does not apply to installations under the exclusive control of an electric utility such as _____.

(a) service drops or service laterals
(b) electric utility office buildings
(c) electric utility warehouses
(d) electric utility garages

3. Electrical hazards frequently arise because the initial _____ did not account for increases in the use of electricity.

(a) inspection
(b) owner
(c) wiring
(d) builder

4. The requirements contained in _____ of the *NEC* apply generally.

(a) Chapters 1 through 4
(b) Chapters 2 through 5
(c) Chapters 3 through 6
(d) Chapters 5 through 7

5. Chapter 9 consists of _____ that apply as referenced in the *NEC*.

(a) tables
(b) informative annexes
(c) specific requirements
(d) all of these

6. The enforcement of the *NEC* is the responsibility of the authority having jurisdiction, who is responsible for _____.

(a) making interpretations of rules
(b) approval of equipment and materials
(c) granting special permission
(d) all of these

7. The authority having jurisdiction may waive specific *NEC* requirements or permit alternative methods where maintaining effective _____.

(a) safety
(b) workmanship
(c) installations
(d) job progress

8. Explanatory material referencing other information on a rule is included in the form of _____ or informative annexes.

(a) informational notes
(b) footnotes
(c) table notes
(d) italicized text

9. Information in informative annexes is _____.

(a) mandatory

(b) acceptable

(c) enforceable as a requirement of the *Code*

(d) included for information purposes only and are not enforceable requirements of the *Code*

10. Listed factory-installed _____ wiring of equipment does not need to be inspected for *NEC* compliance.

(a) external

(b) associated

(c) internal

(d) supplemental

CHAPTER

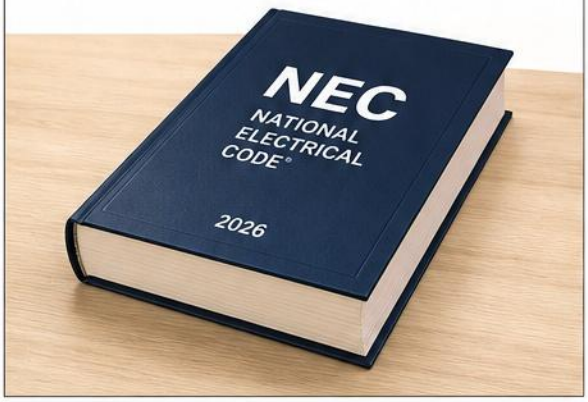
1 GENERAL RULES

INTRODUCTION TO CHAPTER 1—GENERAL RULES

Chapter 1—General Rules establishes the foundational requirements and definitions that apply throughout the *Code*. The following articles provide the general information needed to examine, approve, install, use, and gain access to electrical equipment and associated spaces.

Article 100—Definitions

Article 100 contains the definitions essential to the understanding and application of this *Code*.

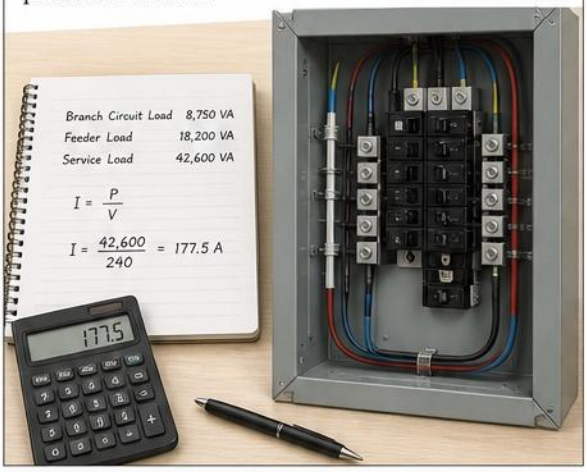


Article 110—General Requirements for Electrical Installations

This article contains the general requirements for the examination, approval, installation and use, and access to spaces around electrical equipment.

Article 120—Branch-Circuit, Feeder, and Service Calculations

This article provides the information required to determine the branch circuit, feeder, and service loads needed to size conductors and overcurrent protective devices.



Article 130—Energy Management Systems

This article addresses energy management systems that monitor and control the use of energy.

ARTICLE 90 INTRODUCTION

Article 90 contains requirements for electrical installations that affect more than one occupancy, or multiple structures, or both. This article covers the design, installation, and maintenance of electrical systems to ensure safety, reliability, and compliance across interconnected occupancies or structures.

It addresses the separation, identification, and operation of systems and equipment that serve more than one building or tenant space, and it helps prevent hazards that could impact adjacent occupancies or structures.

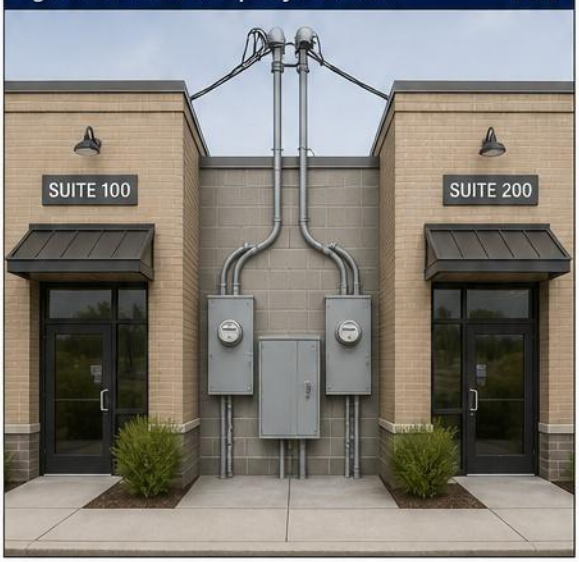
Working knowledge of Article 90 is essential for electricians, designers, and inspectors who work on multi-occupancy buildings, shared services, and interconnecting systems.

90.1 Scope

Article 90 includes all electrical installations that supply two or more occupancies, buildings, or structures. This includes requirements for equipment, raceways, conductors, and disconnecting means that cross occupancy or property boundaries.

Exceptions to Article 90 are found in 90.1(A) through 90.1(D).

Figure 90.1 Multi-Occupancy Installation **90.1**



Article 90 applies to electrical installations that supply more than one occupancy, building, or structure, including common service equipment and interconnections.

90.2 Application

The requirements of Article 90 apply where the installation involves the following:

(1) One or more service or feeder supplying two or more buildings or structures

(2) Shared equipment or systems that serve multiple occupancies

(3) Systems crossing property lines

(4) Common disconnecting means or overcurrent protection

(5) Metering equipment serving multiple occupancies

(6) Emergency and standby systems serving multiple buildings

(7) Interconnected power and communications systems

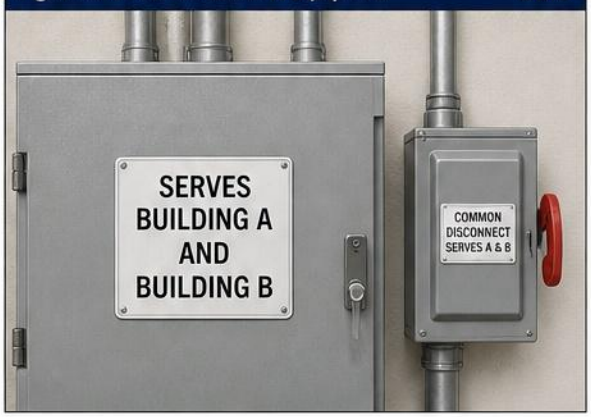
These installations require additional safeguards to ensure that a fault or shutdown in one occupancy does not unnecessarily affect others.

90.3 Identification

Electrical equipment, raceways, and disconnecting means serving more than one occupancy or structure must be permanently identified to indicate the areas or buildings served.

The identification must be legible, durable, and located where it is likely to be seen during maintenance or emergencies.

Figure 90.2 Identification of Equipment **90.3**



Equipment, raceways, and disconnecting means that serve more than one occupancy or structure must be permanently identified to indicate the areas or buildings served.

KEY POINTS

- Article 90 covers electrical installations that affect more than one occupancy, building, or structure.
- It addresses systems, equipment, and disconnecting means that cross occupancy or property lines.
- Identification of shared equipment is required to ensure safe operation and maintenance.
- Understanding Article 90 helps prevent hazards that could impact adjacent occupancies or structures.

ARTICLE 100

Definitions

Introduction to Article 100—Definitions

When discussing electrical installations, it is common practice in the industry to use terminology specific to the trade, often called "field" language. However, this field language is not appropriate for conveying the understanding and application of the *NEC*. For *NEC* rules, "*Code*" language must always be used. The first place to look for *Code* language is Article 100. You must review the definitions of terms in Article 100 before you can fully understand a *Code* requirement.

100 Scope

This article includes only the definitions that are necessary for applying the provisions of this *Code*. It is not intended to contain the general or technical terms defined elsewhere in related codes and standards.

Author's Comment:

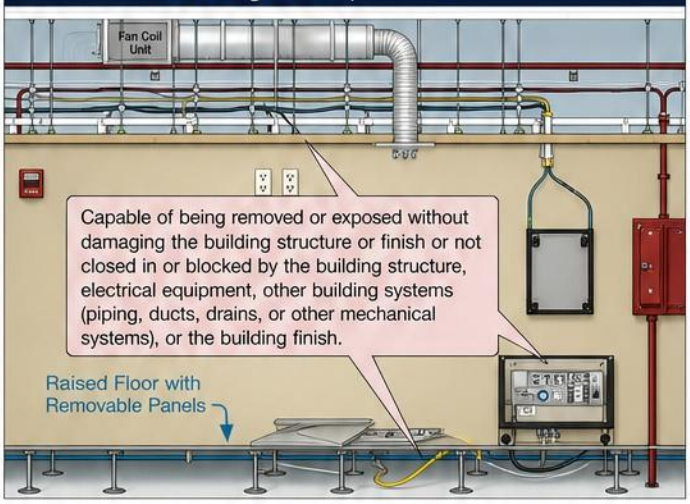
- If the *NEC* does not define a term, a *Webster's Collegiate* 11th edition dictionary or a building code definition that is acceptable to the authority having jurisdiction (AHJ) may be used.

Accessible *(as applied to wiring methods)*. Capable of being removed or exposed without damaging the building structure or finish or not closed in or blocked by the building structure, electrical equipment, other building systems (piping, ducts, drains, or other mechanical systems), or the building finish. See Figure 100–1.

Author's Comment:

- The wiring within a box located above a suspended ceiling that is blocked by mechanical duct work is an example of a violation of this requirement.

Figure 100–1 Accessible (as applied to wiring methods) NEC 100

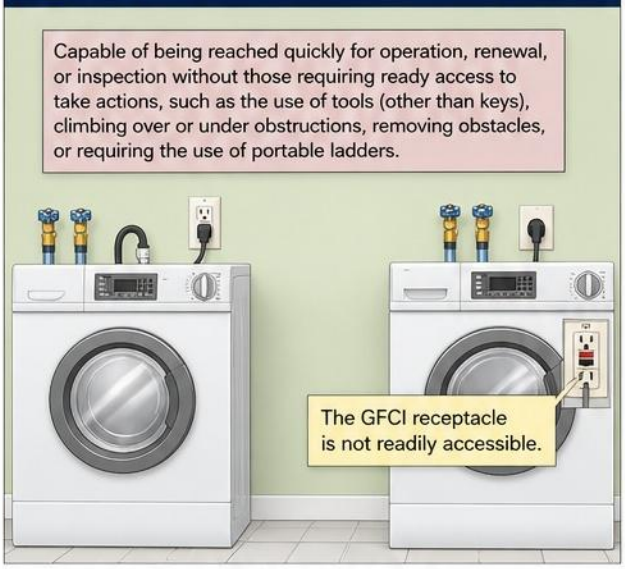


Describes wiring that can be removed or exposed without causing damage and is not concealed or blocked by building components.

Figure 100–2 Accessible, Readily Accessible NEC 100

Capable of being reached quickly for operation, renewal, or inspection without needed access actions—such as using tools (other than keys), climbing over or under obstructions, removing obstacles, or using portable ladders. See Figures 100–2 and 100–3.

Figure 100–2 Readily Accessible — *Article 100 Definition*

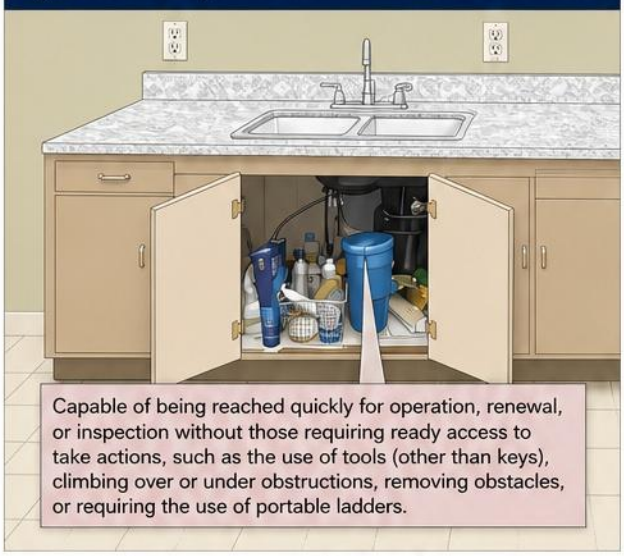


An example of equipment that is not readily accessible.

Figure 100–4 Adjustable-Speed Drive System — *Article 100 Definition*

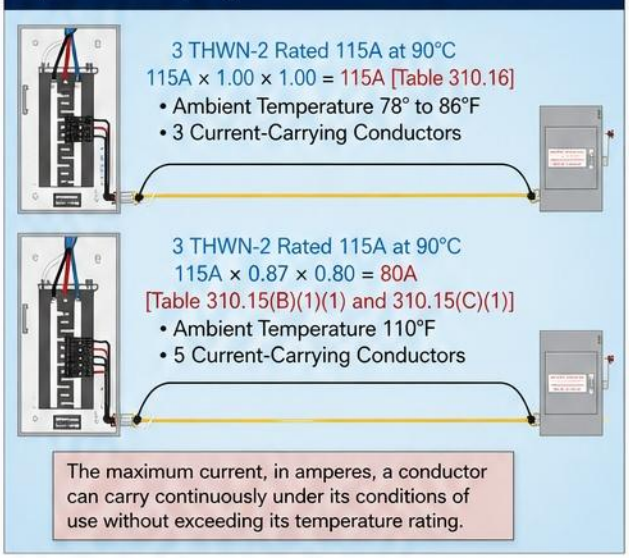
This illustrates an adjustable-speed drive system.

Figure 100–3 Readily Accessible — *Article 100 Definition*



An example of equipment that is readily accessible.

Figure 100–5 Ampacity — *Article 100 Definition*



Examples showing how ampacity is determined.

Adjustable-Speed Drive System. A combination of an adjustable-speed drive, its associated motor(s), and other associated equipment. [Figure 100–4]

Ampacity. The maximum current, in amperes, a conductor can carry continuously under its conditions of use without exceeding its temperature rating. [Figure 100–5]

Author's Comment:

- For details and examples of types of conductors suitable for the conditions of use, temperature ratings, and the ampacity corrections and adjustments depending on the condition of use of those conductors, see 310.14 and 310.15.

Approved. Acceptable to the authority having jurisdiction (AHJ)—usually the electrical inspector. [Figure 100–6]

Arc-Fault Circuit Interrupter (AFCI). A device intended to de-energize the circuit when it detects the current waveform characteristics unique to an arcing fault. [Figure 100–7]

Author's Comment:

- For parallel arching faults, the electronics within an AFCI will open the circuit if, within the last 30 half-cycle waveforms, it detects eight or more arcing waveforms of over 75A peak in accordance with *UL 1699, Standard for Arc-Fault Circuit Interrupters.* [Figure 100–8]

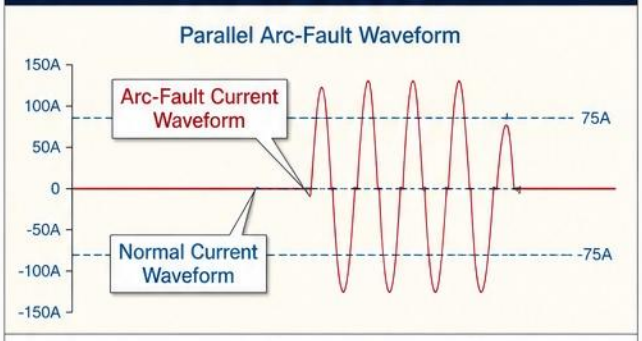
Figure 100–6 Approved *Article 100 Definition*

Material, equipment, or work that is acceptable to the authority having jurisdiction (AHJ)—typically the electrical inspector.

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 100–8 Arc-Fault Circuit Interrupter (AFCI) *Article 100 Comment*



The electronics within an AFCI will open the circuit if, within the last 30 half-cycle waveforms, it detects eight or more arcing waveforms of over 75A peak [UL 1699].

Author's Comment:

For series arcing faults, the electronic circuit within an AFCI will open the circuit within one second if it detects a carbonized conductive path of 5A or more at the AFCI-rated voltage (120V) in accordance with *UL 1699, Standard for Arc-Fault Circuit Interrupters.*

Attachment Plug. A wiring device at the end of a flexible cord inserted into a receptacle to make an electrical connection. **Figure 100–9**

Figure 100–9 Attachment Plug *Article 100 Definition*

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

Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible for enforcing the *NEC* requirements and approving equipment, materials, or an installation. **Figure 100–10**

Figure 100–10 Authority Having Jurisdiction (AHJ) *Article 100 Definition*

The organization, office, or individual responsible for enforcing the NEC requirements and approving equipment, materials, or an installation.

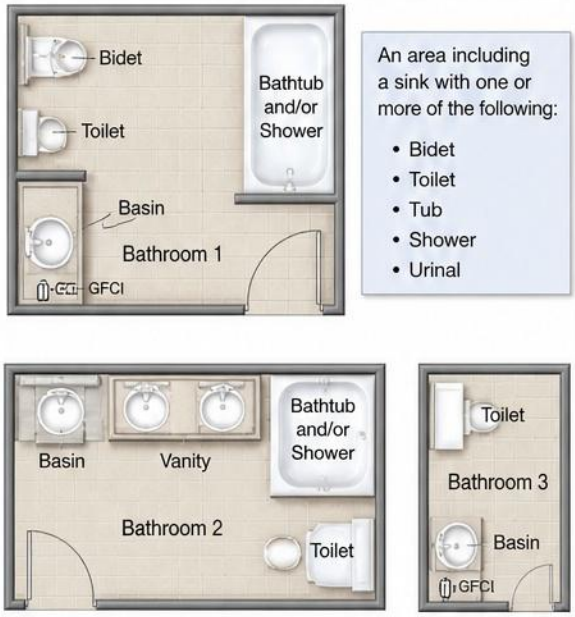
Note: The authority having jurisdiction (AHJ) may be a federal, state, or local government department or individual (such as a fire chief, fire marshal, chief of a fire prevention bureau, labor or health department, a building official, electrical inspector), or others having statutory authority. In some circumstances, the property owner's agent assumes the role, and at government installations, the commanding officer, or departmental official may be the AHJ.

Author's Comment:

- The AHJ is typically the electrical inspector who has legal statutory authority. In the absence of federal, state, or local regulations, the facility operator's agent (such as an architect or engineer of the facility) can assume the role.
- Most expect the AHJ to have at least some prior experience in the electrical field (such as having studied electrical engineering or having obtained an electrical contractor's license). In a few states this is a legal requirement. Memberships, certifications, and active participation in electrical organizations such as the International Association of Electrical Inspectors (IAEI) speak to an individual's qualifications. Visit www.IAEI.org for more information about that organization.

Bathroom. An area including a sink with one or more of the following: a toilet, urinal, tub, shower, or bidet. ▸ Figure 100–11

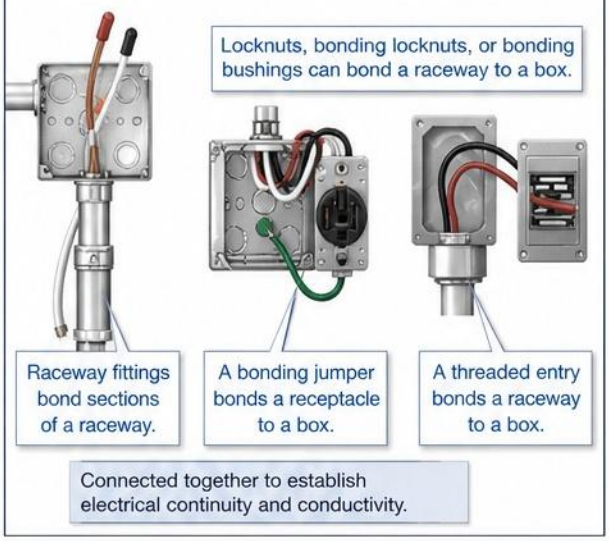
Figure 100–11 Bathroom — Article 100 Definition



An area including a sink with one or more of the following: a toilet, urinal, tub, shower, or bidet.

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

Figure 100–12 Bonded (Bonding) — Article 100 Definition



Bonding Jumper, Main Bonding Jumper. A component of the effective ground-fault current path used to connect the service grounded neutral conductor to the equipment grounding conductor at the service equipment enclosure. ▸Figure 100–13, Figure 100–14, and Figure 100–15

Figure 100–13 Main Bonding Jumper — Article 100 Definition

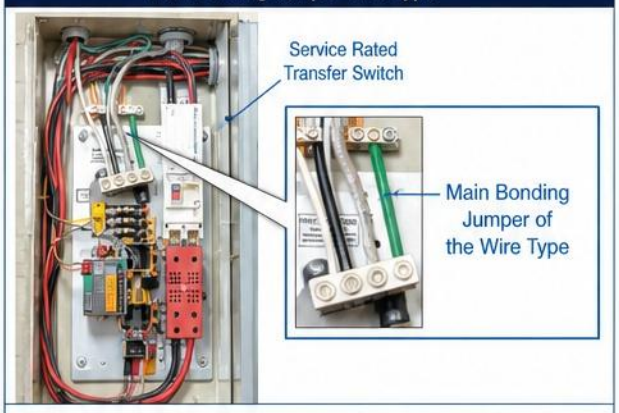
A component of the effective ground-fault current path used to connect the service grounded neutral conductor to the equipment grounding conductor at the service equipment enclosure.

Bonding Jumper, Supply-Side Bonding Jumper. A component of the effective ground-fault current path installed on the supply side of a service, within the service equipment enclosure, or a separately derived system that ensures conductivity between metal parts. Figure 100–16, Figure 100–17, and Figure 100–18

Figure 100-14 **Article 100 Definition**
Main Bonding Jumper Busbar Type

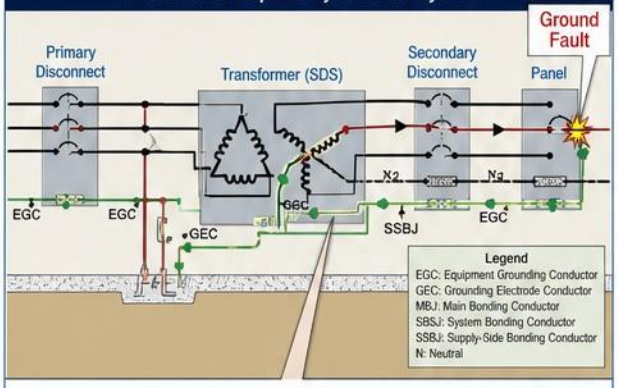
A component of the effective ground-fault current path used to connect the service grounded neutral conductor to the equipment grounding conductor at the service equipment enclosure.

Figure 100-15 **Article 100 Definition**
Main Bonding Jumper Wire-Type



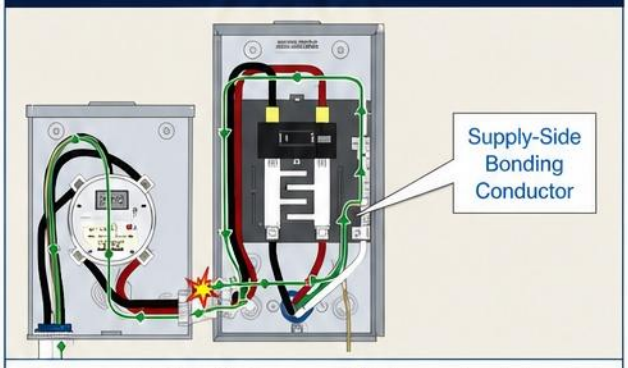
A component of the effective ground-fault current path used to connect the service grounded neutral conductor to the equipment grounding conductor at the service equipment enclosure.

Figure 100-16 **Article 100 Definition**
Supply-Side Bonding Jumper
Transformer Separately Derived System



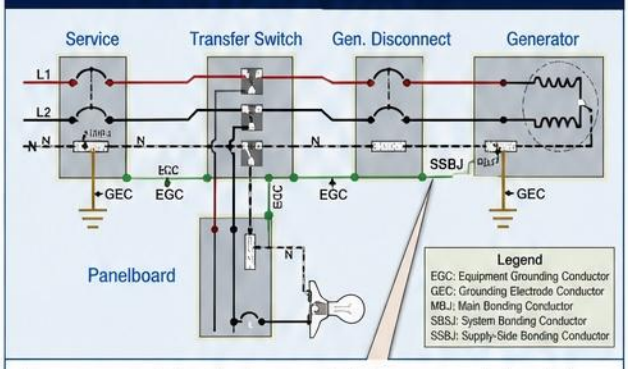
A component of the effective ground-fault current path is the bonding conductor installed for a transformer separately derived system that ensures conductivity between metal parts.

Figure 100-17 **Article 100 Definition**
Supply-Side Bonding Jumper
Service Equipment



A component of the effective ground-fault current path installed on the supply side of a service or within the service equipment enclosure that ensures conductivity between metal parts.

Figure 100-18 **Article 100**
Supply-Side Bonding Jumper
Generator Separately Derived System



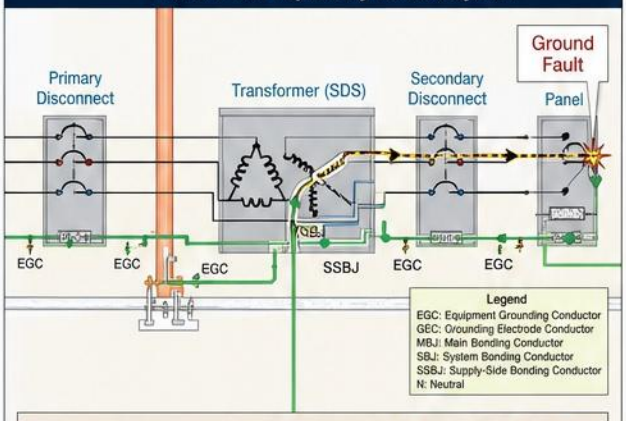
A component of the effective ground-fault current path installed on the supply side of a generator separately derived system that ensures conductivity between metal parts.

Bonding Jumper, System Bonding Jumper. A component of the effective ground-fault current path that is the connection between the grounded neutral conductor or grounded-phase conductor and the equipment grounding conductor at a separately derived system. ▸Figure 100-19 and ▸Figure 100-20

Branch Circuit. The circuit conductors between the final overcurrent protective device (OCPD) protecting the circuit and the outlets. ▸Figure 100-21

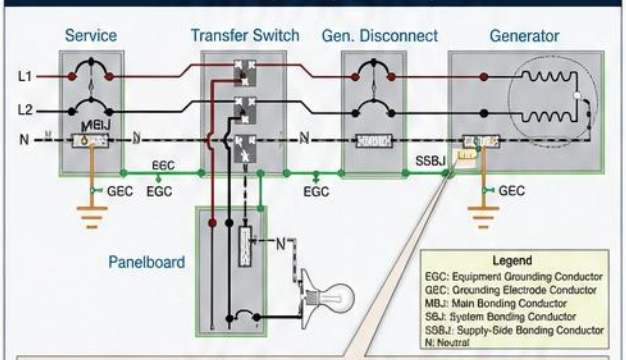
Branch Circuit, Individual. A branch circuit that supplies only one utilization equipment. ▸Figure 100-22

Figure 100–19 System Bonding Jumper Transformer Separately Derived System Article 100 Definition



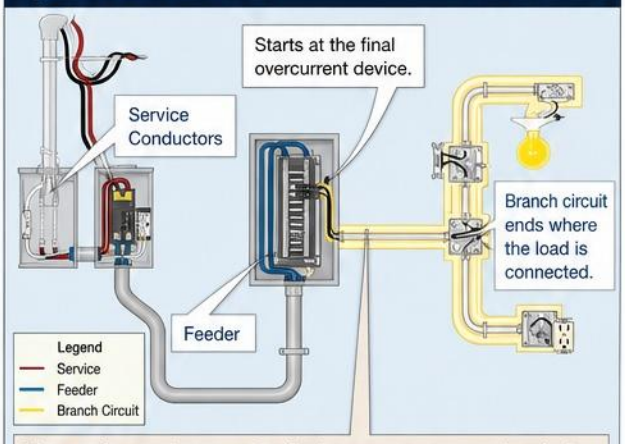
A component of the effective ground-fault current path that creates the connection between the grounded neutral conductor and the equipment grounding conductor at a separately derived system.

Figure 100–20 System Bonding Jumper Generator Separately Derived System Article 100 Definition



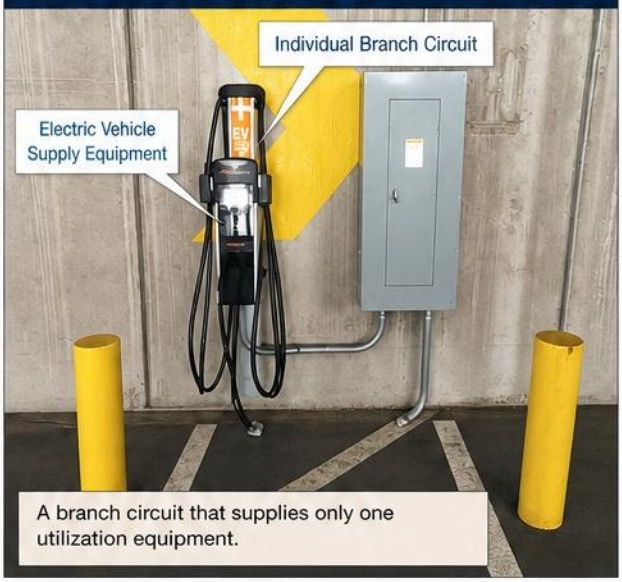
A component of the effective ground-fault current path that creates the connection between the grounded neutral conductor and the equipment grounding conductor at a separately derived system.

Figure 100–21 Branch Circuit Article 100 Definition



The conductors between the final overcurrent protective device and the receptacle outlets, lighting outlets, or other outlets.

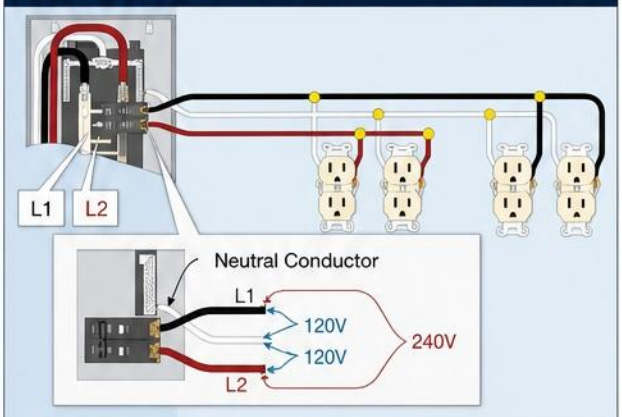
Figure 100–22 Individual Branch Circuit Article 100 Definition



A branch circuit that supplies only one utilization equipment.

Branch Circuit, Multiwire. A branch circuit consisting of two or more phase conductors with a neutral conductor that has a voltage between the phase conductors and an equal voltage from each phase conductor to the neutral conductor. **Figure 100–23**

Figure 100–23 Multiwire Branch Circuit Article 100 Definition



A branch circuit consisting of two or more phase conductors with a neutral conductor that has a voltage between the phase conductors and an equal voltage from each phase conductor to the neutral conductor.

AUTHOR'S COMMENT:

- Multiwire branch circuits are a cost-saving wiring technique that shares one common neutral wire between multiple branch circuits. This approach saves wiring costs but introduces a handful of dangerous side effects (such as, potential confusion, safety risks, and equipment damage risks).

- Multiwire branch circuits require each branch to be on separate phases. Doing this guarantees their shared neutral will never carry a higher current than any of the branch phase wires. This is why it is possible to use the same ampacity for all the current-carrying wires of the multiwire branch circuit. Preventing the need to use a larger neutral is when the cost savings happen, so this is only permitted by the *NEC* when the branches are on separate phases.
- Multiwire branch circuits offer the advantage of fewer conductors within a raceway. This results in smaller raceways and reduced costs for material and labor. ▸**Figure 100–24** and ▸**Figure 100–25**

Figure 100–24 NEC 100
Multiwire Branch Circuit — Fewer Conductors in a Raceway

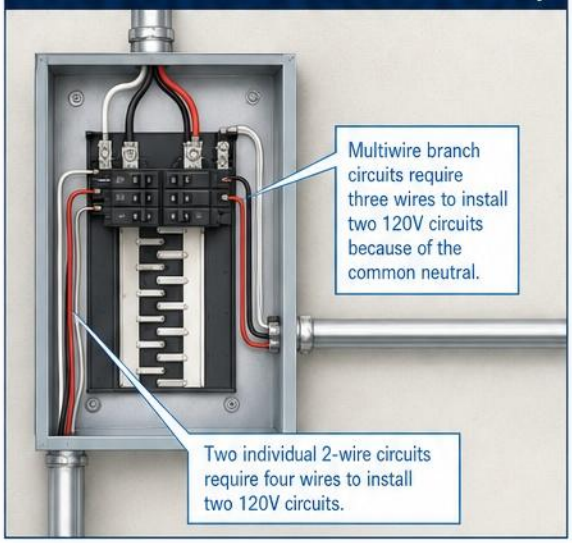
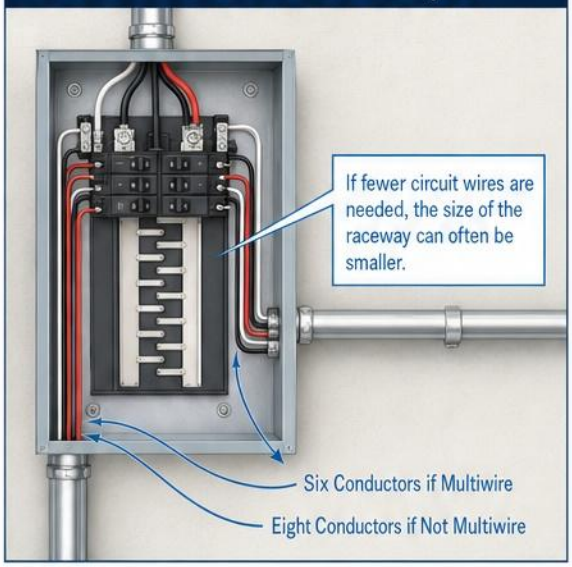
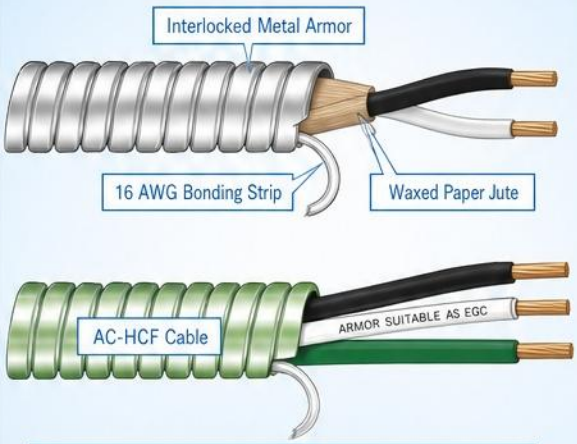


Figure 100–25 NEC 100
Multiwire Branch Circuit — Reduced Raceway Size



Cable, Armored Cable (AC). A fabricated assembly of conductors in a flexible interlocked metallic armor with an internal bonding strip in intimate contact with the armor for its entire length. ▸**Figure 100–26**

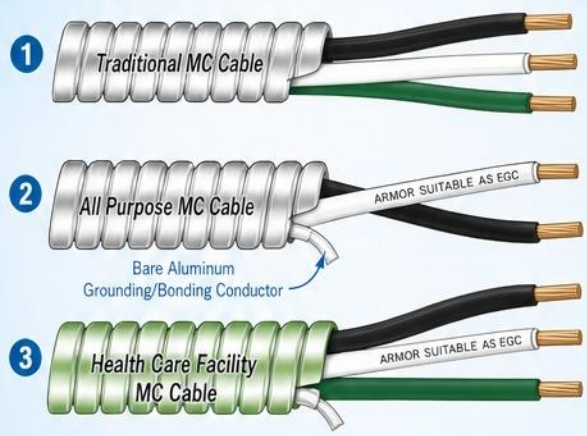
Figure 100–26 NEC 100
Armored Cable (AC Cable)



A fabricated assembly of conductors in a flexible interlocked metallic armor with an internal bonding strip in intimate contact with the armor for its entire length.

Cable, Metal-Clad Cable (MC). A factory assembly of conductors enclosed in an interlocking metal tape armor. ▸**Figure 100–27** and ▸**Figure 100–28**

Figure 100–27 NEC 100
Metal-Clad Cable (MC Cable)



A factory assembly of conductors enclosed in an interlocking metal tape armor.

Figure 100–28 Metal-Clad Cable (MC Cable)
Article 100 Definition

A factory assembly of conductors enclosed in an armor of interlocking metal tape.

Cable, Nonmetallic-Sheathed Cable (NM Cable). A cable with insulated circuit conductors and an equipment grounding conductor enclosed within an outer nonmetallic jacket. ▶Figure 100–29 and ▶Figure 100–30

Figure 100–29 Nonmetallic-Sheathed Cable (NM Cable)
Article 100 Definition

A cable with insulated circuit conductors and an equipment grounding conductor enclosed within an outer nonmetallic jacket.

Author's Comment:

- It is the generally accepted practice in the electrical industry to call nonmetallic-sheathed (NM) cable "Romex®," a registered trademark of the Southwire Company.

Cable, Power and Control Tray Cable (TC). A factory assembly of conductors with or without bare or covered equipment grounding conductors under a nonmetallic jacket. ▶Figure 100–31

Figure 100–30 Nonmetallic-Sheathed Cable (NM Cable)
Article 100 Definition

A cable with insulated circuit conductors and an equipment grounding conductor enclosed within an outer nonmetallic jacket.

Figure 100–31 Power and Control Tray Cable (TC Cable)
Article 100 Definition

A factory assembly of conductors with or without bare or covered equipment grounding conductors, under a nonmetallic jacket.

Cable, Service-Entrance Cable (SE and USE Cable). A single or multiconductor cable primarily used for services. ▶Figure 100–32

Cable, Service Entrance Cable (SE). SE cables have a flame-retardant, moisture-resistant covering for aboveground installations.

Cable, Service Entrance Cable (USE). USE cables have a moisture-resistant covering, but not flame retardant, and is identified as a wiring method for underground use.

Cable, Underground Feeder and Branch-Circuit Cable (UF). A factory assembly of conductors with an integral or overall covering of nonmetallic material suitable for direct burial. ▶Figure 100–33

Cable Tray System. A unit or assembly of units or sections with associated fittings forming a structural system used to securely fasten or support cables and raceways. ▶Figure 100–34

Figure 100-32 Service-Entrance Cable (SE and USE Cable) 100 Definitions

Aboveground

SE cable may be used only in aboveground installations and is permitted for branch-circuit or feeders when installed in accordance with 338.10(B).

Underground Only

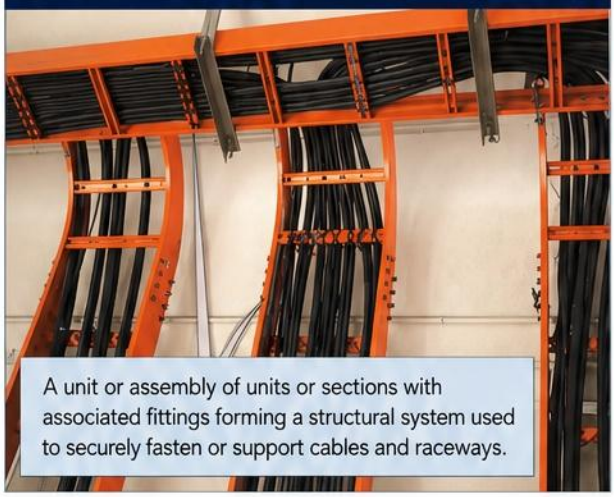
USE cable is identified for underground use. Its outer jacket is moisture resistant but not required to be flame retardant, and it isn't suitable for indoor use.

A single- or multiconductor cable primarily used for services.

Figure 100-33 Underground Feeder and Branch-Circuit Cable (UF Cable) 100 Definitions

A factory assembly of conductors with an integral or overall covering of nonmetallic material suitable for direct burial.

Figure 100-34 Cable Tray System 100 Definitions

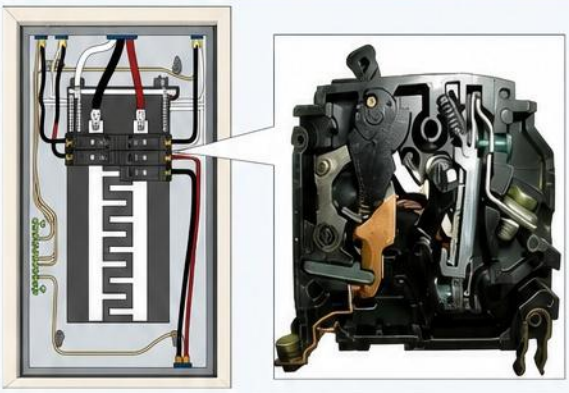


A unit or assembly of units or sections with associated fittings forming a structural system used to securely fasten or support cables and raceways.

Child Care Facility. A building or portion of a building used for educational, supervision, or personal care services for five or more children, seven years of age or less.

Circuit Breaker. A device designed to open and close the circuit manually but opens the circuit automatically during an overcurrent condition. ▶Figure 100–35

Figure 100-35 Circuit Breaker 100 Definitions



A device designed to open and close the circuit manually but opens the circuit automatically during an overcurrent condition.

Author's Comment:

- The 40°C marking indicates the maximum ambient temperature in which a thermal-magnetic circuit breaker can be applied at its marked ampere rating in accordance with *UL* 489. ▶Figure 100–36

Figure 100-36 Circuit Breaker 100 Comment

In accordance with UL 489, the 40°C marking indicates the maximum ambient temperature in which a thermal-magnetic circuit breaker can be applied at its marked ampere rating.

Circuit Breaker, Adjustable. Circuit breakers that can be set to trip at various values of current, time, or both within a predetermined range. ▶Figure 100–37 and ▶Figure 100–38

Figure 100–37 *NEC 100 Definitions Article 100 Definition*

Circuit breakers that can be set to trip at various values of current, time (or both), within a predetermined range.

Figure 100–38 *NEC 100 Definitions Article 100 Definition*

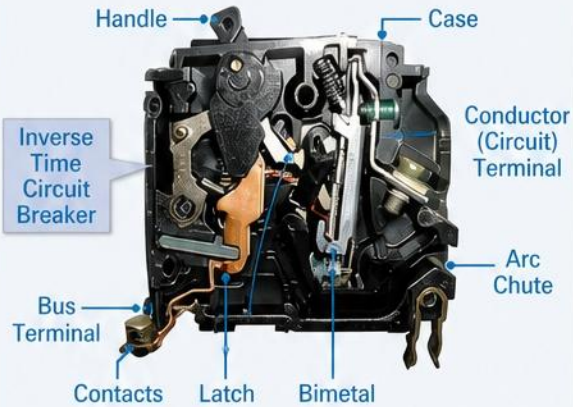
Circuit breakers that can be set to trip at various values of current, time (or both), within a predetermined range.

Circuit Breaker, Inverse Time. A circuit breaker purposely designed to delay its tripping action during an overcurrent condition, and the delay decreases as the magnitude of the current increases.

Author's Comment:

▶ Inverse time breakers operate on the principle that as the current increases, the time it takes for the devices to open decreases. They provide ordinary overcurrent protection during overload, short-circuit, or ground-fault conditions. This is the most common type of circuit breaker purchased over the counter. ▶Figure 100–39

Figure 100–39 *NEC 100 Definitions Article 100 Comment*



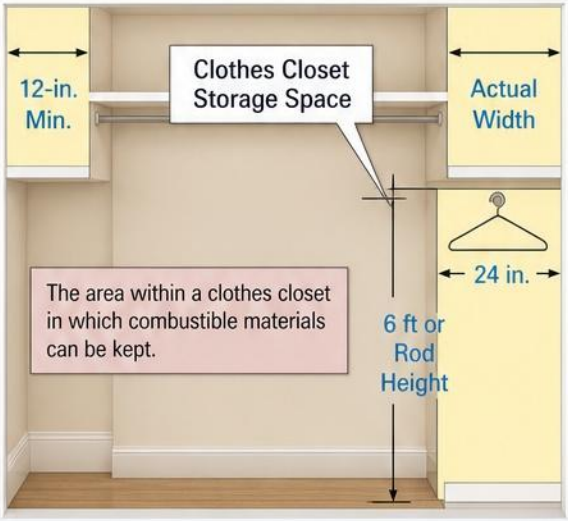
Inverse time breakers operate on the principle that as the current increases, the time it takes for the devices to open decreases.

Author's Comment:

▶ Most inverse time breakers are "thermal magnetic," with the thermal element providing the inverse time function for clearing overloads, and the magnetic element providing a much quicker clearing of short circuits and ground faults. The magnetic function is also known as the "instantaneous" function.

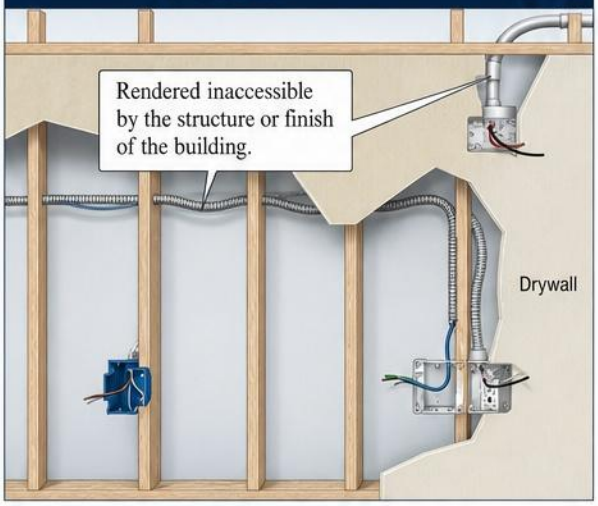
Clothes Closet Storage Space. The area within a clothes closet in which combustible materials can be kept. ▶Figure 100–40

Figure 100–40 *NEC 100 Definitions Article 100 Definition*



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

Figure 100–41 Concealed
Article 100 Definition NEC 100



Conduit or raceway that is concealed by the building structure or finished surfaces, making it inaccessible without removing those materials.

CONDUIT, FLEXIBLE METAL CONDUIT (FMC)

A raceway of circular cross section made of a helically wound, formed, and interlocked metal strip.

Figure 100–42 Flexible Metal Conduit (FMC)
Article 100 Definition NEC 100

A raceway of circular cross section fabricated from a helically wound, shaped, and interlocked metal strip.

CONDUIT, INTERMEDIATE METAL CONDUIT (IMC)

A steel raceway of circular cross section that can be threaded with couplings and fittings listed for the installation of electrical conductors.

CONDUIT, LIQUIDTIGHT FLEXIBLE METAL CONDUIT (LFMC)

A raceway of circular cross section having an outer liquidtight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core, with connectors and fittings listed for the installation of electrical conductors.

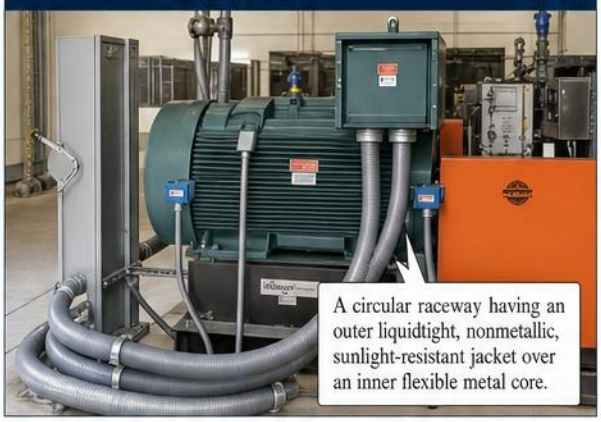
Figure 100–43 Intermediate Metal Conduit (IMC)
Article 100 Definition NEC 100

A steel raceway of circular cross section that can be threaded with couplings and fittings.

Figure 100–44 Liquidtight Flexible Metal Conduit (LFMC)
Article 100 Definition NEC 100

A raceway with a nonmetallic, liquidtight, sunlight-resistant outer jacket surrounding a flexible metal core.

Figure 100–45 Liquidtight Flexible Metal Conduit (LFMC)
Article 100 Definition NEC 100



A raceway with an outer liquidtight, nonmetallic, sunlight-resistant jacket that encloses a flexible metal core.

Conduit, Liquidtight Flexible Nonmetallic Conduit (LFNC). A raceway of circular cross section designated as follows:

(1) A smooth, seamless inner core and cover bonded together and having one or more reinforcement layers between the core and covers, designated as LFNC-A

(2) A smooth inner surface with integral reinforcement within the raceway wall, designated as LFNC-B

(3) A corrugated internal and external surface without integral reinforcement within the raceway wall, designated as LFNC-C (**Figure 100–46**)

Figure 100–46 **Article 100 Definition**

A circular raceway having an outer liquidtight, nonmetallic, sunlight-resistant jacket over a flexible nonmetallic inner core.

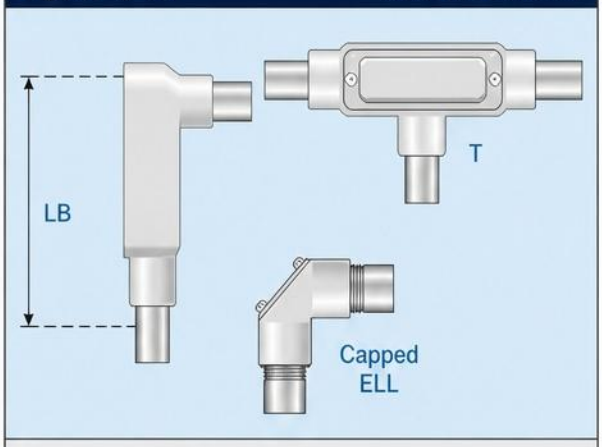
Conduit, Rigid Metal Conduit (RMC). A metal raceway of circular cross section that can be threaded with couplings and fittings listed for the installation of electrical conductors. (**Figure 100–47**)

Figure 100–47 **Article 100 Definition**

A metal raceway of circular cross section that can be threaded with couplings and fittings.

Conduit Body. A raceway fitting that provides access to conductors through a removable cover. (**Figures 100–48** and **100–49**)

Figure 100–48 **Article 100 Definition**



A raceway fitting that provides access to conductors through a removable cover.

Figure 100–49 **Article 100 Definition**

A raceway fitting that provides access to conductors through a removable cover.

Continuous Load. A load where the maximum current is expected for three hours or more continuously. (**Figure 100–50**)

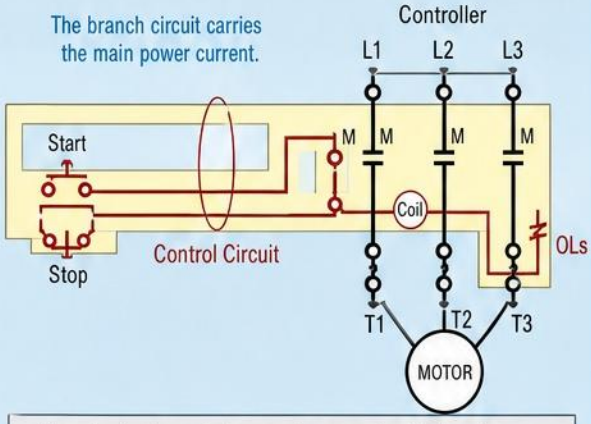
Control Circuit. The circuit of a control apparatus or system that carries the electric signals directing the performance of a controller—but does not carry the main power current. (**Figure 100–51**)

Controller, Motor Controller. Any switch or device used to start and stop a motor by making and breaking the motor circuit current. (**Figure 100–52**)

Figure 100–50 Continuous Load *Article 100 Definition*

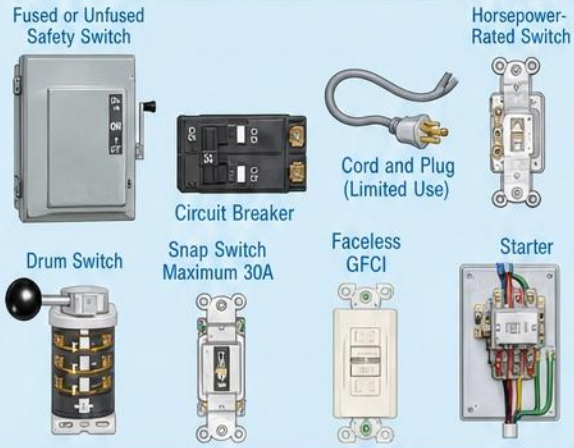
A load where the maximum current is expected for three hours or more continuously.

Figure 100–51 Control Circuit *Article 100 Definition*



The circuit of a control apparatus or system that carries the electric signals directing the performance of the controller, but doesn't carry the main power current.

Figure 100–52 Motor Controller *Article 100 Definition*



Any switch or device used to start and stop a motor by making and breaking the motor circuit current.

Cord, Flexible Cord. Two or more insulated conductors enclosed in a flexible covering. ***Article 100 Definition***

Figure 100–53 Flexible Cord *Article 100 Definition*

Two or more flexible insulated conductors enclosed in a flexible covering.

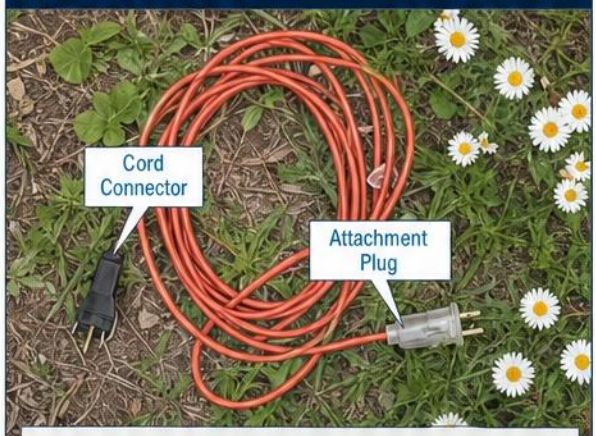
Author's Comment:

- Article 400 contains the primary requirements for flexible cords.

Cord Connector. A contact device terminated to a flexible cord that accepts an attachment plug or other insertion.

Cord Set. A flexible cord having an attachment plug at one end and a cord connector at the other end. ***Article 100 Definition***

Figure 100–54 Cord Set *Article 100 Definition*



A flexible cord having an attachment plug at one end and a cord connector at the other end.

Countertop. A surface intended for food or beverage preparation/serving, personal lavation (sink), or laundering (sink) that presents a routine risk of spillage of large quantities of water.

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

Dormitory. A space in which sleeping accommodations are provided for more than 16 persons not of the same family, under joint occupancy and single management, but without individual cooking facilities.

Figure 100–55 Dormitory — Article 100 Definition

A space in which sleeping accommodations are provided for more than 16 persons not of the same family, under joint occupancy and single management, but without individual cooking facilities.

Note: Examples of dormitories are college dormitories, fraternity/sorority houses, and military barracks.

Dwelling Unit. A single unit that provides permanent provisions for living, sleeping, cooking, and sanitation.

Figure 100–56 Dwelling Unit — Article 100 Definition

A unit that provides permanent provisions for living, sleeping, cooking, and sanitation.

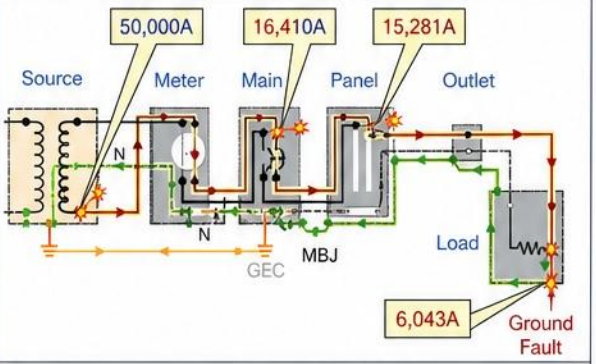
Energy Management System (EMS). A system that monitors and controls power within an electrical system.

Figure 100–57 Energy Management System (EMS) — Article 100 Definition

A system that monitors and controls power within an electrical system.

Fault Current, Available Fault Current. The largest amount of current capable of being delivered at a point on the electrical system during a short-circuit condition.

Figure 100–58 Available Fault Current — Article 100 Definition



The largest amount of current capable of being delivered at a point on the electrical system during a short-circuit condition.

Note: A short-circuit can occur as a fault between circuit conductors or a ground fault.

Feeder. The conductors between a service disconnect, transformer, generator, or other power-supply source (PV or ESS) and the branch-circuit overcurrent protective device.

Figure 100–59 Feeder — Article 100 Definition

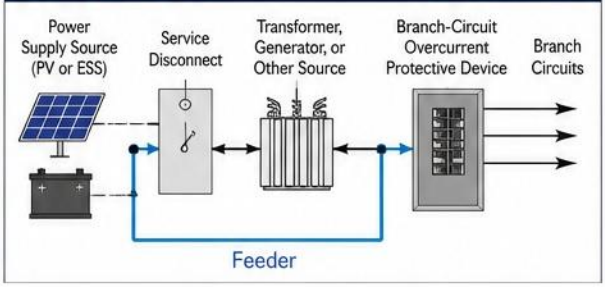
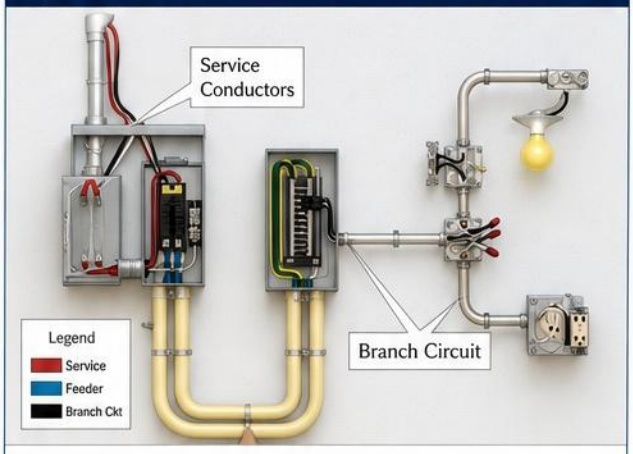
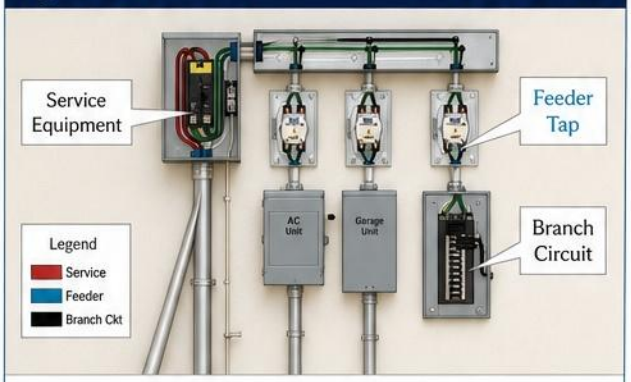


Figure 100–59 Feeder *Article 100 Definition*



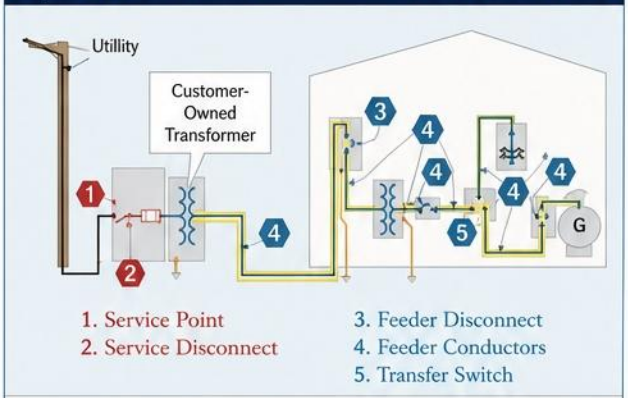
The conductors between a service disconnect, transformer, generator, or other power-supply source (PV or ESS) and the branch-circuit overcurrent protective device.

Figure 100–60 Feeder *Article 100 Definition*



The conductors between a service disconnect, transformer, generator, or other power-supply source (PV or ESS) and the branch-circuit overcurrent protective device.

Figure 100–61 Feeder *Article 100 Definition*

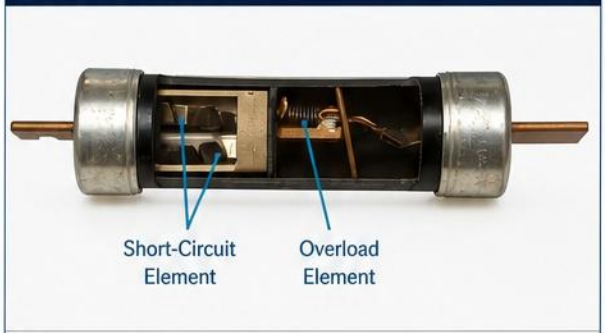


The conductors between a service disconnect, transformer, generator, or other power-supply source (PV or ESS) and the branch-circuit overcurrent protective device.

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). This indicates the equipment or materials were evaluated and found to comply with the requirements described in the accompanying field evaluation report.

Fuse. An overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent. Figure 100–62

Figure 100–62 Fuse *Article 100 Definition*



An overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent.

Garage. A building or portion of a building in which one or more vehicles can be kept for use, sale, storage, rental, repair, exhibition, or demonstration purposes. Figure 100–63

Figure 100–63 Garage *Article 100 Definition*

A building or portion of a building in which one or more vehicles can be kept for use, sale, storage, rental, repair, exhibition, or demonstration purposes.

Generator. A machine that converts mechanical energy into electrical energy by means of a prime mover.

Figure 100–64 Generator *Article 100 Definition*

A machine that converts mechanical energy into electrical energy by means of a prime mover.

Ground. The Earth.

Figure 100–65 Ground *Article 100 Definition*

Ground Fault. An unintentional electrical connection between a phase conductor and equipment grounding conductors, metal parts of enclosures, metal raceways, or metal equipment.
Article 100 Definition

Ground-Fault Circuit Interrupter (Class A). A device intended to protect people by de-energizing a circuit when ground-fault current exceeds the value for a Class A device (6 mA or higher).
Article 100 Definition

Figure 100–66 Ground Fault *Article 100 Definition*

An unintentional electrical connection between a phase conductor and equipment grounding conductors, metal parts of enclosures, metal raceways, or metal equipment.

Figure 100–67 Ground-Fault Circuit Interrupter (Class A GFCI) *Article 100 Definition*

A device intended to protect people by de-energizing a circuit when ground-fault current exceeds the value for a Class A device (6 mA or higher).

Note: A GFCI opens the circuit when the ground-fault current is 6 mA or higher, and it does not open when the ground-fault current is less than 4 mA.
Article 100 Definition

Author's Comment:
A GFCI-protective device is designed to protect people against electric shock. It operates on the principle of monitoring the unbalanced current between the current-carrying circuit conductors. On a 120V circuit, the GFCI will monitor the unbalanced current between the phase and neutral conductors. On a 240V circuit, the monitoring is between circuit conductors. Receptacles, circuit breakers, cord sets, and other types of devices that incorporate GFCI protection are commercially available.
Article 100 Definition

Figure 100–68 Ground-Fault Circuit Interrupter (Class A GFCI) *Article 100 Note*

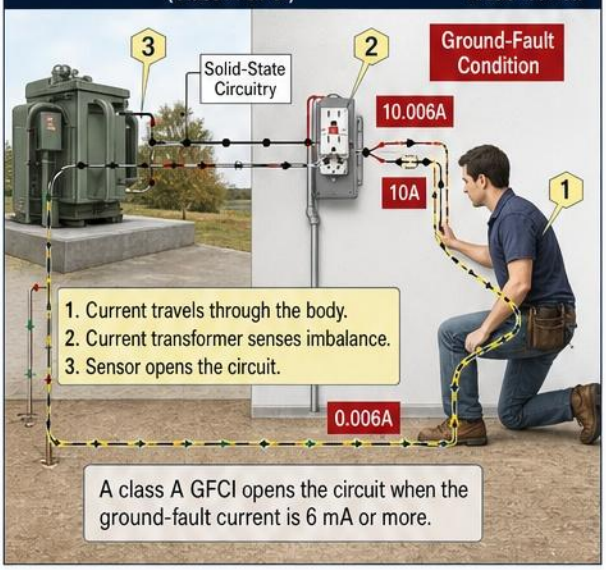


Figure 100–69 Ground-Fault Circuit Interrupter (Class A GFCI) *Article 100 Comment*

Author's Comment:

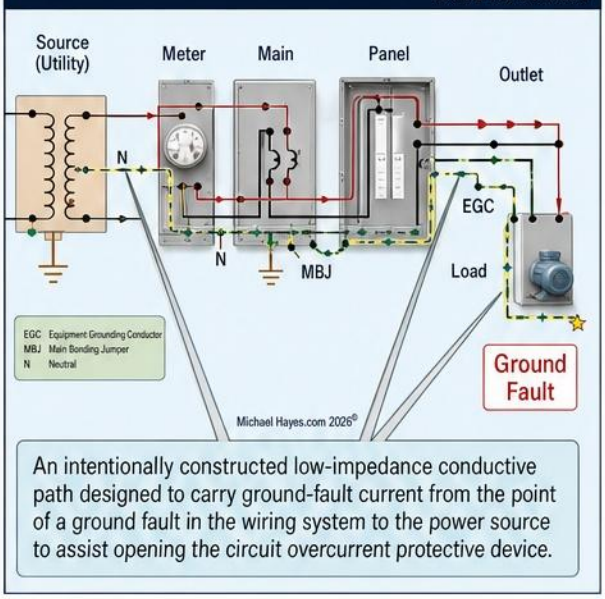
- GFCI devices should be tested monthly for functionality as recommended by the manufacturer's instructions.

Ground-Fault Current Path, 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 in the wiring system to the power source to assist in opening the circuit overcurrent protective device. (See **Figure 100–70**.)

Author's Comment:

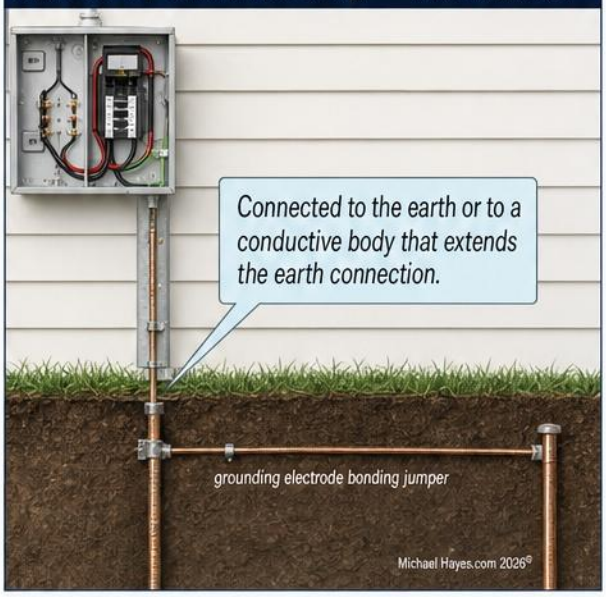
- *The effective ground-fault current path is intended to help remove dangerous voltage from a ground fault by opening the circuit overcurrent protective device.*

Figure 100–70 Effective Ground-Fault Current Path *Article 100 Definition*



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

Figure 100–71 Grounded (Grounding) *Article 100 Definition*

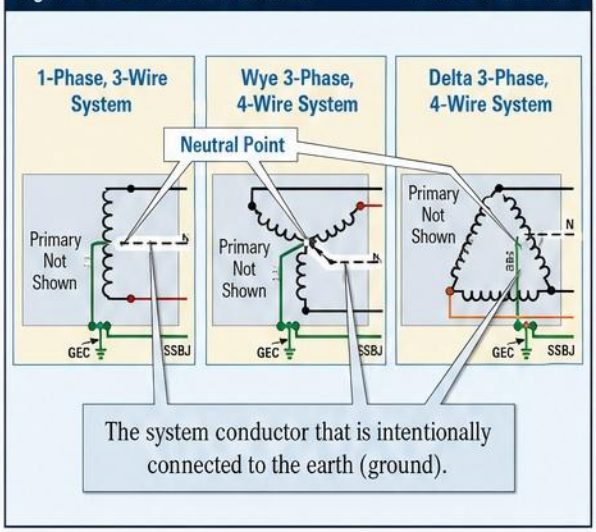


Author's Comment:

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

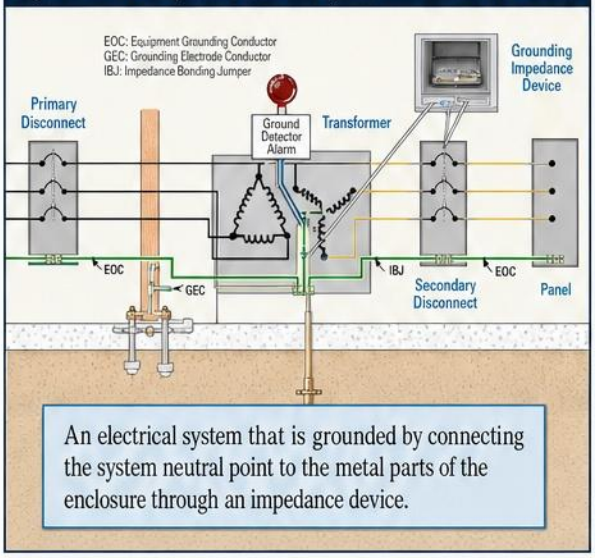
Grounded Conductor. The system conductor that is intentionally connected to the earth (ground). (See **Figure 100–72**.)

Figure 100–72 Grounded Conductor *Article 100 Definition*



Grounded System, Impedance Grounded System. An electrical system that is grounded by connecting the system neutral point to the metal parts of the enclosure through an impedance device. **Article 100–73**

Figure 100–73 Impedance Grounded System *Article 100 Definition*

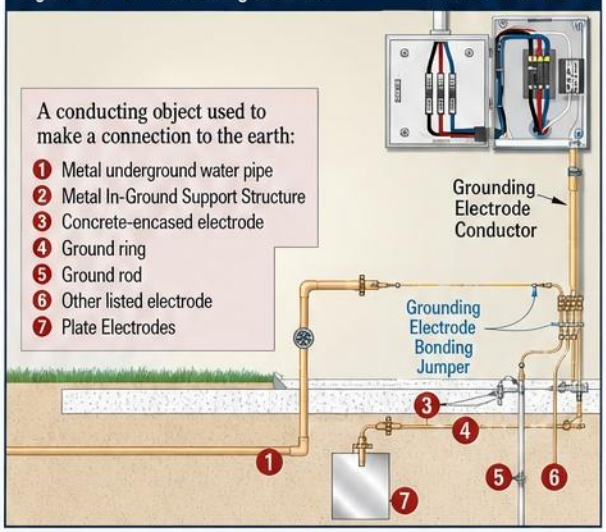


Author's Comment:

- Section 250.36 contains the primary requirements for impedance grounded systems.

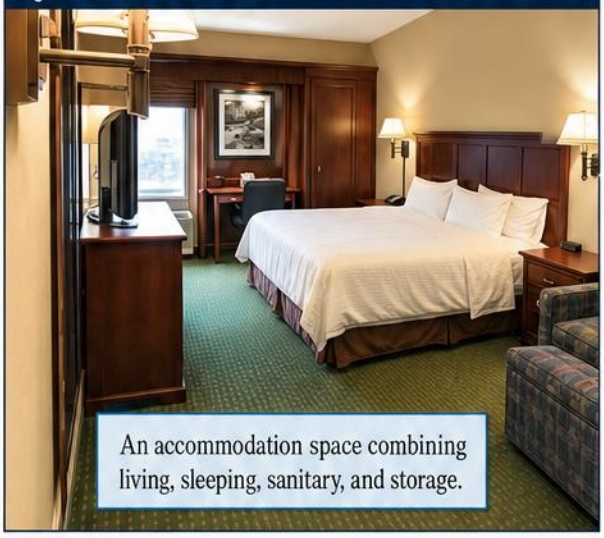
Grounding Electrode. A conducting object used to make a connection to the earth [250.50 through 250.70]. **Article 100–74**

Figure 100–74 Grounding Electrode *Article 100 Definition*



Guest Room. An accommodation space combining living, sleeping, sanitary, and storage. **Article 100–75**

Figure 100–75 Guest Room *Article 100 Definition*



Guest Suite. An accommodation space with two or more rooms that provides living, sleeping, sanitary, and storage. **Article 100–76**

Habitable Room. A room for living, sleeping, eating, or cooking, but excluding bathrooms, toilet rooms, closets, hallways, storage/utility spaces, and similar areas. **Article 100–77**

Handhole Enclosure. An underground enclosure with an open or closed bottom that is sized to allow personnel to reach into but not enter the enclosure. **Article 100–78**

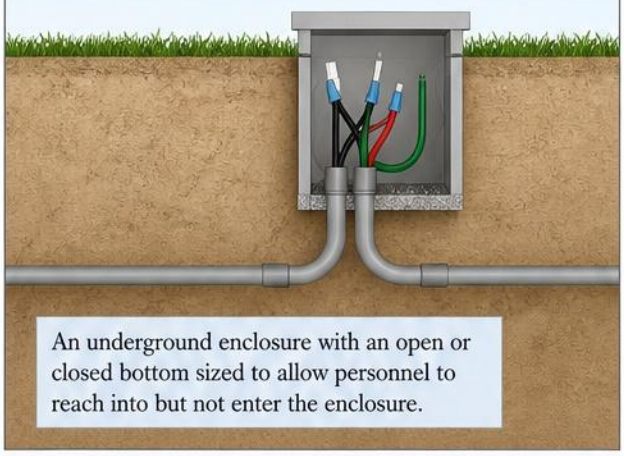
Figure 100–76 Guest Suite Article 100

An accommodation space with two or more rooms that provides living, sleeping, sanitary, and storage.

Figure 100–77 Habitable Room Article 100

A room for living, sleeping, eating, or cooking, but excluding bathrooms, toilet rooms, closets, hallways, storage/utility spaces, and similar areas.

Figure 100–78 Handhole Enclosure Article 100



An underground enclosure with an open or closed bottom sized to allow personnel to reach into but not enter the enclosure.

Author's Comment:

- For the installation requirements for handhole enclosures, see 314.30.

Hermetic Refrigerant Motor-Compressor. A compressor and motor enclosed in the same housing, with no external shaft or shaft seals, and operating in a refrigerant. ▶Figure 100–79

Figure 100–79 Hermetic Refrigerant Motor-Compressor Article 100

A compressor and motor enclosed in the same housing, with no external shaft or shaft seals, and operating in refrigerant.

Identified. Recognized as being suitable for a specific purpose, function, use, environment, or application.

Author's Comment:

- Suitability of equipment use may be identified by a description marked on, or provided with, a product to identify the suitability of the product for a specific purpose, environment, or application. See 110.3(A)(1) Note 2.

Interrupting Rating. The highest fault current at rated voltage that the device is identified to interrupt under standard test conditions. ▶Figure 100–80

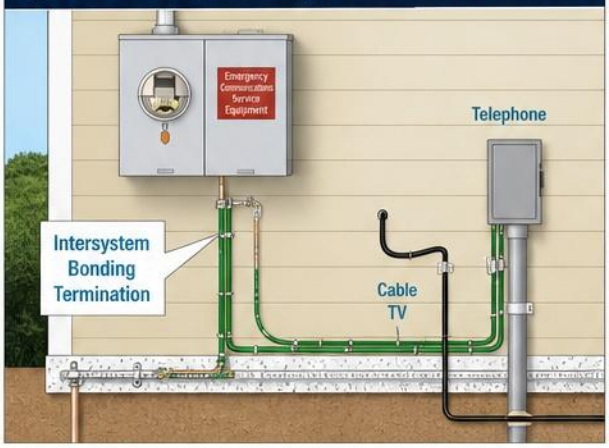
Intersystem Bonding Termination (IBT). A device that provides a means to connect intersystem bonding conductors for communications systems (such as antennas) to the grounding electrode system. ▶Figure 100–81

Kitchen. An area with a sink and permanent provisions for food preparation and cooking. ▶Figure 100–82

Figure 100–80 Interrupting Rating — Article 100 Definition

This is the maximum short-circuit current at the device's rated voltage that it is designed and tested to safely interrupt.

Figure 100–81 Intersystem Bonding Termination — Article 100 Definition



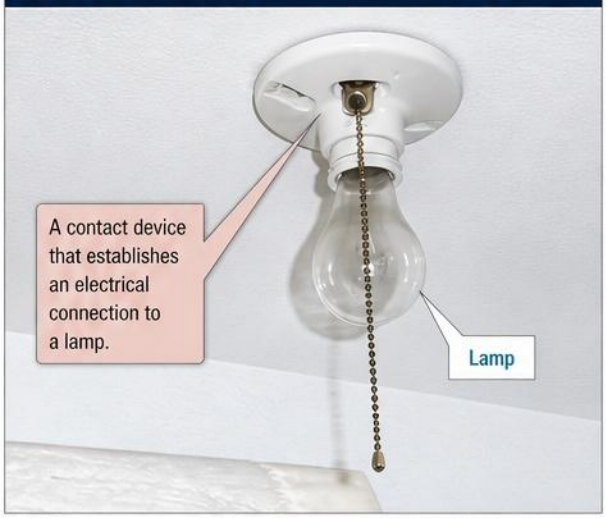
A means that provides a connection point for intersystem bonding conductors used with communications systems to the grounding electrode system.

Figure 100–82 Kitchen — Article 100 Definition

A space that includes a sink and fixed facilities for food preparation and cooking.

Lampholder. A contact device that establishes an electrical connection to a lamp. ▸ Figure 100–83

Figure 100–83 Lampholder — Article 100 Definition



This device provides the electrical interface for connecting a lamp to the branch circuit.

Laundry Area. A space that contains clothing laundry equipment, such as a clothes washer or dryer. ▸ Figure 100–84

Figure 100–84 Laundry Area — Article 100 Definition

A space that contains clothing laundry equipment, such as a clothes washer or dryer.

Lighting, Track Lighting. A manufactured assembly designed to support and supply power to luminaires mounted on a track. Its overall length may be adjusted by adding or removing sections of track.

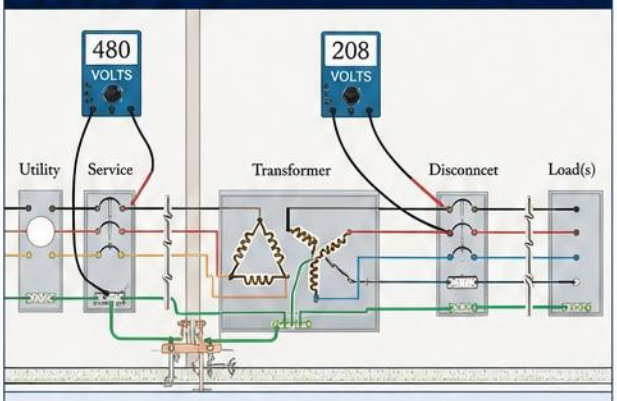
Limited Care Facility. A building or a portion of a building used for the 24-hour housing of four or more persons who are incapable of self-preservation due to their condition. These conditions include age, physical limitations from an accident or illness, or limitations from intellectual disability, developmental disability, mental illness, or chemical dependency. ▸ Figure 100–85

Figure 100-85 Limited Care Facility — Article 100 Definition

A building or an area used for the housing, on a 24-hour basis, of four or more persons who are incapable of self-preservation.

Line-to-Line. An electrical reference between two current-carrying conductors in a circuit other than a neutral conductor. **Article 100 Definition.** Figure 100-86

Figure 100-86 Line-to-Line — Article 100 Definition

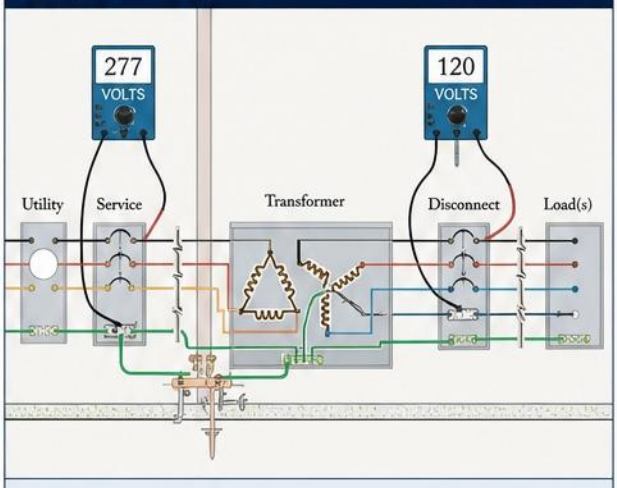


An electrical reference between two current-carrying conductors in a circuit other than a neutral conductor.

Line-to-Neutral. An electrical reference between a current-carrying conductor other than a neutral conductor, and a neutral conductor or neutral point in a circuit. **Article 100 Definition.**

Listed. Equipment or materials included in a list published by a recognized testing laboratory acceptable to the authority having jurisdiction. The listing organization must periodically inspect the production of listed equipment or material to ensure they meet appropriate designated standards and are suitable for a specified purpose.

Figure 100-87 Line-to-Neutral — Article 100 Definition



An electrical reference between a current-carrying conductor other than a neutral conductor, and a neutral conductor or neutral point in a circuit.

Author's Comment:

- The *NEC* does not require all electrical equipment to be listed, but some *Code* requirements do specifically call for product listing.

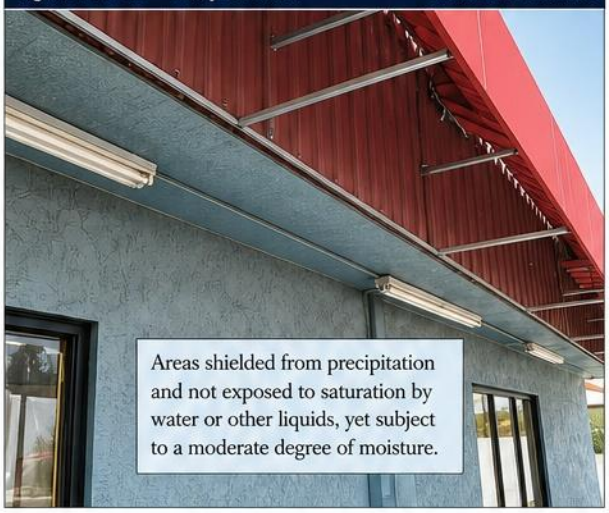
Live Parts. Energized conductive components. Figure 100-88

Figure 100-88 Live Parts — Article 100 Definition

Load Management. The process within an energy management system that limits the total electrical load on an electrical supply system. This process sets a value by adjusting or controlling circuits supplying the load or individual loads.

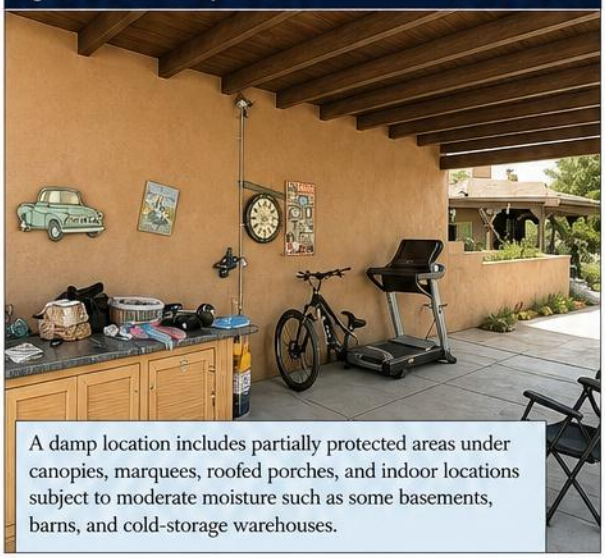
Location, Damp Location. Locations protected from weather and not subject to saturation with water or other liquids, but subject to moderate degrees of moisture. Figure 100-89

Figure 100–89 Damp Location **Article 100 Definition**



Encompasses areas partly protected under canopies, marquees, roofed porches, and indoor locations with moderate moisture exposure (including certain basements, barns, and cold-storage facilities).

Figure 100–90 Damp Location **Article 100 Note**



Author's Comment:

- According to Webster's Dictionary, "moisture" is defined as "liquid condensed in relatively small quantity."

Location, Dry Location. An area not normally subject to dampness or wetness, but which may temporarily be subjected to dampness or wetness such as a building under construction.

Author's Comment:

- Wiring methods and equipment that are listed for dry location use only are permitted to be installed in a building under construction even if the building is subject to temporary dampness or wetness, as it is still considered a dry location. However, the equipment must be protected from damage in accordance with 110.11.

Location, Wet Location. A location that is one of the following:

(1) Unprotected and exposed to weather

(2) Subject to saturation with water or other liquids

(3) Underground

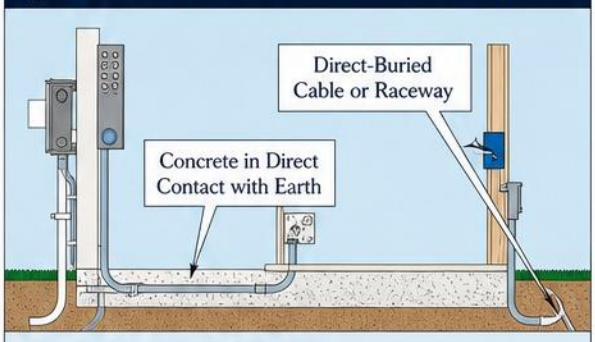
(4) Concrete slabs or masonry in direct contact with the earth

See Figure 100–91 and Figure 100–92.

Figure 100–91 Wet Location **Article 100 Definition**

A location that is one of the following:
(1) Unprotected and exposed to weather
(2) Subject to saturation with water or other liquids
(3) Underground
(4) In concrete slabs or masonry in direct contact with the earth

Figure 100–92 Wet Location **Article 100 Definition**



A location that is one of the following:
(1) Unprotected and exposed to weather
(2) Subject to saturation with water or other liquids
(3) Underground
(4) In concrete slabs or masonry in direct contact with the earth

Note: A vehicle washing area is an example of a wet location saturated with water or other liquids.

Luminaire. Equipment intended to illuminate a space or object(s), to facilitate visual tasks, activities, aesthetics, or security. **Article 100 Definition**

Figure 100–93 Luminaire *Article 100 Definition*

Equipment intended to illuminate a space or object(s), to facilitate visual tasks, activities, aesthetics, or security.

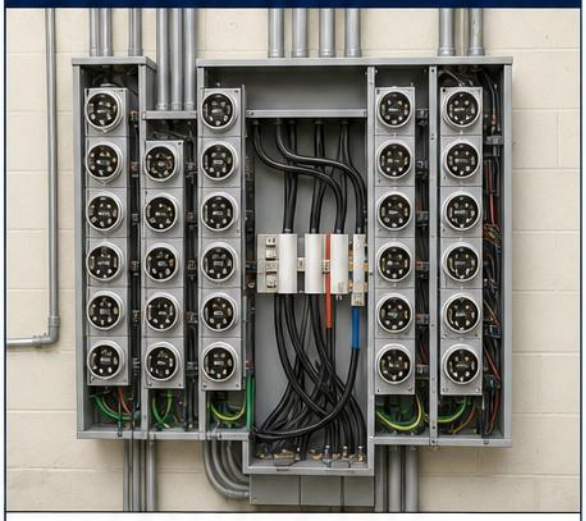
Metering Centers (Meter Center). Panelboards in enclosures also containing one or more meter sockets.
Article 100 Definition

Figure 100–94 Metering Centers (Meter Center) *Article 100 Definition*

Panelboards in enclosures also containing one or more meter sockets.

Multioutlet Assembly. A surface, flush, or freestanding assembly containing receptacles.
Article 100 Definition

Figure 100–95 Metering Centers (Meter Center) *Article 100 Definition*



Panelboards in enclosures also containing one or more meter sockets.

Figure 100–96 Multioutlet Assembly *Article 100 Definition*

A surface, flush, or freestanding assembly containing receptacles.

Author's Comment:
Portable assemblies such as power strips are relocatable power taps—not multioutlet assemblies.
Article 100 Definition

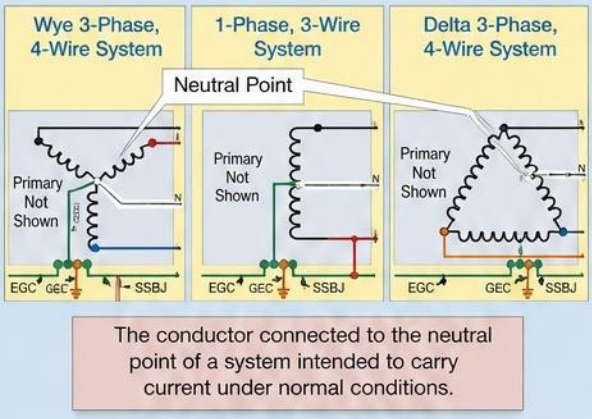
Neutral Conductor. The conductor connected to the neutral point of a system that is intended to carry current under normal conditions.
Article 100 Definition

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.
Article 100 Definition

Figure 100–97 Portable Assemblies *Article 100 Comment*

Portable assemblies such as power strips are relocatable power taps, not multioutlet assemblies.

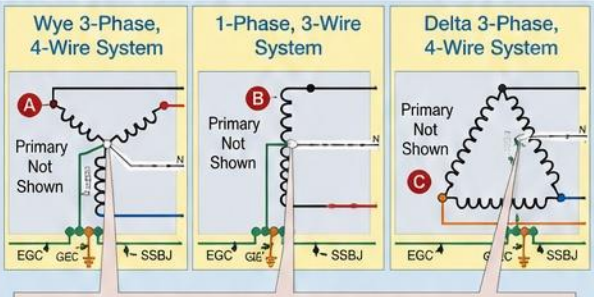
Figure 100–98 Neutral Conductor *Article 100 Definition*



The conductor connected to the neutral point of a system intended to carry current under normal conditions.

Legend: EGC = Equipment Grounding Conductor GEC = Grounding Electrode Conductor
SSBJ = System Bonding Jumper N = Neutral

Figure 100–99 Neutral Point *Article 100 Definition*



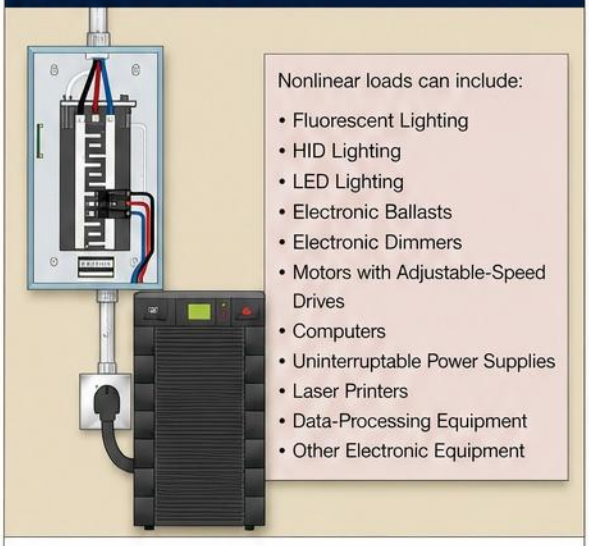
A – Common point of a wye 3-ph, 4-wire system.
B – Midpoint of a 1-ph, 3-wire system.
C – Midpoint of one phase of a delta 3-ph, 4-wire system.

Legend: EGC = Equipment Grounding Conductor GEC = Grounding Electrode Conductor
SSBJ = System Bonding Jumper N = Neutral

Nonlinear Load. A load where the shape of the current waveform does not follow the shape of the voltage waveform.

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 100–100 Nonlinear Load Examples *Article 100 Note*



Nonlinear loads can include the electronic devices and systems listed. Their current waveform does not match the voltage waveform.

Nursing Home. A building or portion of a building used on a 24-hour basis for the housing and nursing care of four 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.

Figure 100–101 Nursing Home *Article 100 Definition*

A building or portion of a building used on a 24-hour basis for the housing and nursing care of four 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.

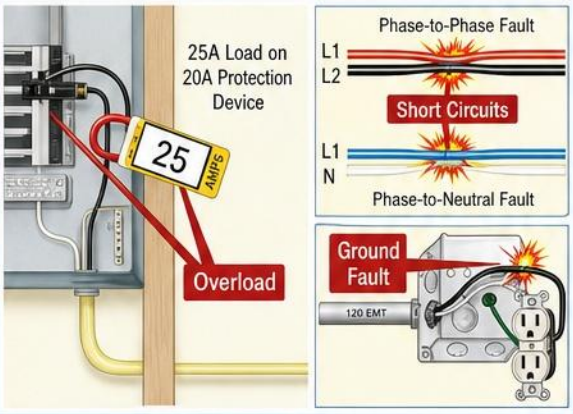
Outlet. A location on the wiring system where current is supplied to utilization equipment.

AUTHOR'S COMMENT

- This includes receptacle outlets, hardwired appliance outlets, and lighting outlets, as well as those for ceiling paddle fans and smoke alarms.

Overcurrent. A current that goes beyond the equipment's ampere rating or the conductor ampacity as a result of an overload, short circuit, or ground fault. ▸Figure 100–102

Figure 100–102 Overcurrent NEC 100



A current that goes beyond the equipment's ampere rating or the conductor ampacity as a result of an overload, short circuit, or ground fault.

Overcurrent Protective Device (OCPD). A device that provides protection from an overcurrent condition (overload, short circuit, or ground fault). ▸Figure 100–103

Figure 100–103 Overcurrent Protective Device (OCPD) NEC 100

A device that provides protection from an overcurrent condition (overload, short circuit, or ground fault).

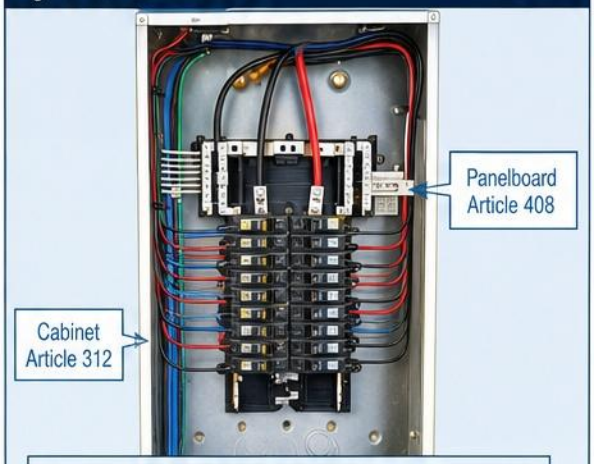
Overload. Equipment operating above its ampere rating or current more than a conductor's ampacity for a length of time that would cause dangerous overheating. A short circuit or ground fault is not an overload. ▸Figure 100–104

Figure 100–104 Overload NEC 100

Equipment operating above its ampere rating or current more than a conductor's ampacity for a length of time that would cause dangerous overheating.

Panelboard. An assembly with buses and overcurrent protective devices designed to be placed in a cabinet or enclosure. ▸Figure 100–105

Figure 100–105 Panelboard NEC 100



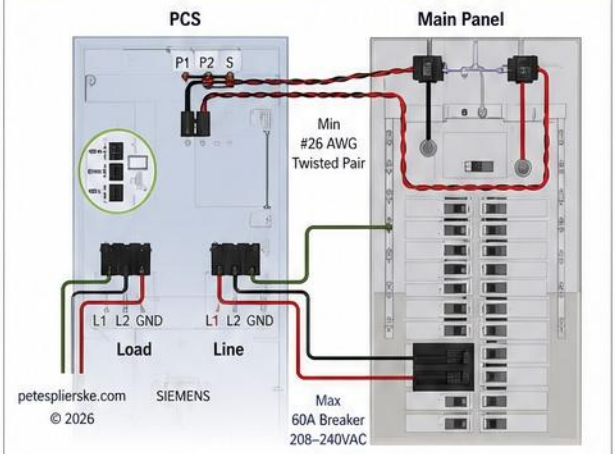
An assembly with buses and overcurrent protective devices designed to be placed in a cabinet or enclosure.

AUTHOR'S COMMENT

- The slang term in the electrical field for a panelboard is "the guts."

Power Control System (PCS). Equipment that monitors and controls power to prevent overload of an electrical service, conductor, or power distribution equipment.

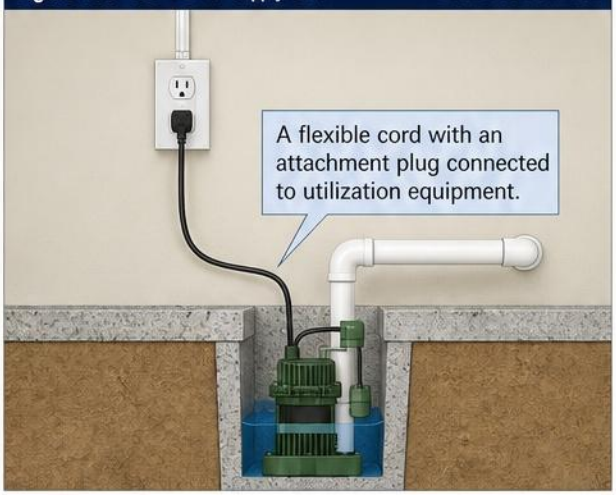
Figure 100–106 Power Control Systems (PCS) — Article 100 Definition



Equipment that monitors and controls power to prevent overload of an electrical service, conductor, or power distribution equipment.

Power-Supply Cord. A flexible cord with an attachment plug connected to utilization equipment.

Figure 100–107 Power-Supply Cord — Article 100 Definition



Author's Comment

- Article 400 contains information on the use of power-supply cords.

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

Figure 100–108 Prime Mover — Article 100 Definition

Qualified Person. A person with skills and knowledge related to the construction, operation, and installation of electrical equipment. This person must have received safety training to recognize and avoid the hazards involved with electrical systems.

Figure 100–109 Qualified Person — Article 100 Definition

A person with skills and knowledge related to the construction, operation, and installation of electrical equipment. This person must have received safety training to recognize and avoid the hazards involved with electrical systems.

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

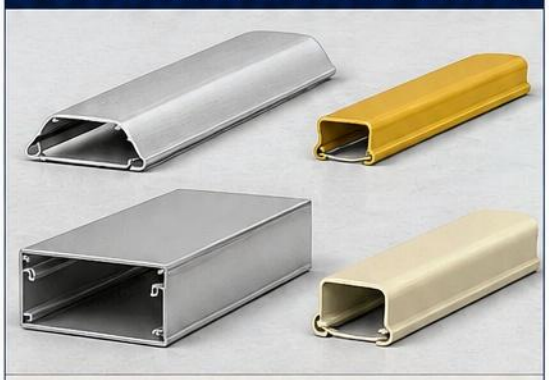
AUTHOR'S COMMENT:

- Examples of this safety training include (but are not limited to) training in the use of special precautionary techniques. These include lockout/tagout procedures, 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. An enclosed channel designed for the installation of conductors, cables, or busbars.

Raceway, Surface Metal Raceway. A metal raceway with associated fittings intended to be mounted on the surface of a structure in which conductors are placed after the raceway has been installed as a complete system. ▸Figure 100–110

Figure 100–110 Surface Metal Raceway *Article 100 Definition*

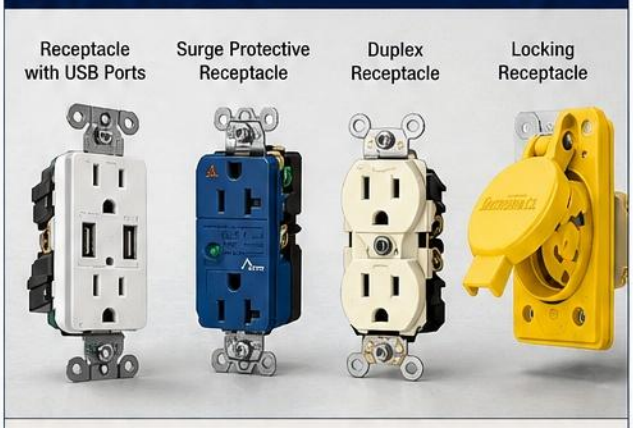


A metal raceway with associated fittings intended to be mounted on the surface of a structure in which conductors are placed after the raceway has been installed as a complete system.

Receptacle. A contact device installed at an outlet for the connection of an attachment plug. ▸Figure 100–111

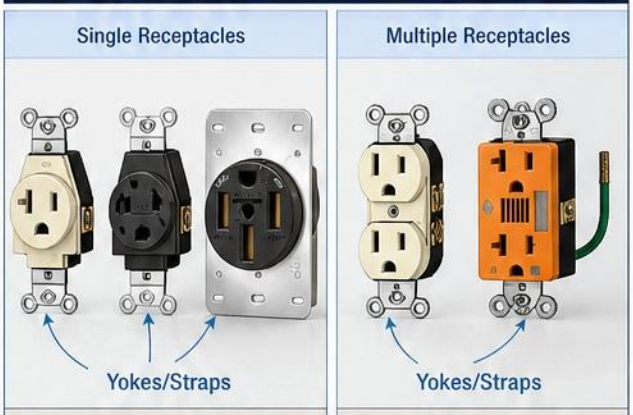
A single receptacle contains one contact device on the same yoke. A multiple receptacle has more than one contact device on the same yoke. ▸Figure 100–112

Figure 100–111 Receptacle *Article 100 Definition*



A contact device for the connection of an attachment plug.

Figure 100–112 Receptacle *Article 100 Definition*



A single receptacle contains one contact device on the same yoke.

A multiple receptacle has more than one contact device on the same yoke.

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

Receptacle, Weather-Resistant Receptacle (WR). A receptacle constructed to be resistant to the adverse effects of damp, wet, or outdoor locations. ▸Figure 100–113 and ▸Figure 100–114

Receptacle Outlet. An outlet where the branch-circuit conductors are connected to one or more receptacles. ▸Figure 100–115

Figure 100–113 Weather-Resistant Receptacle — Article 100 Definition

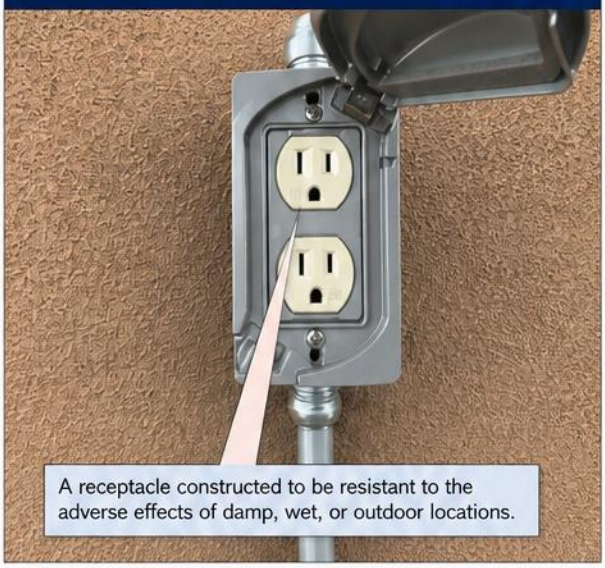


Figure 100–114 Weather-Resistant Receptacle — Article 100 Definition

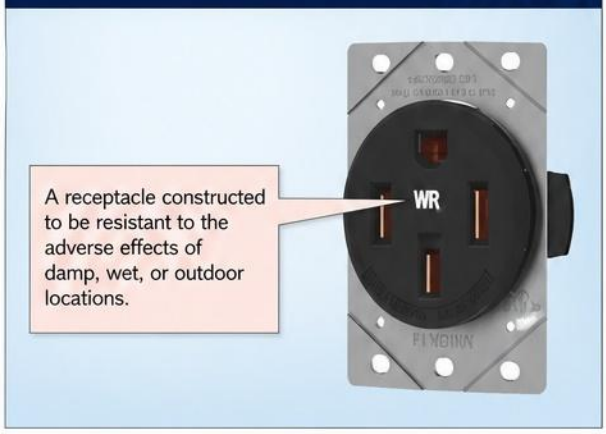
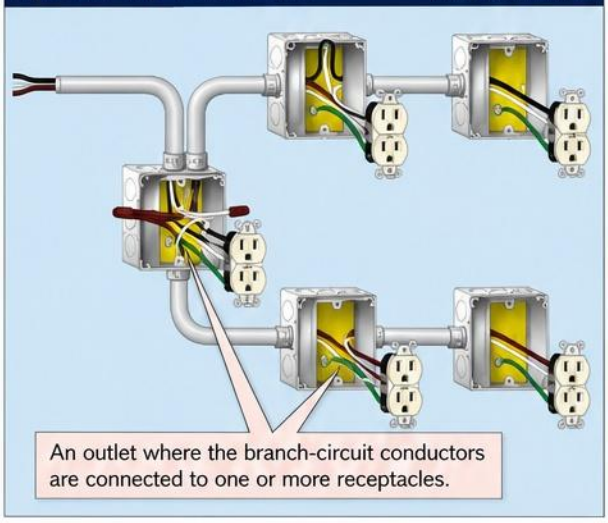


Figure 100–115 Receptacle Outlet — Article 100 Definition



Remote-Control Circuit. Any electrical circuit that controls any other circuit through a relay or an equivalent device.

Separately Derived System. A power supply output having no connections to the circuit conductors of any other electrical source other than grounding and bonding connections.

Figure 100–116 and Figure 100–117

Figure 100–116 Separately Derived Systems – Wye Transformer — Article 100 Definition

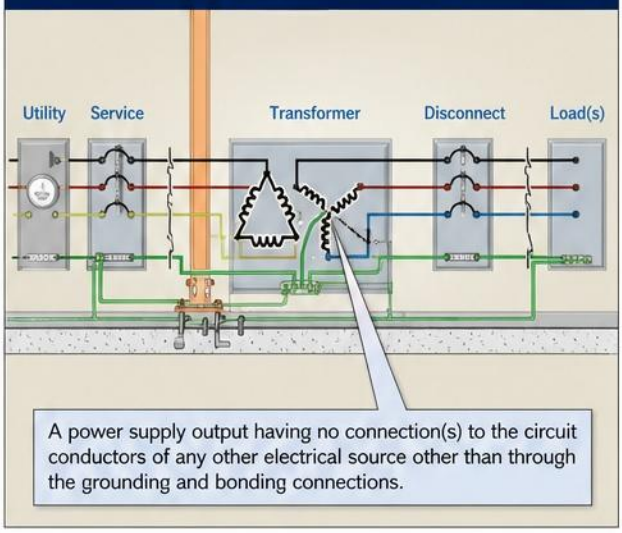
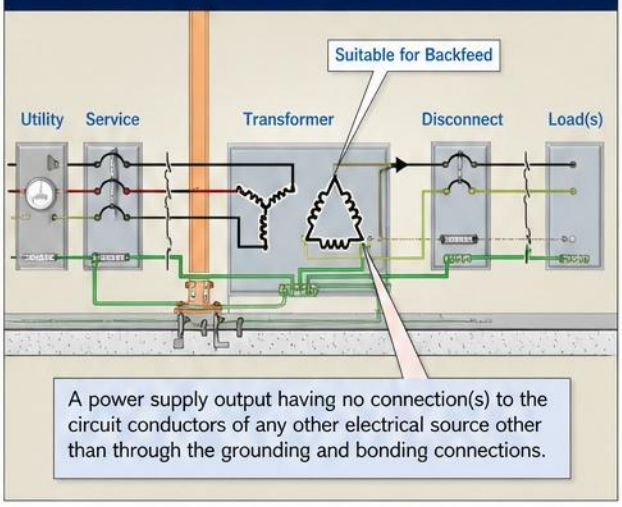


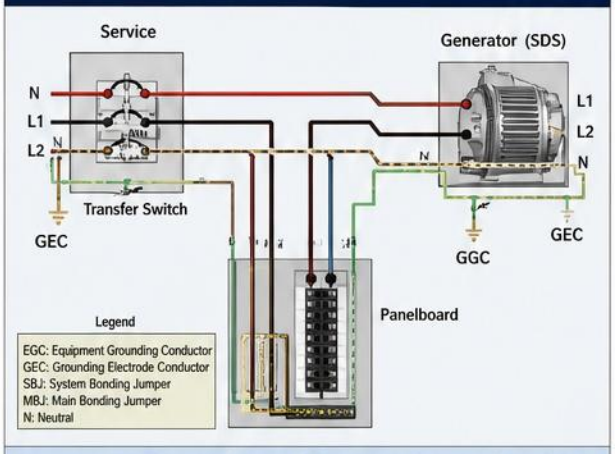
Figure 100–117 Separately Derived Systems – Corner-Grounded Transformer — Article 100 Definition



Author's Comment:

- A generator with a transfer switch that opens the neutral conductor is a separately derived system because the neutral conductor from the generator has a direct electrical connection to the service neutral conductor that is grounded. Figure 100–118

Figure 100–118 Separately Derived System Bonded Neutral Generator — Article 100 Comment

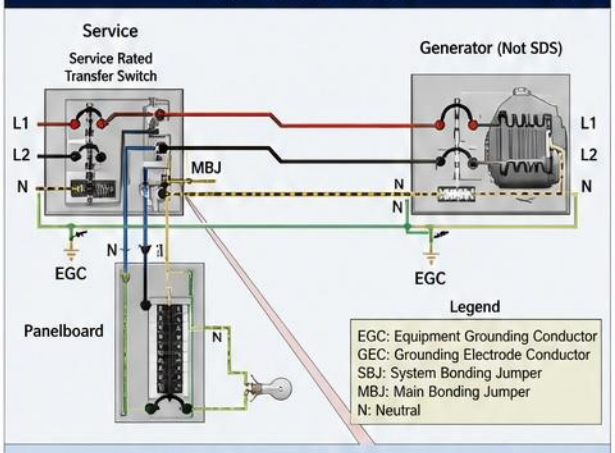


A generator with a transfer switch that opens the neutral conductor is a separately derived system because the neutral conductor from the generator is required to have a direct electrical connection to the service neutral conductor that is grounded.

AUTHOR'S COMMENT:

- A generator with a transfer switch that does not open the neutral conductor is not a separately derived system because the neutral conductor from the generator has a direct electrical connection to the service neutral conductor that is grounded. (Figure 100–119)

Figure 100–119 Separately Derived System Unbonded Neutral Generator — Article 100 Comment



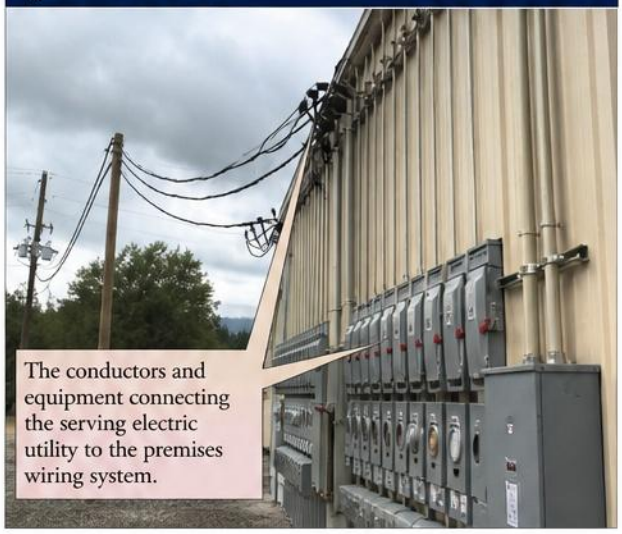
A generator with a transfer switch that does not open the neutral conductor is not a separately derived system because the neutral conductor from the generator has a direct electrical connection to the service neutral conductor that is grounded.

AUTHOR'S COMMENT:

- Section 250.30 contains important information on the use of the term "separately derived system."

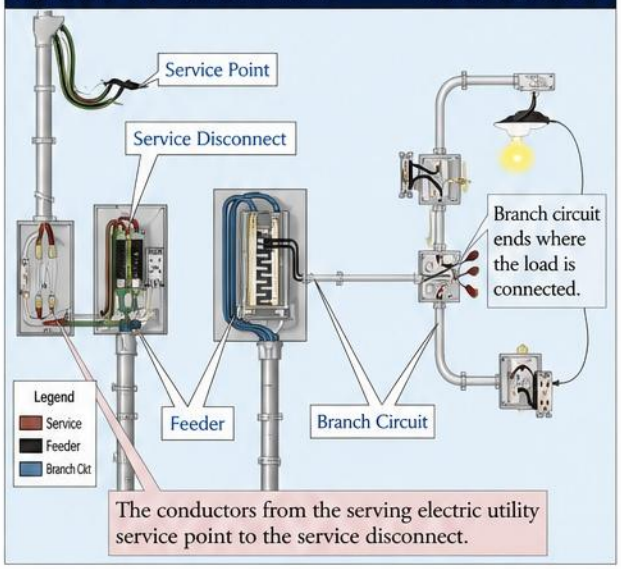
Service. The conductors and equipment connecting the serving electric utility to the premises wiring system. (Figure 100–120)

Figure 100–120 Service — Article 100 Definition



Service Conductors. The conductors from the serving electric utility service point to the service disconnect. (Figure 100–121)

Figure 100–121 Service Conductors — Article 100 Definition

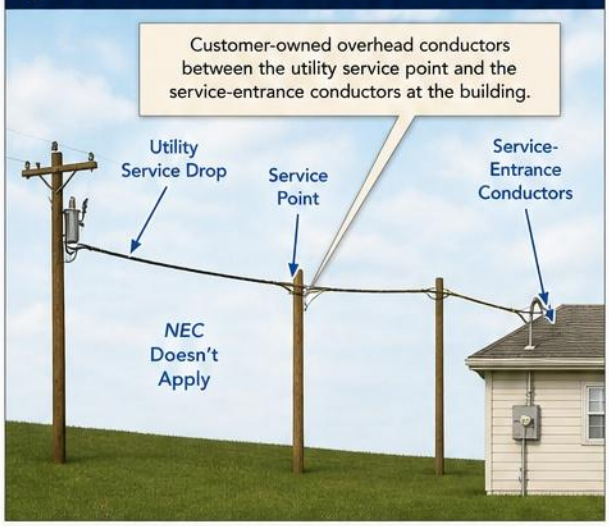


AUTHOR'S COMMENT:

- Service conductors that are not under the exclusive control of the serving electric utility are subject to the requirements in Article 230.

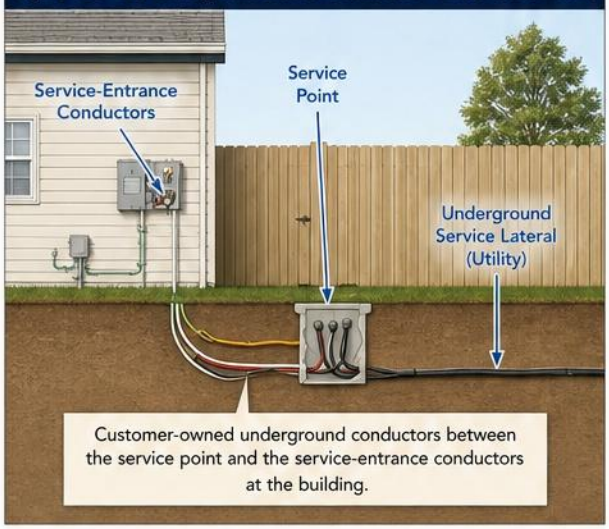
Service, Overhead Service Conductors. Customer-owned overhead conductors between the utility service point and the service-entrance conductors at the building. (Figure 100–122)

Figure 100–122 Overhead Service Conductors *Article 100 Definition*



Customer-owned overhead conductors between the utility service point and the service-entrance conductors at the building.

Figure 100–123 Underground Service Conductors *Article 100 Definitions*



Customer-owned underground conductors between the service point and the service-entrance conductors at the building.

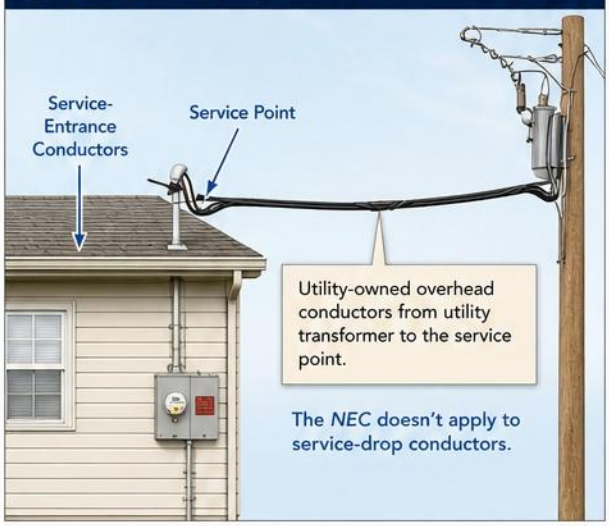
Service Drop Conductors. Utility-owned overhead conductors from utility transformer to the service point. (See Figure 100–124.)

Author's Comment:

The *NEC* does not apply to service drops [90.2(A)(2)(5)].

Service-Entrance Conductors. The service conductors between the terminals of the service equipment to the service drop, overhead service conductors, service lateral, or underground service conductors.

Figure 100–124 Service Drop Conductors *Article 100 Definition*



Utility-owned overhead conductors from utility transformer to the service point.

Figure 100–125 Service Equipment *Article 100 Definition*

Equipment consisting of circuit breakers or fused switches intended to disconnect the power from the serving electric utility.

Service, Underground Service Conductors. Customer-owned underground conductors between the service point and the service-entrance conductors at the building. (See Figure 100–123.)

Service Equipment. Equipment consisting of circuit breakers or fused switches intended to disconnect the power from the serving electric utility. (See Figure 100–125 and Figure 100–126.)

Author's Comment:

- For the convenience of understanding the *NEC*, we sometimes use the slang term "service disconnect" when the *NEC* references "service equipment" in this textbook.
- Meter socket enclosures are not considered service equipment [230.68].
- The service can begin either before or after the metering equipment. (See Figure 100–127.)

Figure 100–126 Service Equipment *Article 100 Definition*

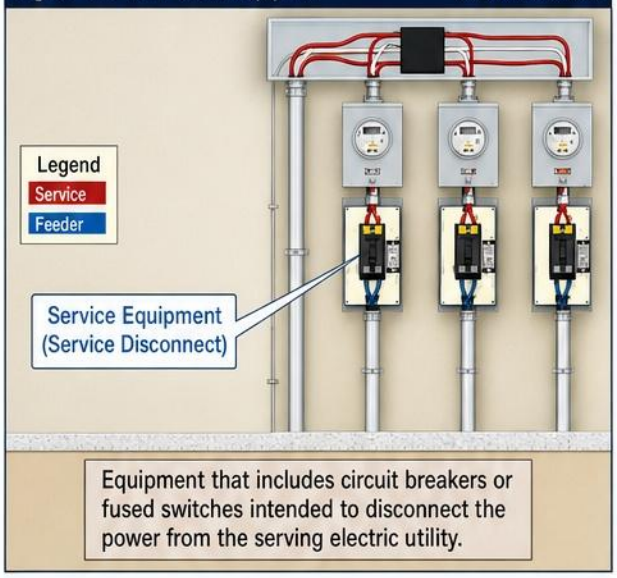


Figure 100–128 Service Point at Service Drop *Article 100 Definition*

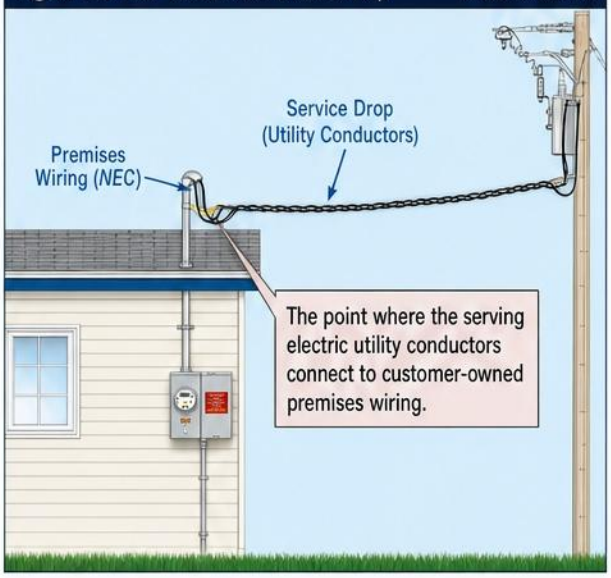


Figure 100–127 Service Equipment *Article 100 Comment*

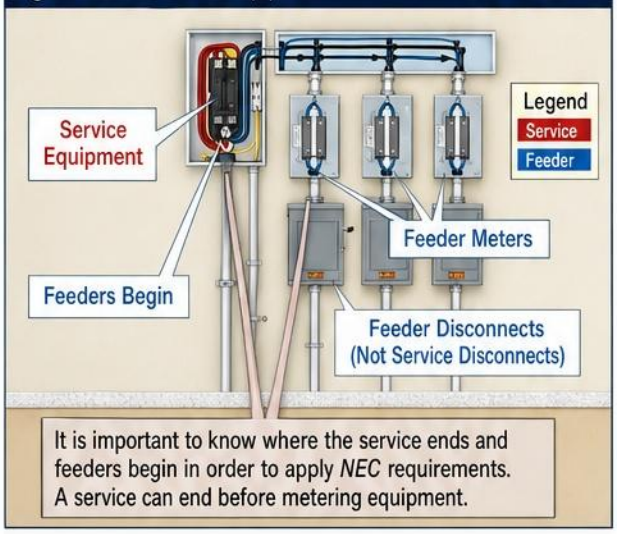
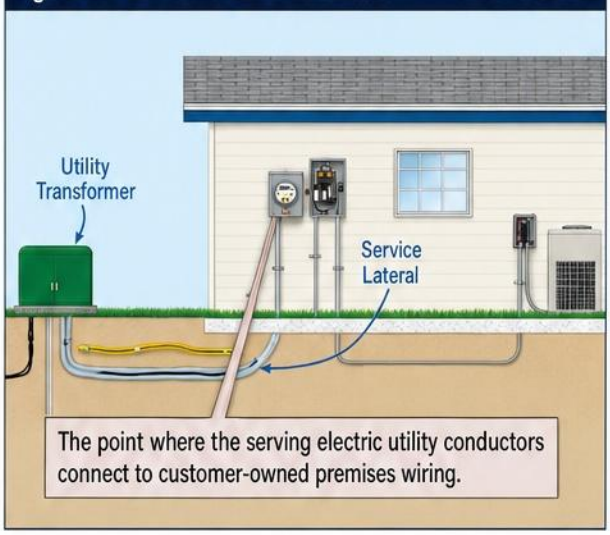


Figure 100–129 Service Point at Meter Enclosure *Article 100 Definition*



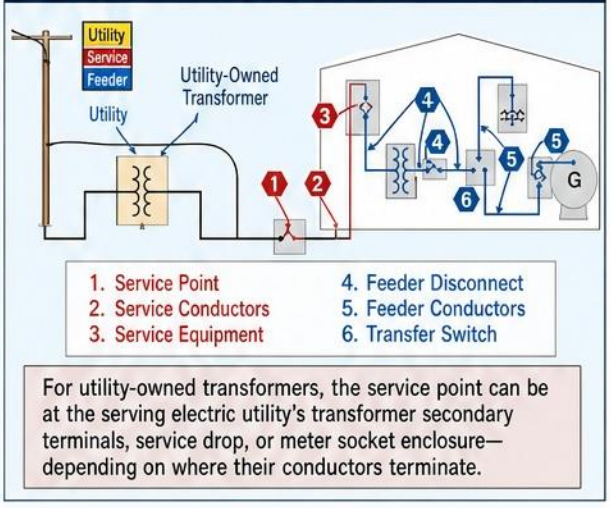
Service Point. The point where the serving electric utility conductors connect to customer-owned premises wiring. See **Figure 100–128** and **Figure 100–129**.

Note: The service point is determined by the serving electric utility.

Author's Comment:

- For utility-owned transformers, the service point can be at the serving electric utility's transformer secondary terminals, service drop, or meter socket enclosure—depending on where their conductors terminate. See **Figure 100–130**.

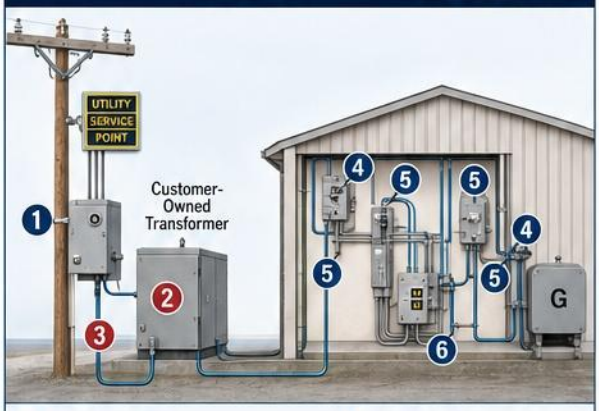
Figure 100–130 Service Point, Utility-Owned Transformers *Article 100 Comment*



AUTHOR'S COMMENT:

- For customer-owned transformers, the service point will be at the termination of the serving electric utility's conductors—often at the utility's pole. Figure 100–131

Figure 100–131 Service Point, Customer-Owned Transformers *Article 100 Comment*

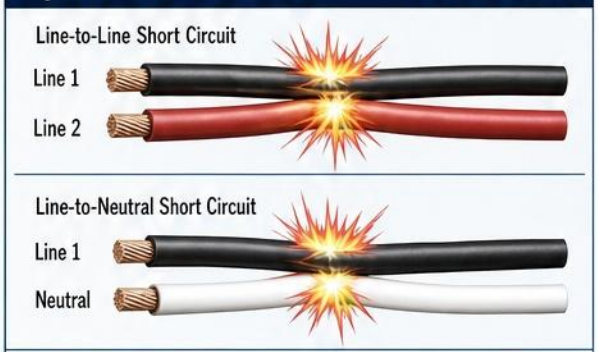


1. Service Point
2. Service Conductors
3. Service Equipment
4. Feeder Disconnect
5. Feeder Conductors
6. Transfer Switch

The service point will be at the termination of the utility conductors; often at the utility pole.

Short Circuit. An abnormal connection of low impedance between two or more points of different potential. Figure 100–132

Figure 100–132 Short Circuit *Article 100 Definition*



An abnormal connection of low impedance between two or more points of different potential.

AUTHOR'S COMMENT:

- A short circuit occurs when there is an unintentional electrical connection between two phase conductors or a phase conductor and neutral conductor.

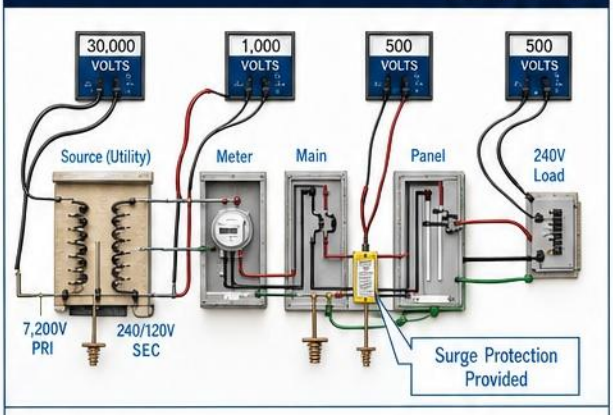
Short-Circuit Current Rating. The fault current at a nominal voltage to which equipment can be connected without sustaining damage exceeding defined acceptance criteria.

Show Window. Windows above doors which are used or designed for the display of goods or advertising material.

Special Permission. Written consent of the authority having jurisdiction (AHJ).

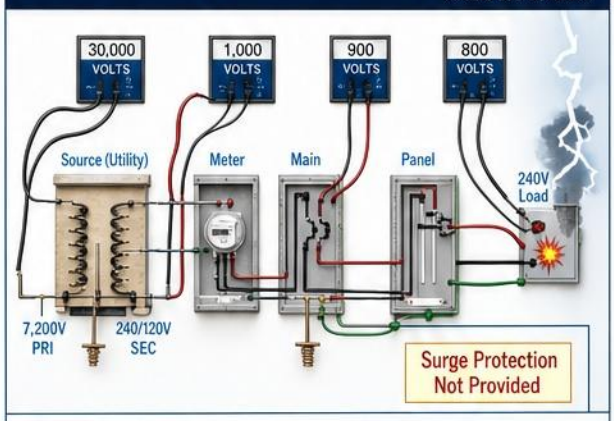
Surge-Protective Device (SPD). A protective device intended to limit transient voltages by diverting or limiting surge current. The device prevents continued flow while remaining capable of repeating these functions. SPDs can be designated as Type 1 and Type 2. Figure 100–133 and Figure 100–134

Figure 100–133 Surge-Protective Device (SPD) *Article 100 Definition*



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 function.

Figure 100–134 Surge-Protective Device (SPD) *Article 100 Definition*



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.

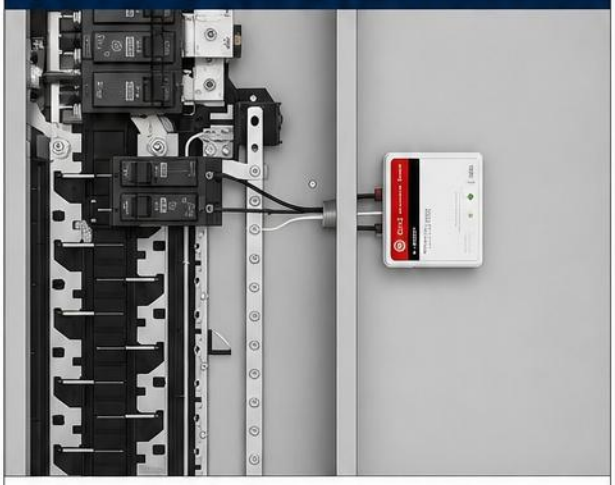
Surge-Protective Device, Type 1. Type 1 surge-protective devices are intended for installation at or on the supply side of the service disconnect. ▶ Figure 100–135

Figure 100–135 Surge-Protective Device, Type 1 Article 100 Definition

Type 1 surge-protective devices are intended to be installed at or on the supply side of the service disconnect.

Surge-Protective Device, Type 2. Type 2 surge-protective devices are intended for installation on the load side of the service disconnect. ▶ Figure 100–136 and ▶ Figure 100–137

Figure 100–136 Surge-Protective Device, Type 2 Article 100 Definition

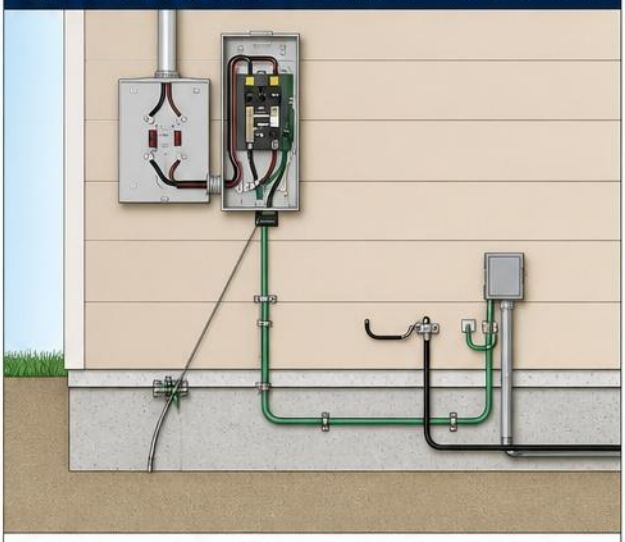


Type 2 surge-protective devices are intended for installation on the load side of the service disconnect.

Switchboard. A large single panel, frame, or assembly of panels which contain switches, overcurrent protection devices, buses, and instruments. ▶ Figure 100–138

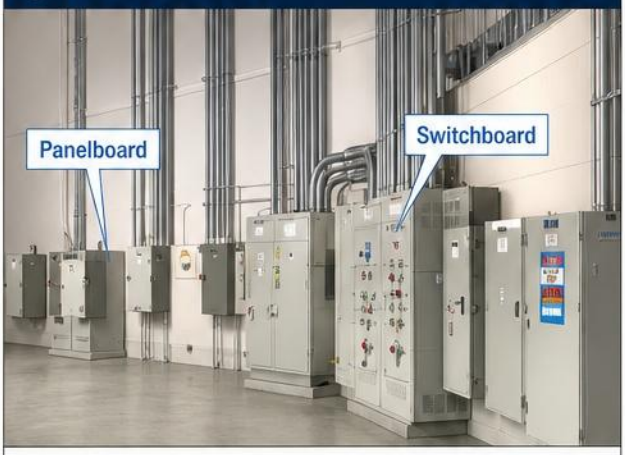
Note: These assemblies can be accessible from the rear, side, or front, and are not intended to be installed in cabinets.

Figure 100–137 Surge-Protective Device, Type 2 Article 100 Definition



Type 2 surge-protective devices are intended for installation on the load side of the service disconnect.

Figure 100–138 Switchboard Article 100 Definition



A large single panel, frame, or assembly of panels which contain switches, overcurrent protection devices, buses, and instruments.

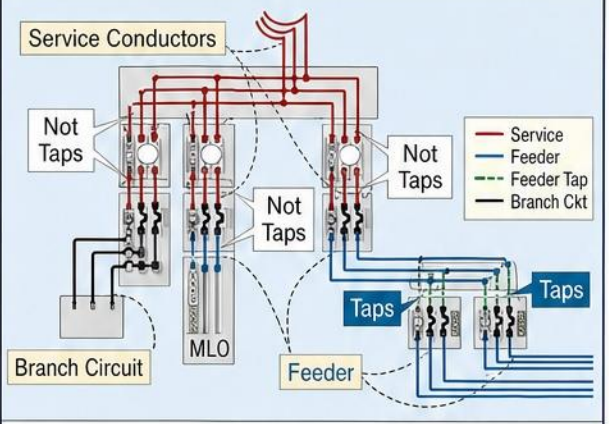
Tap Conductors. A conductor, other than a service conductor, with overcurrent protection rated more than the ampacity of the conductor. ▶ Figure 100–139

Transformer. Single- or three-phase equipment that uses electromagnetic induction to convert current and voltage in a primary circuit into current and voltage in a secondary circuit. ▶ Figure 100–140

Author's Comment:

▶ Article 450 contains the primary requirements for transformers.

Figure 100–139 Tap Conductors *Article 100 Definition*



A conductor, other than a service conductor, with overcurrent protection rated more than the ampacity of the conductor.

Figure 100–141 Transformer Secondary Conductor *Article 100 Definition*

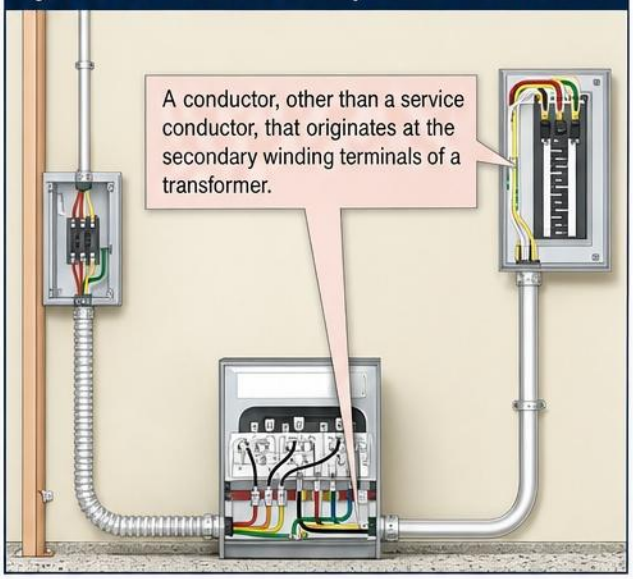
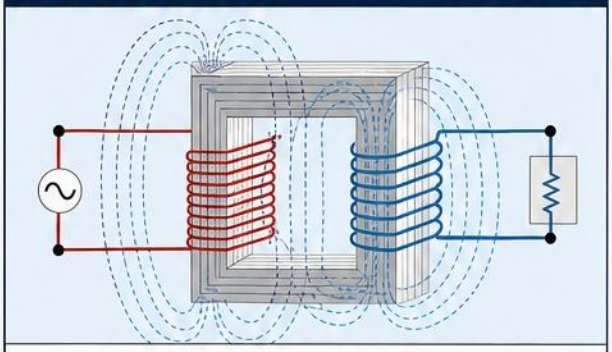
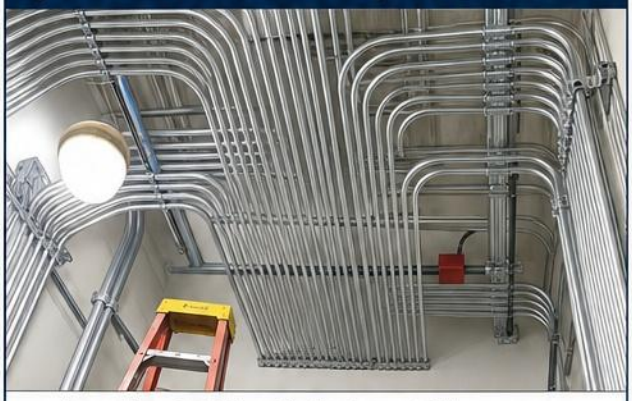


Figure 100–140 Transformer *Article 100 Definition*



Single- or three-phase equipment that uses electromagnetic induction to convert current and voltage in a primary circuit into current and voltage in a secondary circuit.

Figure 100–142 Electrical Metallic Tubing (EMT) *Article 100 Definition*



An unthreaded thinwall circular metallic raceway that when joined together with fittings can be used as an equipment grounding conductor.

Transformer Secondary Conductor. A conductor, other than a service conductor, that originates at the secondary winding terminals of a transformer. (Figure 100–141)

Tubing, Electrical Metallic Tubing (EMT). An unthreaded thinwall circular metallic raceway designed for the physical protection and routing of conductors. When joined together with fittings, it can be used as an equipment grounding conductor. (Figure 100–142)

Tubing, Electrical Nonmetallic Tubing (ENT). A pliable corrugated circular raceway with couplings, connectors, and fittings. This tubing is composed of flame-retardant material which is resistant to moisture and chemical atmospheres. (Figure 100–143)

Figure 100–143 Electrical Nonmetallic Tubing (ENT) *Article 100 Definition*

A pliable corrugated circular raceway with couplings, connectors, and fittings. This tubing is composed of flame-retardant material which is resistant to moisture and chemical atmospheres.

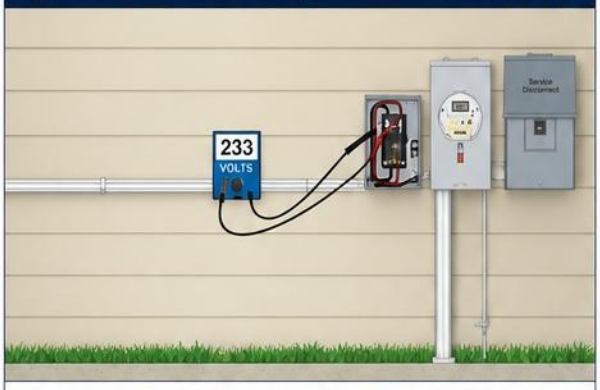
AUTHOR'S COMMENT:

- ENT can be bent by hand with reasonable force and without other assistance.

Voltage, Nominal. A value assigned for designating voltage classes (such as 120/240V, 208Y/120V, and 480Y/277V).

Note 1: The actual voltage at which a circuit operates, which can vary from the nominal within a range that permits satisfactory operation of equipment.
▶ Figure 100–144

Figure 100–144 Nominal Voltage — Article 100 Note 1



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

Weatherproof. Constructed or protected so exposure to the weather will not interfere with successful operation.

Note: Enclosures identified by the manufacturer as rainproof, raintight, or watertight can fulfill the requirements for weatherproof.

Wireway, Metal Wireway. A sheet metal trough with hinged or removable covers for housing and protecting electrical conductors and cable in which conductors are placed after the raceway has been installed. ▶ Figure 100–145

Wiring Device. An electrical device with a yoke or used with flexible cord or cable that serves as either a connection point to facilitate the flow of current, or as a control device in general distribution and branch circuits. ▶ Figure 100–146

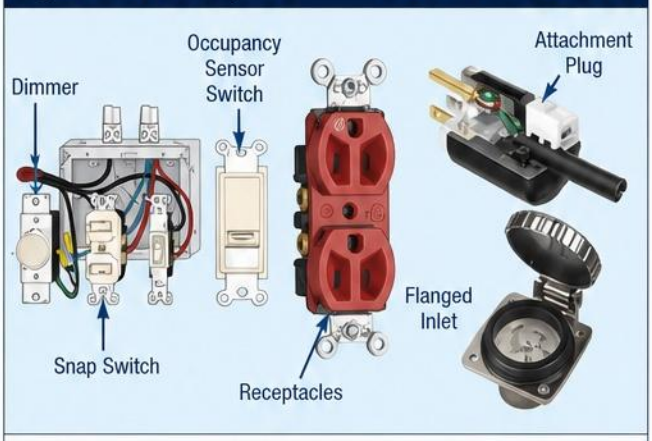
Note: Examples of wiring devices include attachment plugs, receptacles, general-use snap switches, pendant switches, surface switches, dimmers, electronic control switches, and lighting control switches.

Yoke (Strap). The structural frame of a wiring device (such as a receptacle or switch) that serves as the mounting means.
▶ Figure 100–147

Figure 100–145 Metal Wireway — Article 100 Definition

A sheet metal trough with hinged or removable covers for housing and protecting electric wires and cable, and in which conductors are placed after the raceway has been installed.

Figure 100–146 Wiring Device — Article 100 Definition and Note



An electrical device with a yoke or used with flexible cord or cable that serves as either a connection point to facilitate the flow of current or as a control device in general distribution and branch circuits.

Figure 100–147 Yoke (Strap) — Article 100 Definition

The structural frame of a wiring device (such as a receptacle or switch) that serves as the mounting means.

ARTICLE 200 — USE AND IDENTIFICATION OF GROUNDED CONDUCTORS

200.1 General. A grounded conductor (neutral) shall be installed in accordance with the provisions of this article and in accordance with Parts II and III of this article. Identification of grounded conductors shall be in accordance with 200.6.

200.2 Use.

200.2(A) Grounded Conductor at All Buildings. A grounded conductor (neutral) shall be provided at all buildings or structures where system grounding is required.

200.2(B) Utilization Equipment. A grounded conductor (neutral) shall be run with the circuit conductors to each utilization equipment.

200.2(C) Sixth Conductor. A sixth conductor shall be installed in accordance with 250.118(10) and, in buildings or structures required to be equipped with a lighting protection system in accordance with 230.67, shall be installed in accordance with 250.64.

200.2(D) Grounded Conductor for Separately Derived Systems. A separately derived system shall have a grounded conductor (neutral) run with the circuit conductors to each utilization equipment supplied by the system.

200.3 Connections.

200.3(A) Connection of Grounded Conductors. Grounded conductors (neutrals) shall be securely connected to their source of supply at the service, system disconnecting means, or at other approved means.

200.3(B) Connections to Equipment. Grounded conductors (neutrals) shall be connected to the terminals or busbars of electrical equipment in accordance with 110.14.

200.4 Extensions.

Grounded conductors (neutrals) may be extended within equipment in accordance with 200.4(A) and 200.4(B).

200.4(A) Internal Extensions. Grounded conductors (neutrals) may be extended within electrical equipment where splicing, cable tap, or bus tap is necessary.

200.4(B) External Extensions. Grounded conductors (neutrals) may be extended outside the equipment where necessary to facilitate the installation or enlargement of electrical equipment.

200.5 Interruption.

A grounded conductor (neutral) shall be permitted to be interrupted where permitted by 250.142.

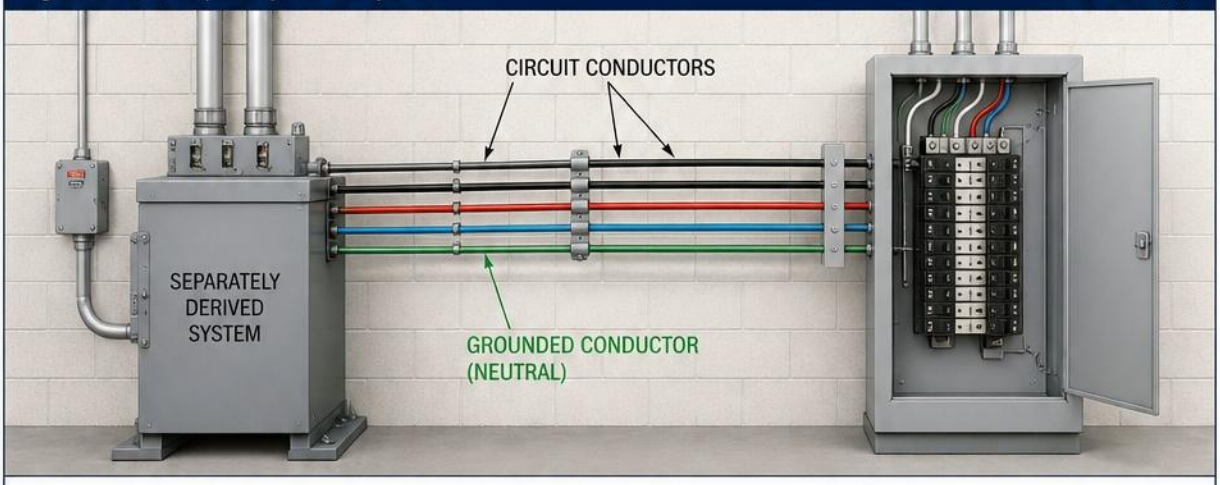
200.6 Identification.

Grounded conductors (neutrals) shall be identified where required by 110.15.

200.7 Maintenance and Identification.

Equipment grounding conductors, equipment bonding jumpers, grounded service conductors (neutrals), and grounded circuit conductors shall be maintained in accordance with 110.15. Equipment grounding conductors, equipment bonding jumpers, grounded service conductors (neutrals), and grounded circuit conductors shall be identified in accordance with 110.15.

Figure 200.2(D) Separately Derived System — NEC 200.2(D)



A separately derived system must include a grounded conductor (neutral) run with the circuit conductors to each utilization equipment it supplies.

ARTICLE 110 General Requirements for Electrical Installations

Introduction to Article 110—General Requirements for Electrical Installations

Article 110 is the first article in the *NEC* that sets forth requirements, as opposed to overall scope, information, or definitions. It includes general rules that apply to all installations and serves as the foundation of the *Code*. This article is divided into five parts, but we only cover Parts I and II, for systems under 1000V, nominal.

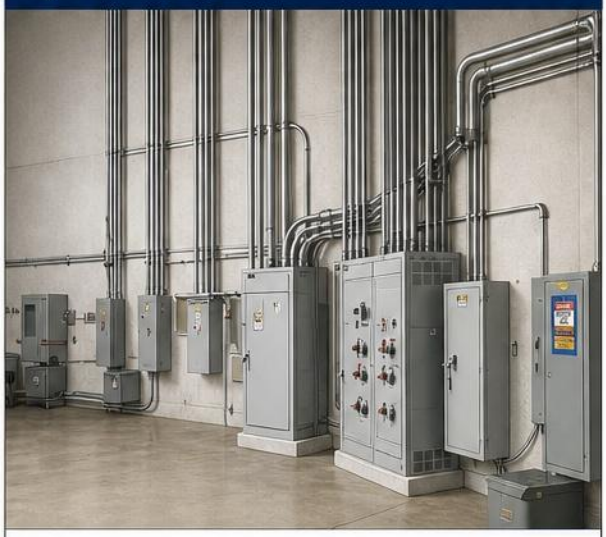
As you begin your journey to understanding the *NEC*, remember that many other *Code* rules are written assuming that you will first refer to Article 110 to determine the general requirements. By taking the time to read—and understand—each of these rules, you will set yourself up for success!

Part I. General Requirements

110.1 Scope

This article establishes the general requirements for the examination, approval, installation, use, and access to spaces around electrical equipment.[1]

Figure 110-1 Scope 110.1



Article 110 sets forth the general requirements for the examination, approval, installation, use, and access to spaces around electrical equipment.

110.2 Approval of Conductors and Equipment

The authority having jurisdiction (AHJ) is required to approve all conductors and equipment.[2]

Figure 110-2 Approval of Conductors and Equipment 110.2

The authority having jurisdiction (AHJ) is required to approve all conductors and equipment.

Author's Comment:

- Authorities Having Jurisdiction (AHJ) generally accept equipment that is listed by a product-testing organization, such as *Underwriters Laboratories, Inc. (UL)*. The *NEC* does not require all equipment to be listed—but many state and local authorities having jurisdiction do.

110.3 Installation and Use of Equipment

(A) Examination. When evaluating equipment for approval, the following factors must be considered:

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

Note 2: The appropriateness of equipment use may be determined by a description placed on or supplied with a product that *identifies* the intended purpose, environment, or application. Suitability may 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 (both normal and abnormal)

(6) Arcing effects

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

(8) Cybersecurity for network-connected life safety equipment to address its ability to withstand unauthorized updates and malicious attacks, while maintaining its safety functionality

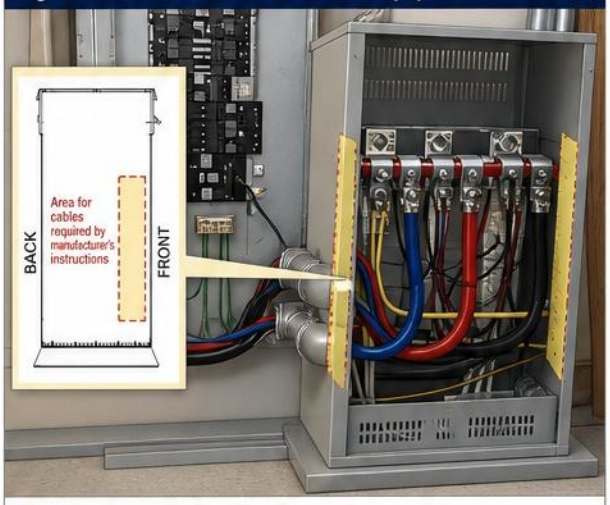
(9) Practical safeguarding of persons using (or in contact with) the equipment

Author's Comment:

- If equipment is not listed or labeled, the authority having jurisdiction (AHJ) may apply the guidelines in 110.3(A) to determine suitability before approving its installation and conductors.

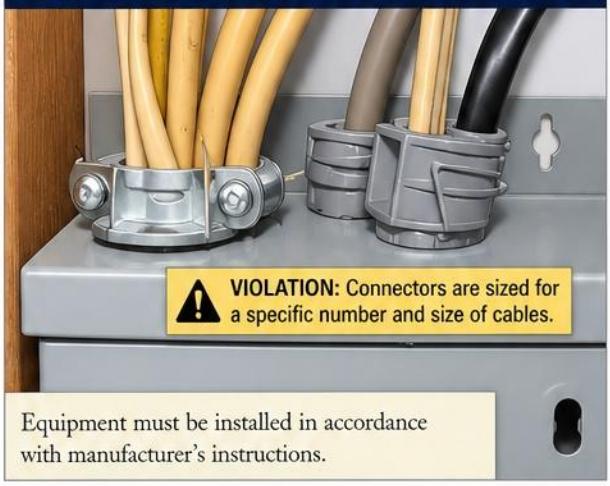
(B) Installation and Use of Equipment. Equipment must be installed in accordance with manufacturer's instructions. See **Figure 110–3** and **Figure 110–4**.

Figure 110–3 Installation and Use of Equipment 110.3(B)



Equipment must be installed in accordance with manufacturer's instructions.

Figure 110–4 Installation and Use of Equipment 110.3(B)



Equipment must be installed in accordance with manufacturer's instructions.

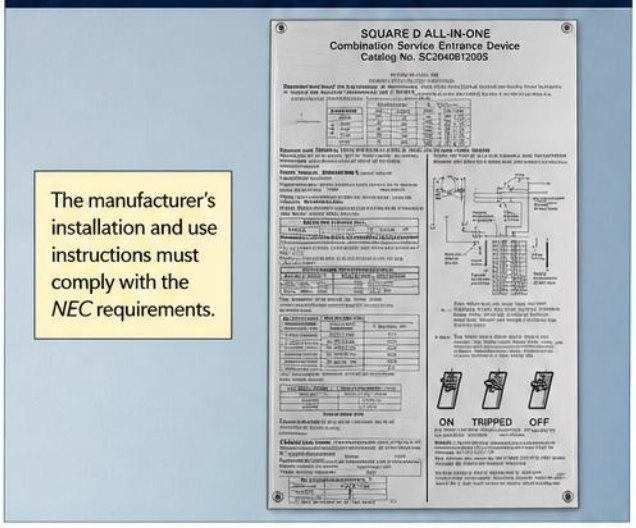
The manufacturer's installation and use instructions must comply with the *NEC* requirements. See **Figure 110–5**.

Note: Manufacturer's installation instructions can be provided as printed material, quick response (QR) code, or web address for download. See **Figure 110–6** and **Figure 110–7**.

Author's Comment:

- Many electricians previously discarded installation instructions, seeing little value in retaining them. That is no longer acceptable because manufacturers now use QR codes on electrical equipment. The instructions are always readily available on their websites.

Figure 110-5 Manufacturer's Instructions 110.3(B)

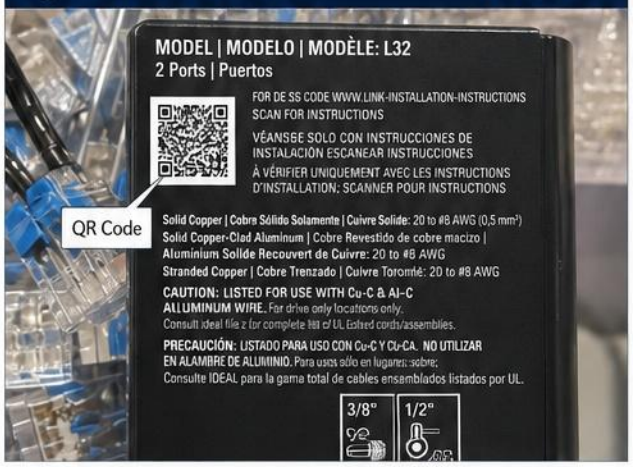


Instructions must accompany the equipment and meet *NEC* requirements.

Figure 110-6 QR Codes 110.3(B) *Note*

The manufacturer's installation instructions can be supplied as printed material, a quick response (QR) code, or a web address for download.

Figure 110-7 Web Address 110.3(B) *Note*



The manufacturer's installation instructions can be supplied as printed material, a quick response (QR) code, or a web address for download.

(C) Listing. Testing, evaluating, and listing of products must be performed by a recognized, qualified electrical testing laboratory in accordance with standards that provide adequate safety to comply with the *NEC*.

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

110.5 Conductor Material

Conductors must be copper, aluminum, or copper-clad aluminum. If the conductor material is not specified, the sizes given in this *Code* only apply to copper conductors.

Figure 110-8

Figure 110-8 Conductor Material 110.5

Conductors must be copper, aluminum, or copper-clad aluminum. If the conductor material is not specified, the sizes given in this *Code* only apply to copper conductors.

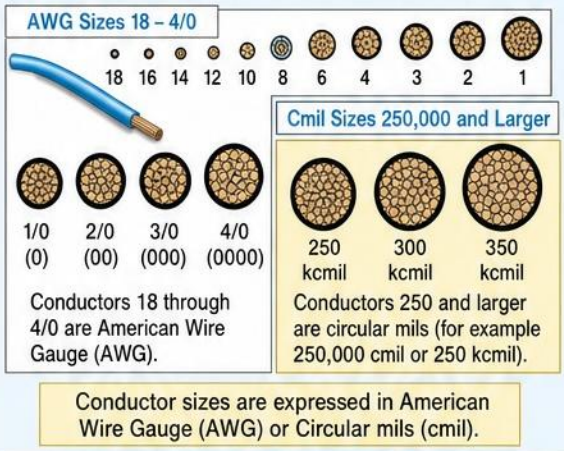
110.6 Conductor Sizes

Conductor sizes are expressed in American Wire Gauge (AWG) or circular mils (cmil). **Figure 110-9**

AUTHOR'S COMMENT:

- Chapter 9, Table 8 gives the circular mil area of AWG conductors.

Figure 110–9 Conductor Sizes 110.6

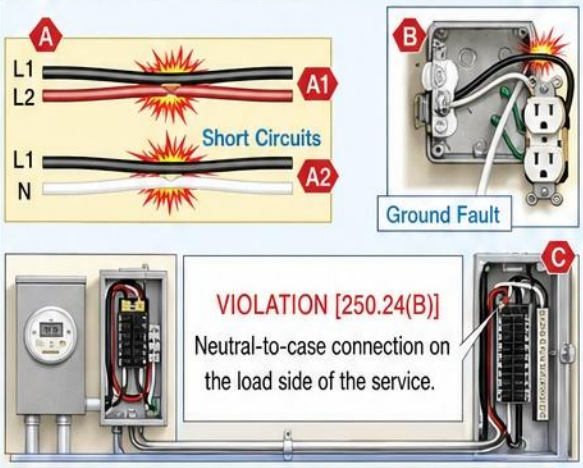


Conductor cross-sectional areas are identified either by American Wire Gauge (AWG) for sizes 18 through 4/0 or by circular mils (cmil) for 250,000 cmil and larger.

110.7 Wiring Integrity

Electrical installations must be free of *short circuits, ground faults,* or *neutral-to-ground* connections, unless required or permitted by the *Code*.

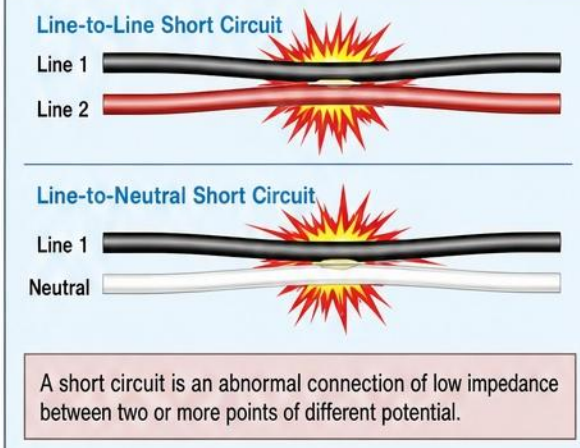
Figure 110–10 Wiring Integrity 110.7



Installations must be free of short circuits (A), ground faults (B), and connections between the neutral conductor and equipment grounding conductor (C), unless required or permitted by the *Code*.

Short Circuit. A short circuit is an abnormal, low-impedance connection between two or more points at different potentials.

Figure 110–11 Short Circuit *Article 100 Definition*

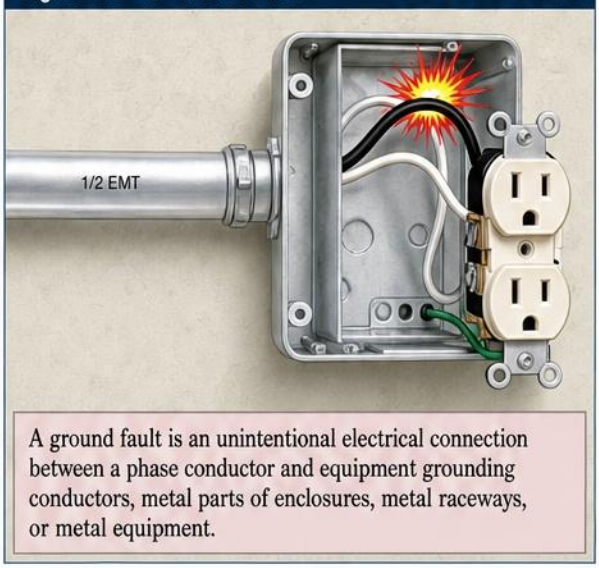


A short circuit is an abnormal, low-impedance connection between two or more points that are at different electrical potentials.

Ground Fault. A ground fault is an unintentional electrical connection between a phase conductor and equipment grounding conductors, metal parts of enclosures, metal raceways, or metal equipment.

Figure 110–12

Figure 110–12 Ground Fault *Article 100 Definition*

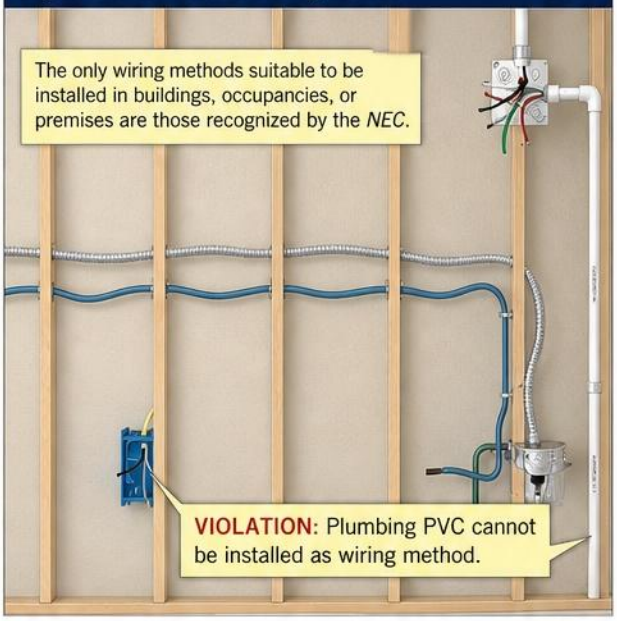


110.8 Suitable Wiring Methods

Only wiring methods that are recognized as suitable for installation in buildings, occupancies, or premises are those recognized by the *NEC*.

Figure 110–13

Figure 110–13 Suitable Wiring Methods 110.8

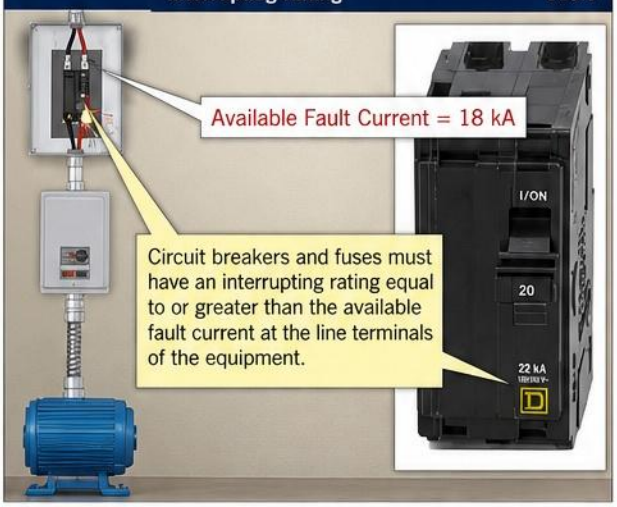


The wiring methods that are permitted for installation in buildings, occupancies, or premises are limited to those specifically recognized in the *NEC*.

110.9 Overcurrent Protective Device Interrupting Rating

Circuit breakers and fuses must have an interrupting rating equal to or greater than the available fault current at the line terminals of the equipment. Figure 110–14

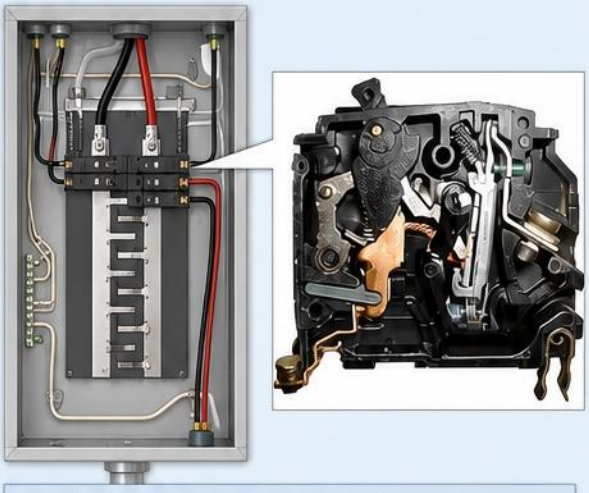
Figure 110–14 Overcurrent Protective Device Interrupting Rating 110.9



Overcurrent protective devices must be rated with an interrupting capacity that is at least as high as the available fault current at the line terminals of the equipment.

Circuit Breaker. A device designed to open and close the circuit manually but opens the circuit automatically during an overcurrent condition. Figure 110–15

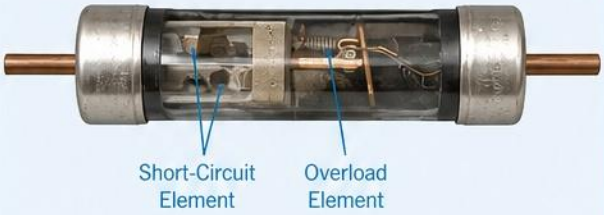
Figure 110–15 Circuit Breaker *Article 100 Definition*



A device designed to open and close the circuit manually but opens the circuit automatically during an overcurrent condition.

Fuse. An overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent. Figure 110–16

Figure 110–16 Fuse *Article 100 Definition*



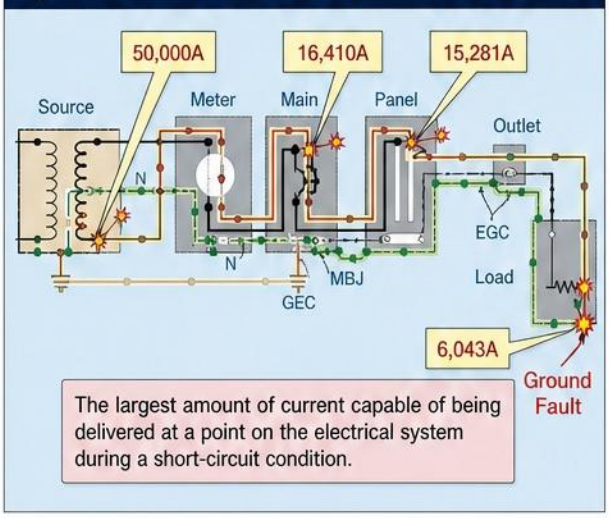
An overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent.

Interrupting Rating. The highest fault current at rated voltage that the device is identified to interrupt under standard test conditions. Figure 110–17

Figure 110-17 Interrupting Rating — Article 100 Definition

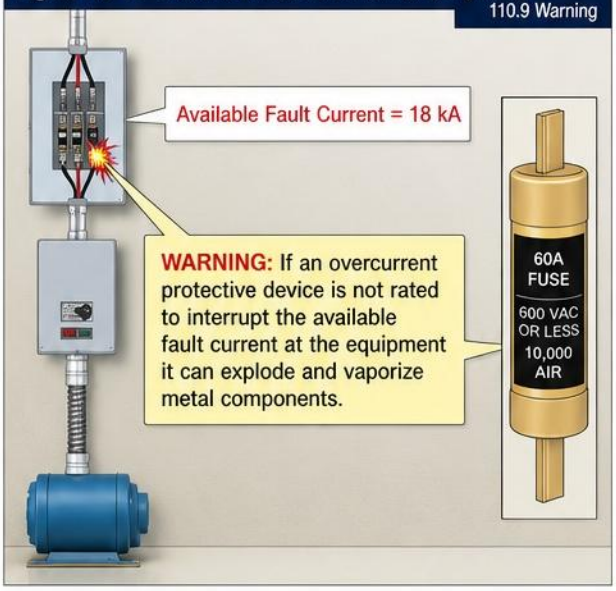
Fault Current, Available Fault Current. The largest amount of current capable of being delivered at a point on the electrical system during a short-circuit condition.

Figure 110-18 Available Fault Current — Article 100 Definition



WARNING: Extremely high values of fault currents caused by short circuits or ground faults produce tremendously destructive thermal and magnetic forces. If an overcurrent protective device is not rated to interrupt the available fault current at the equipment, it can explode and vaporize metal components. This can cause severe injury or death, as well as property damage and electrical system down time.

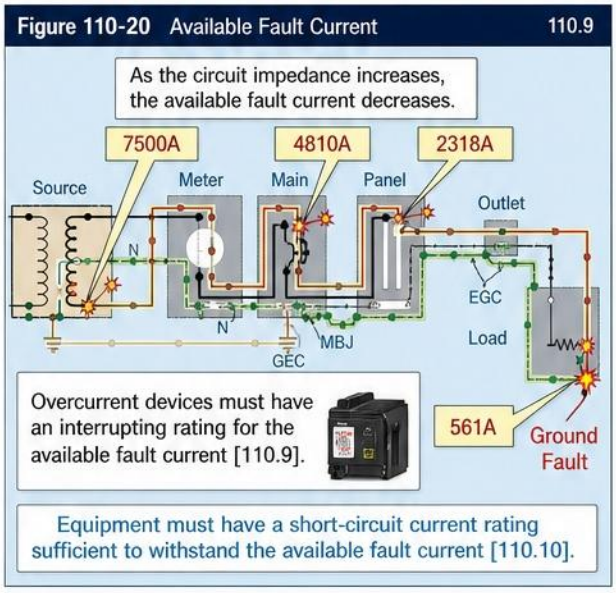
Figure 110-19 Overcurrent Protective Device Interrupting Rating — 110.9 Warning



Available Fault Current

Available fault current is the largest amount of short-circuit or ground-fault current (in amperes), available at a given point in the electrical system [Article 100]. The available fault current is first determined at the secondary terminals of the serving electric utility transformer. After that, it is calculated at the terminals of the service disconnect, then panelboards/other equipment as various connections are made downstream from the main service. The available fault current at any point depends on the impedance of the circuit—as the circuit impedance increases, the available fault current decreases at each downstream connection point of the electrical system.

Figure 110-20 Available Fault Current — 110.9



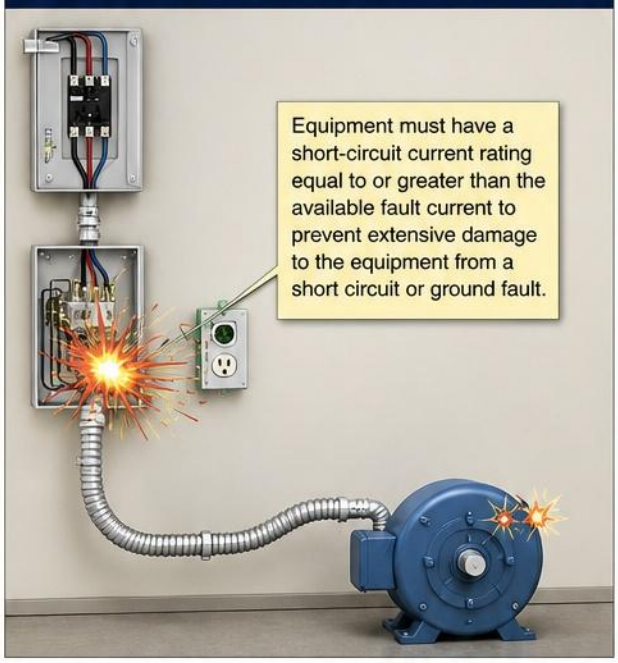
Factors that influence the available fault current at the load end of the serving electric utility transformers include system voltage, transformer kVA rating, and transformer impedance. Characteristics that affect the impedance of downstream circuit conductors include conductor material (copper versus aluminum), conductor cross-sectional area, conductor length, raceway type (metallic versus nonmetallic), and motor load fault current contributions.

110.10 Equipment Short-Circuit Current Rating, Available Fault Current

Electrical equipment must have a *short-circuit current rating* equal to or greater than the available fault current that permits the circuit overcurrent protective device to clear a short circuit or ground fault without extensive damage to the electrical equipment of the circuit.

▶ Figure 110–21

Figure 110–21 Equipment Short-Circuit Current Rating 110.10



Equipment must be rated to withstand the available fault current so that overcurrent devices can clear faults without causing extensive damage.

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

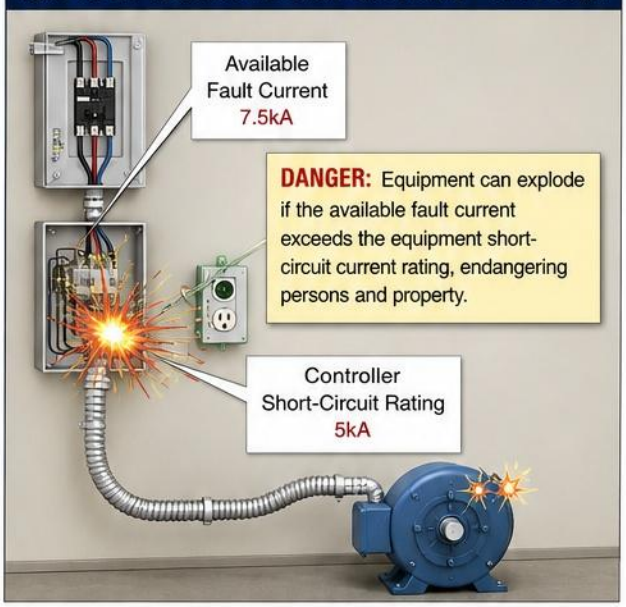
AUTHOR'S COMMENT:

- When the available fault current exceeds the short-circuit current rating of equipment, it can damage busbars, conductors, and equipment from excessive electromagnetic forces and heat.

DANGER: Equipment can explode if the available fault current exceeds the equipment short-circuit current rating, endangering persons and property.

▶ Figure 110–22

Figure 110–22 Equipment Short-Circuit Current Rating 110.10 *Danger*



When available fault current exceeds equipment short-circuit rating, explosion, injury, and property damage can occur.

110.11 Deteriorating Agents

Electrical equipment and conductors must be suitable for the environment and conditions for which they will be used as determined by the AHJ.

▶ Figure 110–23 and ▶ Figure 110–24

Equipment must not be subjected to corrosive gases, fumes, vapors, liquids, or other substances which can have a deteriorating effect on conductors and equipment.

▶ Figure 110–25 and ▶ Figure 110–26

Equipment identified for indoor use must be protected against damage from the weather during construction.

Note 1: Raceways, cable trays, cable armor, boxes, cable sheathing, cabinets, enclosures, elbows, couplings, fittings, supports, and support hardware must be suitable for the environment. See 300.8. ▶ Figure 110–27

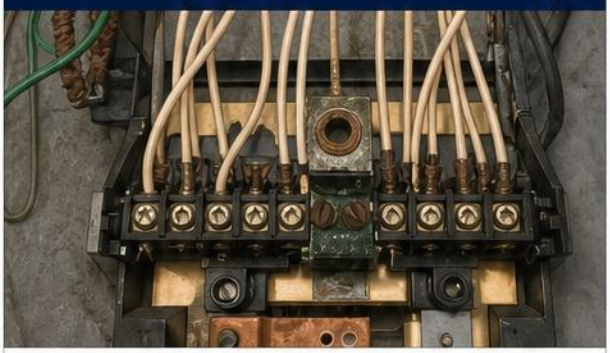
Figure 110–23 Deteriorating Agents: Equipment and Conductors 110.11

Electrical equipment and conductors must be suitable for the environment and conditions for which they will be used as determined by the AHJ.

Figure 110–24 Deteriorating Agents: Equipment and Conductors 110.11

Electrical equipment and conductors must be suitable for the environment and conditions for which they will be used as determined by the AHJ.

Figure 110–25 Deteriorating Agents: Corrosive Substances 110.11

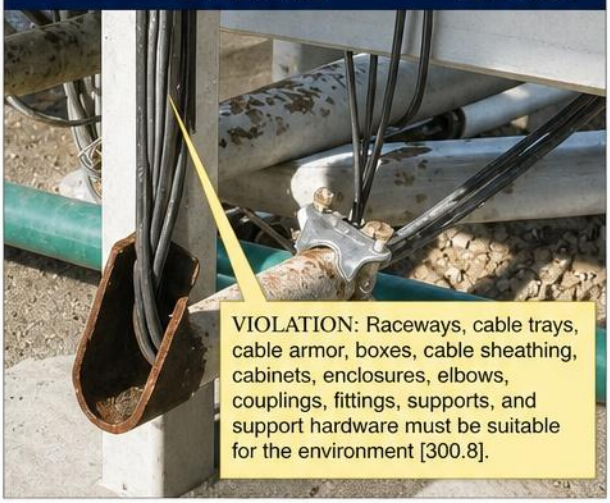


Equipment must not be subjected to corrosive gases, fumes, vapors, liquids, or other substances which can have a deteriorating effect on conductors and equipment.

Figure 110–26 Deteriorating Agents: Corrosive Substances 110.11

Equipment must not be subjected to corrosive gases, fumes, vapors, liquids, or other substances which can have a deteriorating effect on conductors and equipment.

Figure 110–27 Deteriorating Agents: Equipment and Conductors 110.11 Note 1



Note 2: Some cleaning and lubricating compounds contain chemicals that can cause plastic to deteriorate.

Equipment identified for indoor use or enclosure (NEMA Types 1, 2, 5, 12, 12K, or 13) must be protected against the weather during construction.

Note 3: See 110.28 to select an enclosure that is suitable for a specific environment.

Note 4: For minimum flood provisions, see the *International Building Code (IBC)* and the *International Residential Code (IRC)*.

CAUTION: In locations where flooding may occur, electrical equipment must be installed above the design flood elevation (DFE) as defined by *ASCE 24, Flood Resistant Design and Construction.*

110.12 Mechanical Execution of Work

Electrical equipment must be installed in a professional and workmanlike manner as determined by the AHJ. See Figure 110–28 and Figure 110–29.

Figure 110-28 Mechanical Execution of Work 110.12

Electrical equipment must be installed in a professional and workmanlike manner as determined by the AHJ.

Figure 110-29 Mechanical Execution of Work 110.12

Electrical equipment must be installed in a professional and workmanlike manner as determined by the AHJ.

Note: For information on accepted industry practices, see *ANSI/NECA 1, Standard for Good Workmanship in Electrical Construction.*

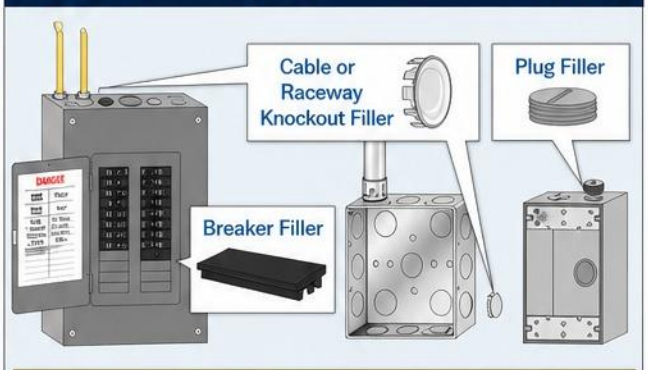
Figure 110-30 Mechanical Execution of Work 110.12 Note

Author's Comment:

- This rule and its application is a judgment call made by the authority having jurisdiction (AHJ). See 90.4(B) and 110.2.

(A) Unused Openings. Unused openings other than those used for mounting or for operation of equipment must be closed by plugs or plates that provide protection substantially equivalent to the wall of the equipment. See Figure 110–31.

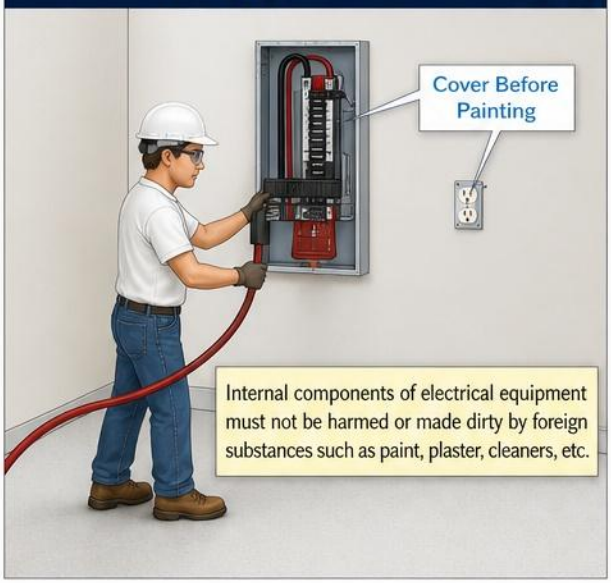
Figure 110-31 Unused Openings 110.12(A)



Unused openings other than those used for mounting or for operation of equipment must be closed by plugs or plates that provide protection substantially equivalent to the wall of the equipment.

(B) Integrity of Electrical Equipment. Internal parts of electrical equipment must not be damaged or contaminated by foreign material, such as paint, plaster, cleaners, and the like. See Figure 110–32.

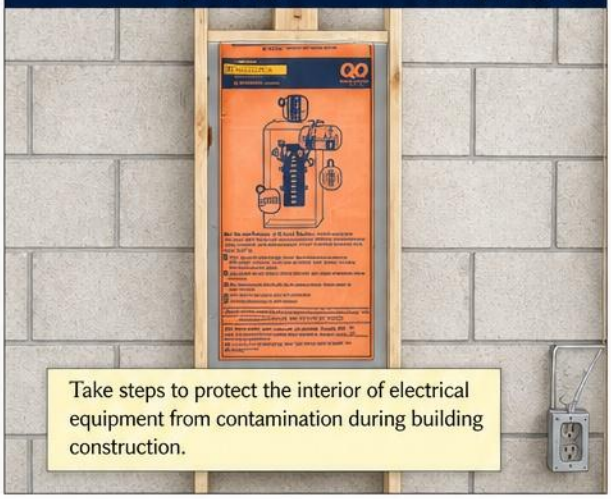
Figure 110–32 Integrity of Electrical Equipment Internal Parts 110.12(B)



Author's Comment:

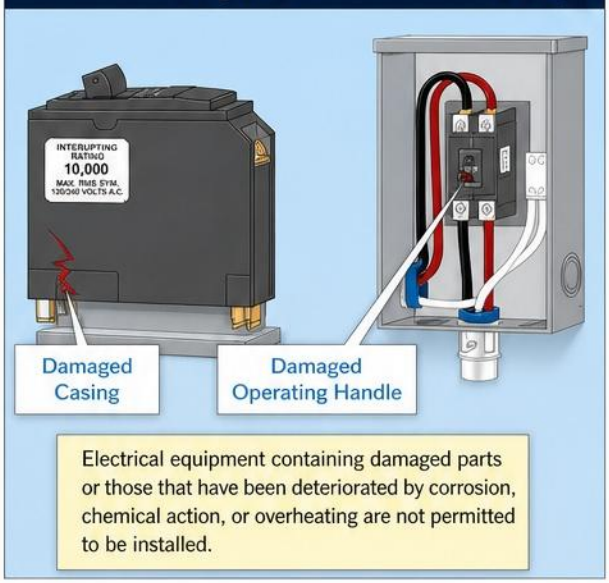
- Appropriate measures are required to prevent foreign materials from contaminating the inside of panels and receptacles during construction. Make sure electrical equipment is covered or protected while drywall, painting, or other work is performed that could cause contamination.

Figure 110–33 Integrity of Electrical Equipment Internal Parts 110.12(B) Comment



Damaged Parts. Electrical equipment that has damaged components (broken, bent, or cut) or that has been affected by corrosion, chemical action, or overheating is prohibited from being installed.

Figure 110–34 Integrity of Electrical Equipment Damaged Parts 110.12(B)



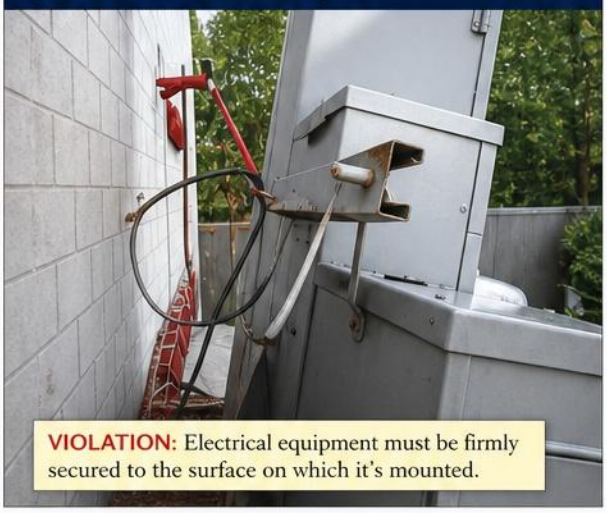
Author's Comment:

- Examples of damage include cracked insulators, missing arc shields, overheated fuse clips, damaged or missing switch handles, and circuit-breaker handles.

110.13 Equipment Mounting and Cooling

(A) Mounting of Equipment. Electrical equipment must be securely fastened to the surface where it is mounted as determined by the AHJ.

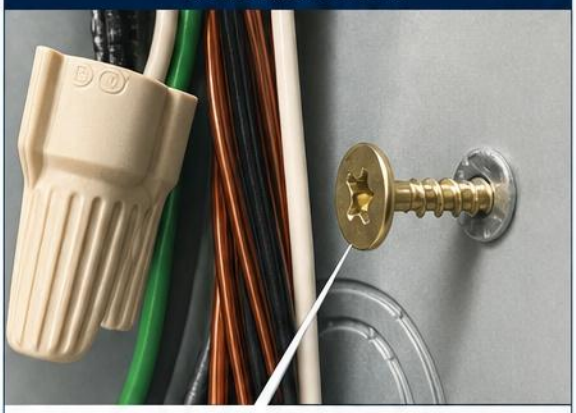
Figure 110–35 Mounting of Equipment 110.13(A)



AUTHOR'S COMMENT:

- The approach and materials used to secure electrical equipment are normally determined by the electrical installer as allowed by the authority having jurisdiction in accordance with 90.4(B) and 110.2.
  Figure 110–36

Figure 110–36 Mounting of Equipment Drywall Screws used for Panels 110.13(A) *Comment*



The method and materials used to secure electrical equipment are generally selected by the electrical installer as approved by the authority having jurisdiction in accordance with 90.4(B) and 110.2.

110.14 ELECTRICAL CONNECTIONS

Identified and Manufacturer's Instructions. Conductor terminals and splicing connectors must be identified, installed, and used for the conductor material (copper, aluminum, or copper-clad aluminum) in accordance with the manufacturer's instructions [110.3(B)]. Figure 110–37

AUTHOR'S COMMENT:

- According to *UL Category ZMWV*, wire connectors are marked with the type of conductor material as follows:
  - Terminals and splicing connectors marked "AL" are intended for aluminum wire only.
  - Terminals and splicing connectors marked "CU" are intended for copper wire only.
  - Terminals and splicing connectors marked "AL-CU" or "CU-AL" are suitable for copper, aluminum, and copper-clad aluminum.
    Figure 110–38
  - Splicing connectors marked "CCA-CU" are suitable for copper and copper-clad aluminum wire.
    Figure 110–39

Figure 110–37 Electrical Connections Manufacturer's Instructions 110.14

- Para uso solo con conductor.
- For use only with installation instructions.

- Emplòıs les cablel con intreza en el conector y terminales.
- Para uso solo ùnicamente con las instrucciones de instalaciòn.

USES
- Listed for use with: copper to copper. Temperatare rating: 221°F. / slot as PRESS / RETYPE wire / conductor size / stranded wire only. Max. building wire, 1000 V max. lighting, fault corriente nominal de 600 V máx., cableado del alimentador a 1000 V máx. / Filo o sól.

USOS
- Clasificado para usario con: cobre a cobre. Especificaciòn de temperatura: 10S °C. Clasificaciòn como un conector de cable TIPO A PRESION para uso solo con conductores de alambre retorcido / trenzado. Y max. building wire, 1000 V max. lighting, fau, corriente nominal de 600 V máx. de alimentador a 1000 V máx. / Filo o sól.

Conductor splicing connectors must be identified, installed, and used for the conductor material in accordance with the manufacturer's instructions.

Figure 110–38 Electrical Connection, Terminal Marking 110.14 Comment

According to *UL* Category *ZMWV*, wire connectors are marked with the type of conductor material as follows:
(1) Terminal connectors marked "AL" are only suitable for aluminum wire only.
(2) Terminal connectors marked "CU" are only suitable for copper wire only.
(3) Terminal connectors marked "AL-CU" or "CU-AL" are suitable for copper, aluminum, and copper-clad aluminum.

Figure 110–39 Electrical Connection, Splicing Connector Marking 110.14 Comment

Installation Instructions:
1. Turn off power before installing or removing connector
2. Select the appropriate wires according to the below wire combinations.
3. Strip wires to recommended strip length of 7/16" (CWLD12 and CWLD13) or 1/2" (CWLD17).
4. Pre-twisting is acceptable but not required. For pre-twisting see step #7.
5. Align any frayed ends and conductors.
6. Hold stripped wires together with ends even. Lead stranded conductors by approx. 1/16".
7. For pre-twisting, strip wires long, insulation ends, twist conductors together, trim to recommended strip length.
8. Insert wires firmly into connector. Make sure the wires are installed firmly after the wires are fully inserted into the connector.

Identification and Usage:

Identified as peres UL® Wire Connectors on the following SOLID and/or STRANDED CCA-TO-CCA, CCA-TO-CU AND CU-TO-CU CONDUCTOR wire combinations SUITABLE FOR USE with Copperweld CCA wire. IDENTIFIED for intermixing between CU conductors and Coppperweld CCA conductors.

> Temperature Rating 90 °C (221 °F) Flammability V-0
> Voltage Rating (Max.) 600V
> Standards: Conforms UL STD 486C, Certified to CSA STD C22.2# 188

Intertek 5027144

Splicing connectors marked "CCA-CU" are only suitable for copper and copper-clad aluminum wire.

Conductors and conductor materials. Conductors such as copper, aluminum, or copper-clad aluminum are not allowed in a terminal or as a splice connection unless the terminal or splicing connector is identified for combining dissimilar conductor materials. ▸ Figure 110–40

Figure 110–40 **110.14**
Electrical Connections—Dissimilar Conductor Material

Connectors such as copper, aluminum, or copper-clad aluminum are not allowed in a splice unless the splicing connector is identified for combining dissimilar conductor materials.

Author's Commentary:

- Termination and splicing connector devices listed for use with aluminum and copper conductors must be identified for the product package or on the terminal connectors. The reason copper and aluminum should not contact one another is that corrosion develops between the two conductors because of galvanic corrosion. This increases contact resistance at the terminal or splice point, and higher resistance can cause overheating at the terminal or connector and may result in a fire. ▸ Figure 110–41

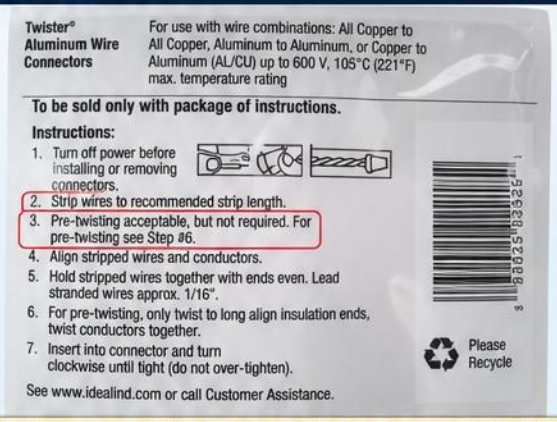
- Pre-twisting conductors before applying twist-on wire connectors is common practice, but the *NEC* does not require it. In fact, Ideal® Wing-Nut® twist-on connectors instructions state, "Pre-twisting is acceptable, but not required." ▸ Figure 110–42

- The *NEC* requires aluminum wire to be manufactured with AA-8000 series aluminum alloy, which does not require antioxidant paste at terminations [310.5(B)]. ▸ Figure 110–43

Figure 110–41 **110.14**
Electrical Connections—Dissimilar Conductor Material

Splicing connectors listed for combining aluminum and copper conductors will be marked on the product package or terminal connectors.

Figure 110–42 **110.14**
Electrical Connections—Twist-On Wire Connectors



Conductors that have been spliced using a connector identified for splicing are not required to be twisted together before installing a twist-on wire connector.

Figure 110–43 **110.14**
Electrical Connections—Aluminum Conductor Termination

The *National Electrical Code* [310.15(B)] requires aluminum wire to be manufactured with AA-8000 series aluminum alloy, which does not require antioxidant paste at terminations.

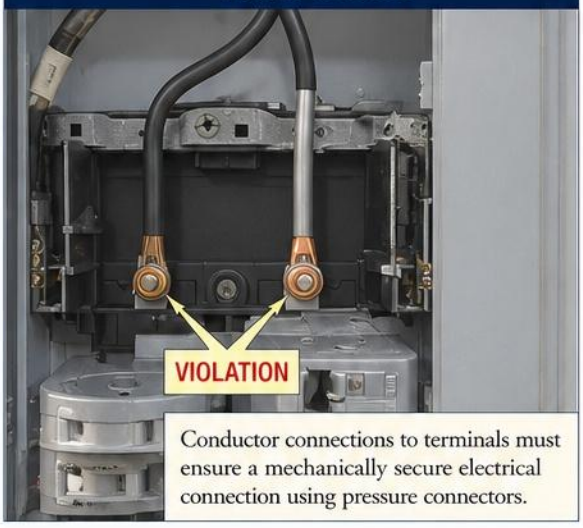
Finely-Stranded Conductors. Terminal or splicing connectors for conductors more finely stranded than Class B and Class C stranding as shown in Chapter 9, Table 10 must be identified for the specific conductor class.

Figure 110–44 Electrical Connections Finely Stranded Conductors 110.14

Terminal or splicing connectors for conductors more finely stranded than Class B and Class C stranding as shown in Chapter 9, Table 10 must be identified for the specific conductor class.

(A) Conductor Terminations. Conductor connections to terminals must ensure a mechanically secure electrical connection using pressure connectors.

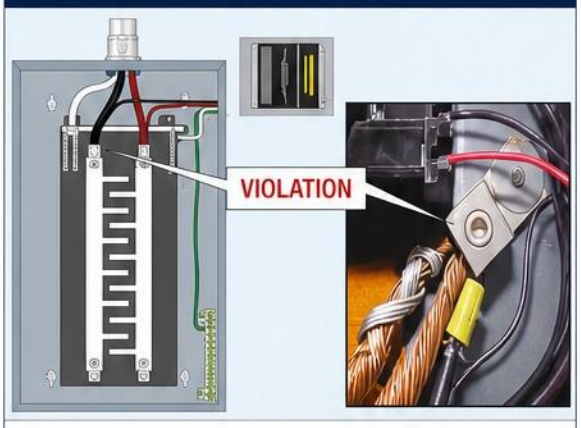
Figure 110–45 Conductor Terminations Pressure Connectors 110.14(A)



Conductor connections to terminals must ensure a mechanically secure electrical connection using pressure connectors.

Terminals are only suitable to be used for one conductor, unless the terminal is identified for more than one conductor. See Figure 110–46, Figure 110–47, Figure 110–48, and Figure 110–49.

Figure 110–46 Conductor Terminations More Than One Per Terminal 110.14(A)



Terminals are only suitable to be used for one conductor, unless the terminal is identified for more than one conductor.

Figure 110–47 Conductor Terminations More Than One Per Terminal 110.14(A)

Terminals are only suitable to be used for one conductor, unless the terminal is identified for more than one conductor.

Figure 110–48 Conductor Terminations More Than One Per Terminal 110.14(A)

Terminals are only suitable to be used for one conductor, unless the terminal is identified for more than one conductor.

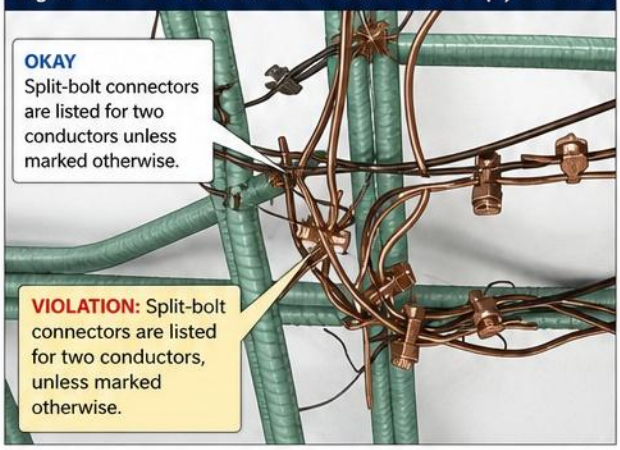
Figure 110–49 — Conductor Terminations *110.14(A)*

Terminals are intended for a single conductor unless the terminal is marked for more than one conductor.

Author's Comment

Split-bolt connectors are commonly listed for only two conductors, although some are listed for three. However, it is a common industry practice to terminate as many conductors as possible within a split-bolt connector, even though this violates the *NEC*. Figure 110–50

Figure 110–50 — Conductor Terminations *110.14(A) Comment*

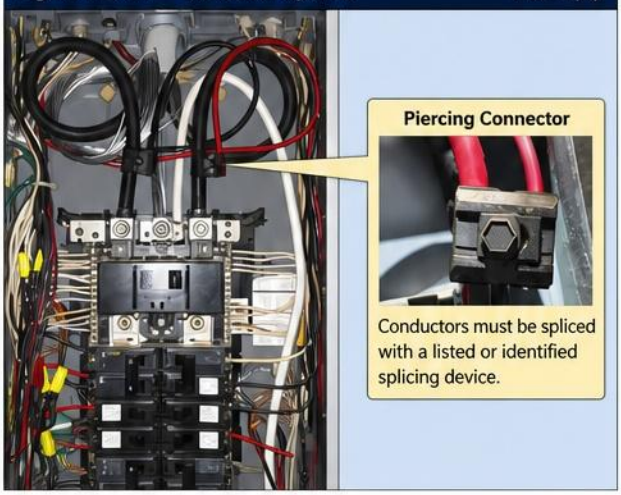


This installation violates the listing of the split-bolt connector by terminating more than the permitted number of conductors.

(B) Conductor Splices. Splices must be made with a splicing device that is identified for that purpose. Figure 110–51

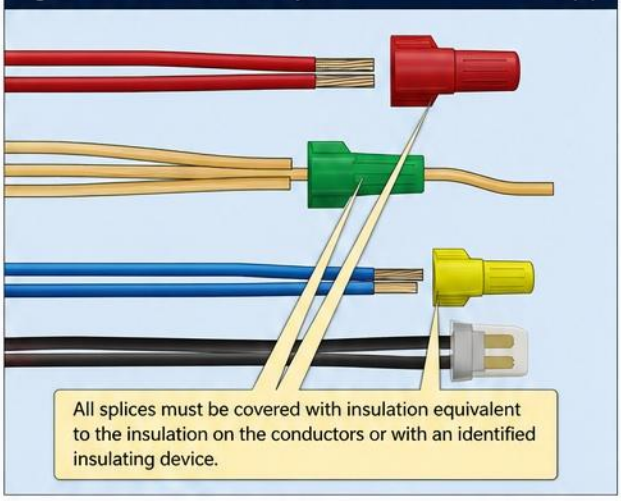
All splices, joints, and conductor free ends must be covered with insulation equivalent to that of the conductors or with an identified insulating device. Figure 110–52

Figure 110–51 — Conductor Splices *110.14(B)*



Splices must be made with a listed or identified splicing device.

Figure 110–52 — Conductor Splices *110.14(B)*



Cover splices with insulation having insulation equivalent to the conductors or with an identified insulating device.

Author's Comment

- Confirm the manufacturer's specifications for the maximum number of conductors allowed in a splicing device [110.3(B)].
- Keep the free ends of conductors insulated to prevent exposure of energized parts if those conductors are touched. This erquirement can be satisfied using an insulated twist-on connector or a push-on wire connector. Figure 110–53

Underground single conductor direct burial UF or USE cable can be spliced with a device listed for direct burial [300.7(E) and 300.17(G)]. Figure 110–54

Multiconductor UF or USE cable can be spliced underground with an underground listed splice kit for multiconductor cables.

(C) Conductor Sized to Terminal Temperature Rating. Conductors must be sized in accordance with 110.14(C)(1) and (2).

Figure 110-53 Conductor Splices, Free Ends *110.14(B) Comment*

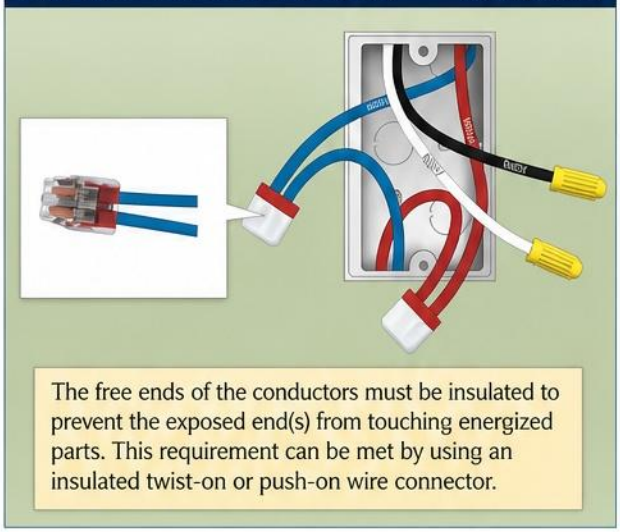
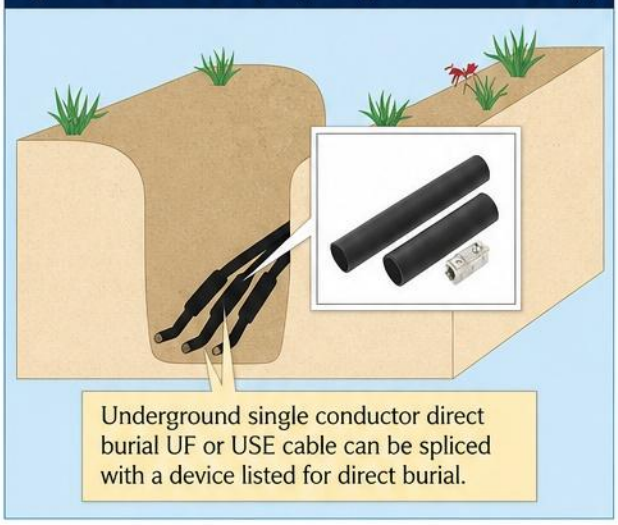


Figure 110-54 Conductor Splices, Underground *110.14(B)*



(1) **Equipment Terminations.** Conductors are sized based on Table 310.16 ampacities in accordance with 110.14(C)(1)(a) or (b) as follows:

(a) **Circuits Rated 100A or Less.** Conductors terminating on equipment for circuits rated 100A or less must be sized as follows:

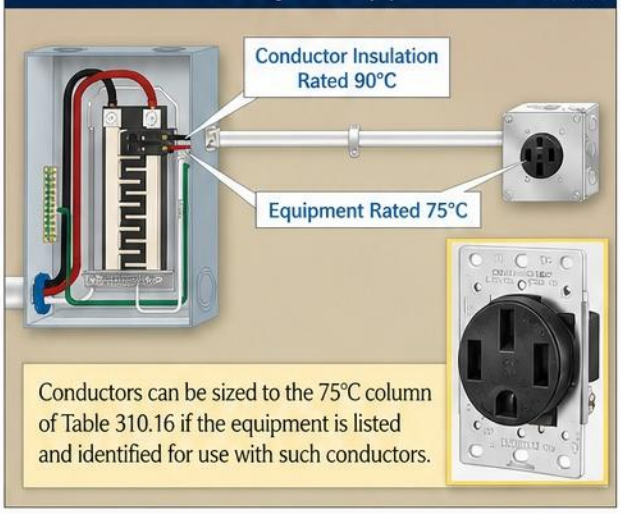
(2) Conductors must be sized to the 60°C temperature column ampacities of Table 310.16.

(3) Conductors can be sized to the 75°C temperature column of Table 310.16 if the equipment is listed and identified for use with such conductors. **Figure 110-55**

AUTHOR'S COMMENT:

- For all practical purposes, all equipment terminations are rated 75°C, therefore circuit conductors are sized to the 75°C column of Table 310.16.

Figure 110-55 Circuits Rated 100A or Less Conductor Sizing to 75°C Equipment *110.14(C)(1)(a)(3)*

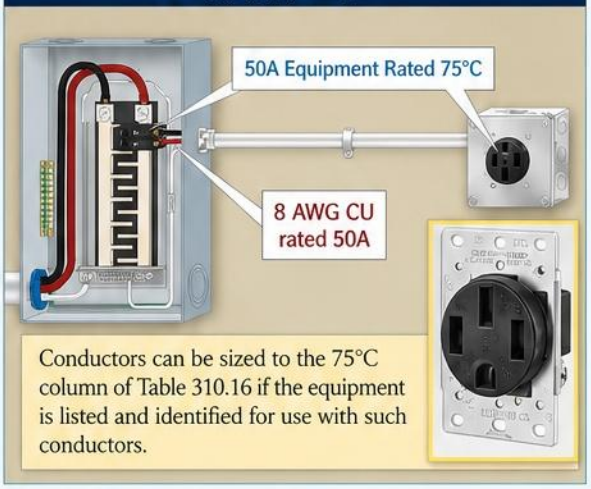


Conductor Sizing for Circuits 100A or Less [110.14(C)(1)(a)(3)] Example

Question: What size conductor is required for a 50A circuit where the equipment is rated for 75°C conductors? **Figure 110-56**

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

Figure 110-56 Circuits Rated 100A or Less Conductor Sizing to 75°C Equipment *110.14(C)(1)(a)(3) Example*

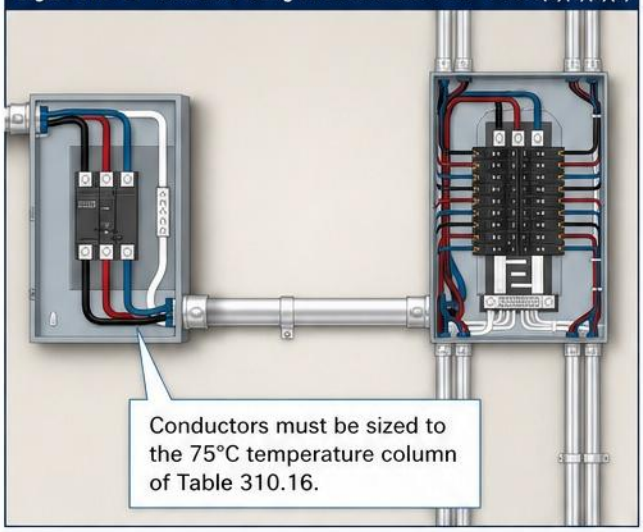


Answer: *(b) 8 AWG rated 50A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]*

(b) **Circuits Rated Over 100A.** Conductors terminating on equipment for circuits rated over 100A must be sized as follows:

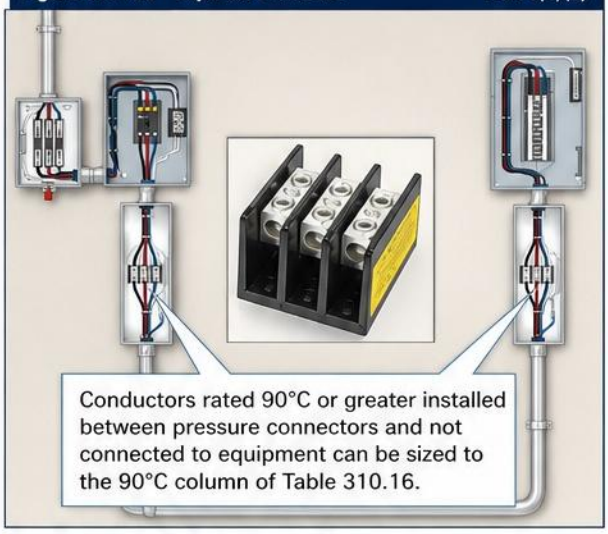
(2) Conductors must be sized to the 75°C temperature column ampacities of Table 310.16. **Figure 110-57**

Figure 110–57 Conductor Sizing for Circuits Over 100A *110.14(C)(1)(b)(2)*



Conductors for circuits rated over 100A must be sized using the 75°C temperature column from Table 310.16.

Figure 110–59 Separate Connector *110.14(C)(2)*



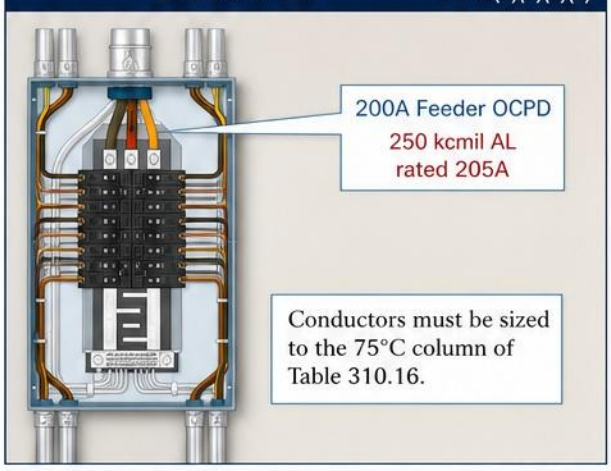
Conductors rated 90°C and located between pressure connectors that are not connected to equipment may be sized according to the 90°C column in Table 310.16.

Conductor Sizing for Circuits Over 100A [110.14(C)(1)(b)(2)] Example

Question: *What size aluminum conductor is required to supply a 200A feeder?*

(a) *2/0 AWG* (b) *3/0 AWG* (c) *4/0 AWG* (d) *250 kcmil*

Figure 110–58 Aluminum Conductor Example for Circuits Over 100A *110.14(C)(1)(b)(2)*



Answer: *(d) 250 kcmil rated 205A at 75°C [110.14(C)(1)(b)(2) and Table 310.16]*

(2) Separate Connector. Conductors rated 90°C between separately installed pressure connectors and not connected to electrical equipment can be sized to the 90°C temperature column capacities of Table 310.16. [Figure 110–59]

(D) Torquing Terminal Connections. Terminal tightening torque values must be as indicated on equipment or instructions with a tool or device approved by the authority having jurisdiction (AHJ). [Figure 110–60]

Figure 110–60 Torquing Terminal Connections *110.14(D)*

TERMINAL CONNECTION TORQUE

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TORQUE WIRE PRESSURE SCREW(S) AS FOLLOWS:			
WIRE SIZE 60/75°C AL-CU AWG/ KCMIL	NEUTRAL & GROUND BAR LB-IN	GROUND LUG (G1) & NEUTRAL LUG (N2) LB-IN	PANEL LUGS (A & B) & MAIN NEUTRAL (N1) LB-IN
#14–10	20	–	–
#8	25	–	–
#6–4	35	60	60
#3–2/0	–	60	60
#6–300	–	–	–

Terminal tightening torque values must be as indicated on equipment or instructions with a tool or device approved by the AHJ.

Note 1: Examples of approved means of achieving the indicated torque values include the use of torque tools or devices (such as shear bolts or breakaway-style devices) with visual indicators that show the proper torque has been applied. [Figure 110–61]

TABLE 310.16
Allowable Ampacities of Insulated Conductors Having Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

This table specifies the allowable ampacities for insulated conductors with up to three current-carrying conductors installed in raceways, cables, or directly buried in earth. The ampacity values are based on conductor temperature ratings and insulation types as listed.

When more than three current-carrying conductors are present, adjustment factors must be applied in accordance with 310.15(B). Ampacity also must be adjusted for ambient temperature conditions outside of those shown in this table in accordance with 310.15(A).

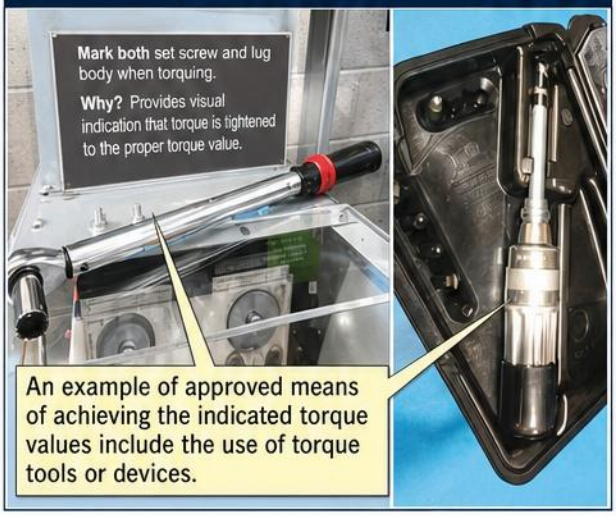
Size	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			Size
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
AWG kcmil	TW, UF	RHW, THHW THW, THWN XHHW, USE	RHH, RHW-2 THHN, THHW THW-2, THWN-2 USE-2, XHHW XHHW-2	TW, UF	RHW, THW, THWN, XHHW, USE	THHN, THWN-2, RHW-2 THHW, USE-2 XHHW, XHHW-2	AWG kcmil
14	15	20	25				14
12	20	25	30	15	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

UNDERSTANDING AND USE

Select the conductor size from the AWG or kcmil column at the left. Read horizontally to find the allowable ampacity under the appropriate temperature rating and insulation type. Use the column under COPPER for copper conductors and the column under ALUMINUM OR COPPER-CLAD ALUMINUM for those conductor materials.

Ensure that the selected conductor, installation method, ambient temperature, and number of current-carrying conductors comply with all applicable adjustment requirements in 310.15(A) and 310.15(B) when conditions differ from those in this table.

Figure 110-61 Terminal Connection Torque Approved Tool or Device 110.14(D) Note 1



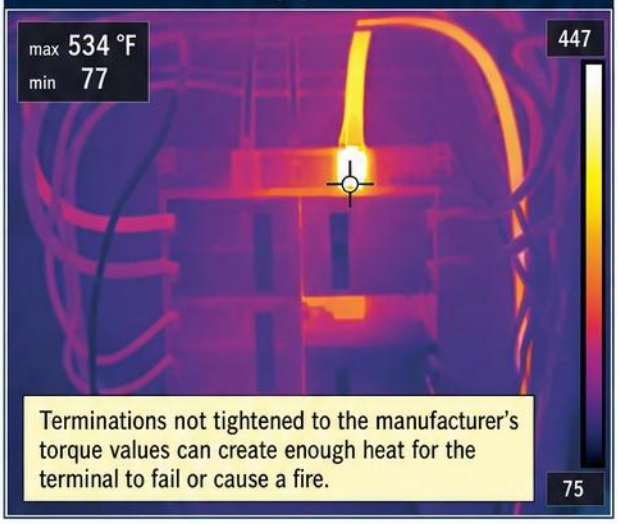
Author's Comment:

- Conductors must terminate on connectors or equipment terminals in accordance with the manufacturer's torque specifications included with equipment instructions. Figure 110-62

Figure 110-62 Terminal Connection Torque Loose Connection 110.14(D) Comment

- Failure to torque terminals properly can result in excessive heating of connectors or equipment terminals due to a loose connection. A loose connection can cause a short circuit or ground fault which may result in a fire or other failure. Figure 110-63

Figure 110-63 Terminal Connection Torque Thermal Imaging 110.14(D) Comment



Note 2: In the absence of manufacturers' torque requirements for torque values, see Annex I or *UL Standard 486A-486B, Standard for Safety-Wire Connectors*. The equipment manufacturer can be contacted if numeric torque values are not indicated on the equipment, or the instructions are not available.

Note 3: For information on torquing threaded connections and terminations, see *NFPA 70B, Recommended Practice for Electrical Equipment Maintenance*, Section 7.2. Figure 110-64 and Figure 110-65

Figure 110-64 Terminal Connection Torque Witness Mark 110.14(D) Note 3

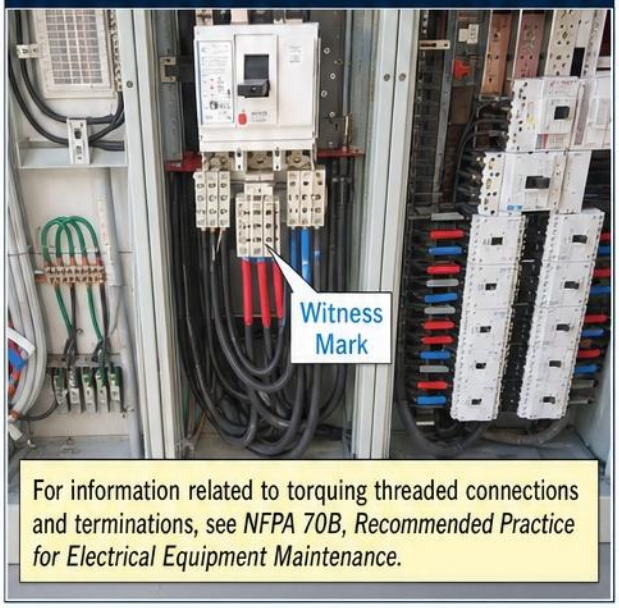
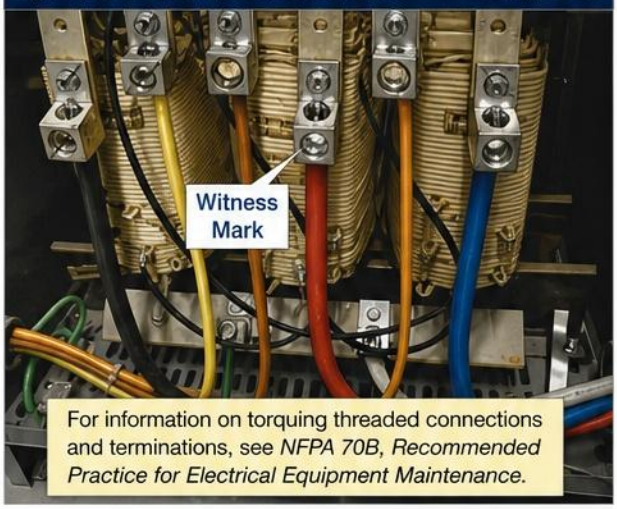
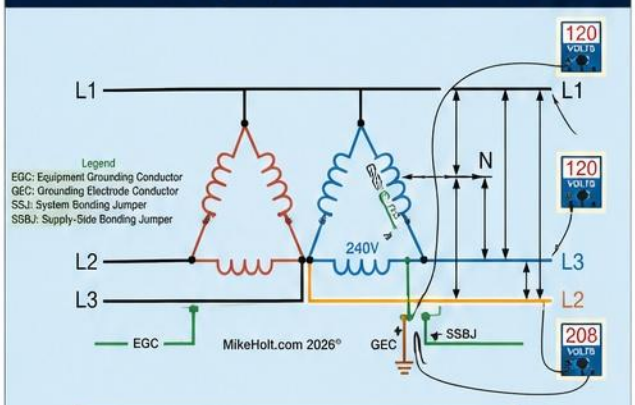


Figure 110-65 Terminal Connection Torque *110.14(D) Note 3*



For information on torquing threaded connections and terminations, see *NFPA 70B, Recommended Practice for Electrical Equipment Maintenance.*

Figure 110-67 Voltage to Ground Delta High Leg Grounded System *Article 100 Definition*

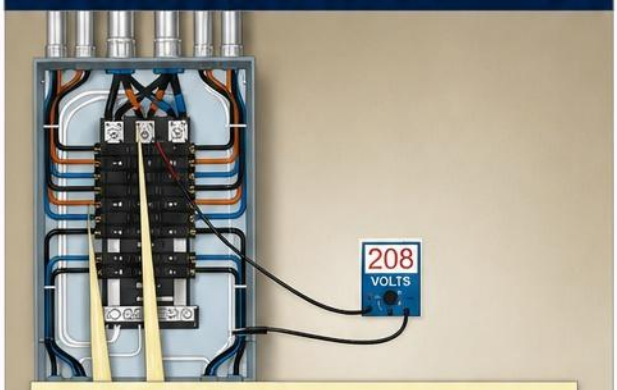


The voltage between any conductor and the point of the circuit that is grounded.

110.15 High-Leg Conductor Identification

On a 240V/120V 4-wire, delta-connected, three-phase system, the higher phase *voltage-to-ground* (*high-leg*) conductor must be durably and permanently marked orange by an outer finish or other effective means that is orange at all splices and terminations. This orange identification is required where a connection to the neutral conductor is present. ▶ Figure 110-66 and ▶ Figure 110-67

Figure 110-66 High-Leg Conductor Identification *110.15*



On a 240V/120V 4-wire, delta-connected, three-phase system, the high-leg conductor must be durably and permanently marked orange by an outer finish or other effective means that is orange at all splices and terminations. This orange identification is required where a connection to the neutral conductor is present.

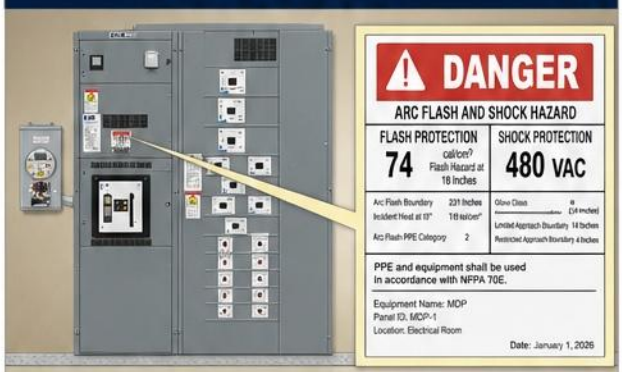
Author's Comment:

- The high-leg conductor is also called the "wild-leg" or "stinger-leg." On three-phase, 4-wire, delta-connected system panelboards, the B phase busbar must be the high-leg [408.10(F)(1)]. The panelboard itself must be identified, "CAUTION B PHASE HAS 208V-TO-GROUND" [408.10(F)(1)].

110.16 Arc-Flash Hazard Marking, Other Than Dwelling Units

In other than dwelling units, a permanent arc-flash marking must be applied to service and feeder equipment such as switchboards, enclosed panelboards, and meter socket enclosures. ▶ Figure 110-68

Figure 110-68 Arc-Flash Hazard Marking Other Than Dwelling Units *110.16*



An arc-flash marking must be applied to service and feeder equipment such as switchboards, enclosed panelboards, and meter socket enclosures.

Author's Comment:

- An arc-flash event can reach temperatures of 35,000°F, which turns metal from a solid to gas vapors. This releases molten shrapnel that pierces the skin, causing severe burns—even death. The reason the arc-flash label is not required in dwelling units is because the nominal voltage will be single-phase, 120V line-to-ground (240V line-to-line), so the arc fault will self-extinguish with every zero crossing of the sinusoidal waveform. A three-phase arc fault is sustainable in accordance with *IEEE-1584*.

Figure 110–69 *Arc-Flash Hazard Marking* *110.16 Comment*

An arc-flash event can reach temperatures of 35,000°F, which turns metal from a solid to gas vapors, and releases molten shrapnel that pierces the skin causing severe burns and even death.

The arc-flash hazard marking must be permanently affixed to the equipment and cannot be handwritten in accordance with 110.21(B), be clearly visible to qualified persons, and installed in accordance with industry practices containing the following information:

(1) Nominal system voltage

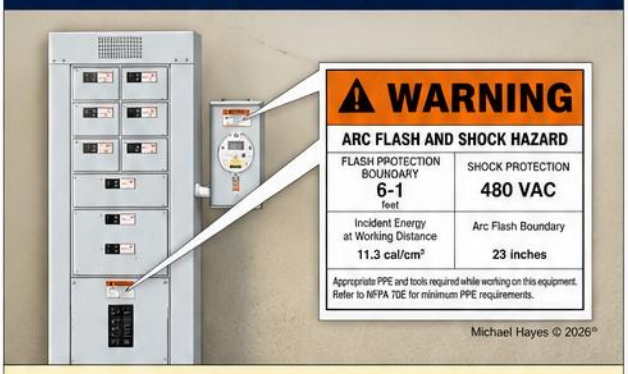
(2) Arc-flash boundary

(3) Available incident energy or minimum required level of personal protective equipment (PPE)

(4) Date the assessment was completed

Note 2: *NFPA 70E, Standard for Electrical Safety in the Workplace, provides applicable industry practices for developing arc-flash equipment markings that include nominal system voltage, incident energy levels, arc-flash boundaries, and by selecting an appropriate level of personal protective equipment.*

Figure 110–70 Arc-Flash Hazard Marking, Other Than Dwelling Units Industry Practice *110.16*



The arc-flash hazard marking must be permanently affixed to the equipment and cannot be handwritten in accordance with 110.21(B), be clearly visible to qualified person, and installed in accordance with industry practices containing the following information:

(1) Nominal system voltage
(2) Arc-flash boundary
(3) Available incident energy or minimum required level of personal protective equipment (PPE)
(4) Date the assessment was completed

Figure 110–71 Arc-Flash Hazard Marking Industry Practice *110.16 Note 2*

NFPA 70E, provides industry practices for developing arc-flash equipment markings that include nominal system voltage, incident energy levels, arc-flash boundaries, and selecting an appropriate level of PPE.

110.21 HAZARD MARKINGS

(B) Field-Applied Hazard Markings. Where caution, warning, or danger hazard markings are required by the *NEC*, the markings must meet the following requirements:

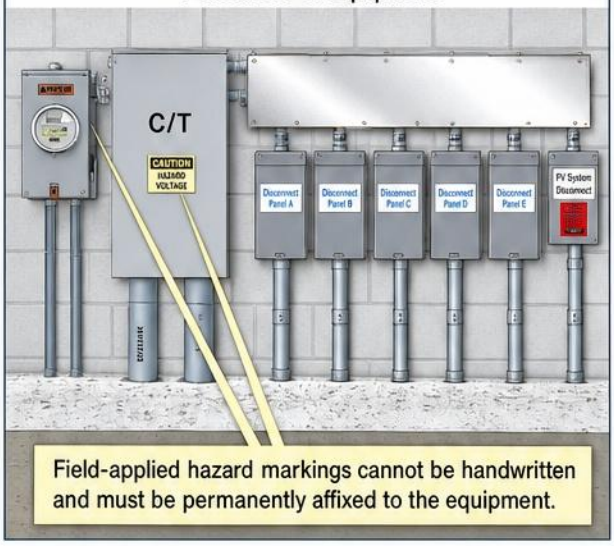
(1) Must be of sufficient durability to withstand the environment and warn of the hazards using effective words, colors, symbols, or a combination of the three

Note: For guidelines for the design and durability of signs and labels, see *ANSI Z535.4, Product Safety Signs and Labels*

(2) Cannot be handwritten and must be permanently affixed to the equipment

Figure 110–72 110.21(B)(2)

Field-Applied Hazard Markings
Permanent on Equipment



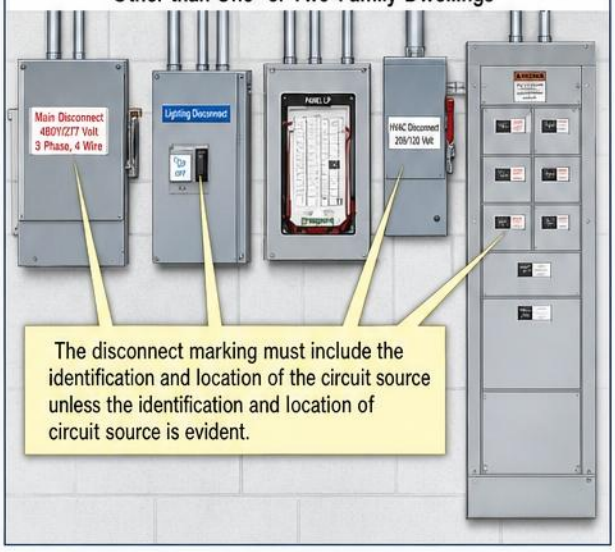
Example: Markings containing information that is likely to change can be handwritten if it is legible.

110.22 Identification of Disconnecting Means

(A) General. Every disconnecting means must be marked to indicate its purpose unless it is located and arranged so the purpose is evident. For other than one- or two-family dwellings, the disconnect marking must include identification and the circuit source unless the identification and circuit source are evident as determined by the AHJ. The marking must be of sufficient durability to withstand the environment involved. **(Figure 110–73)**

Figure 110–73 110.22(A)

Identification of Disconnecting Means
Other than One- or Two-Family Dwellings

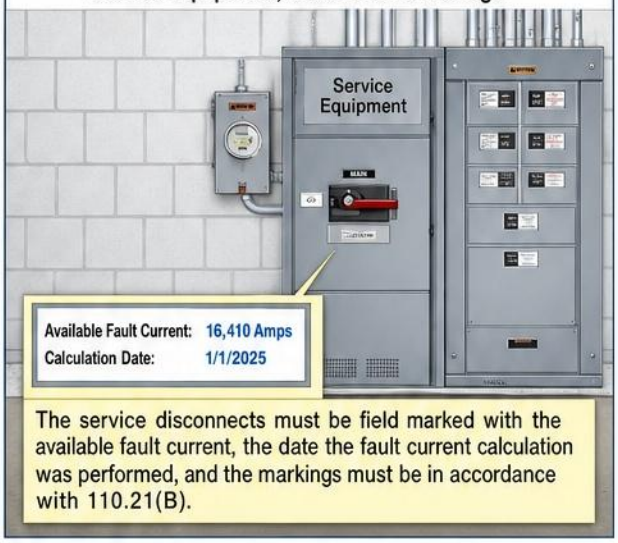


110.24 Available Fault-Current Marking

(A) Field Marking. For other than dwelling units, service disconnects must be field marked with the available fault current on the line side of the service disconnect, and the date the fault current calculation was performed. The marking must be of sufficient durability to withstand the environment, cannot be handwritten and must be permanently affixed to the equipment in accordance with 110.21(B). **(Figure 110–74)**

Figure 110–74 110.24(A)

Available Fault Current Marking
Service Equipment, Other Than Dwellings

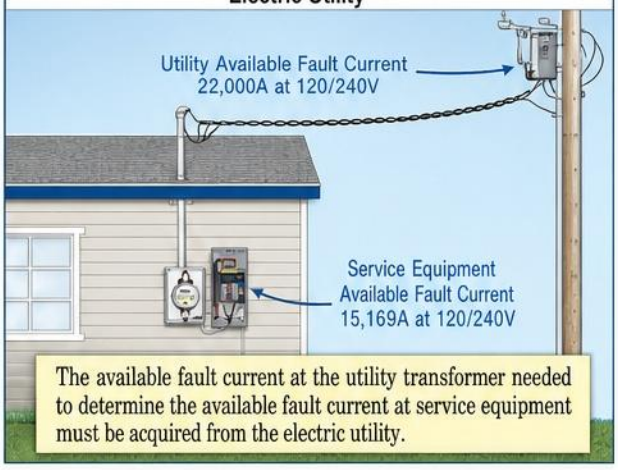


The available fault current calculation must be documented and available to those who are authorized to design, install, inspect, maintain, or operate the system.

Note 2: The available fault current at the utility transformer, needed to determine the available fault current at service equipment, must be acquired from the electric utility. **(Figure 110–75)**

Figure 110–75 110.24(A) Note 2

Available Fault Current Marking
Electric Utility



(B) Modifications. When changes to the electrical system affect the available fault current at the service, the available fault current must be recalculated to confirm that the service equipment ratings remain adequate for the new fault current level. The field markings required by 110.24(A) must be updated to reflect the revised available fault current.

110.25 Lockable Disconnecting Means

If a rule calls for a disconnecting means to be lockable in the open position, that disconnect must be capable of being locked in the open position, and the provisions for locking must stay in place—whether or not the lock is installed. ▶ Figure 110–76 and ▶ Figure 110–77

Figure 110–76 Lockable Disconnecting Means 110.25

Where a rule requires the disconnecting means to be lockable in the open position, the disconnect must be capable of being locked in the open position, and the provisions for locking must remain in place—whether the lock is installed or not.

Figure 110–77 Lockable Disconnecting Means 110.25

Where a rule requires the disconnecting means to be lockable in the open position, the disconnect must be capable of being locked in the open position, and the provisions for locking must remain in place—whether the lock is installed or not.

Author's Comment:

▶ The means to lock the disconnect in the open position must be an integral part of the enclosure, or be an accessory that is not readily removed. ▶ Figure 110–78

Figure 110–78 Lockable Disconnecting Means 110.25 Comment

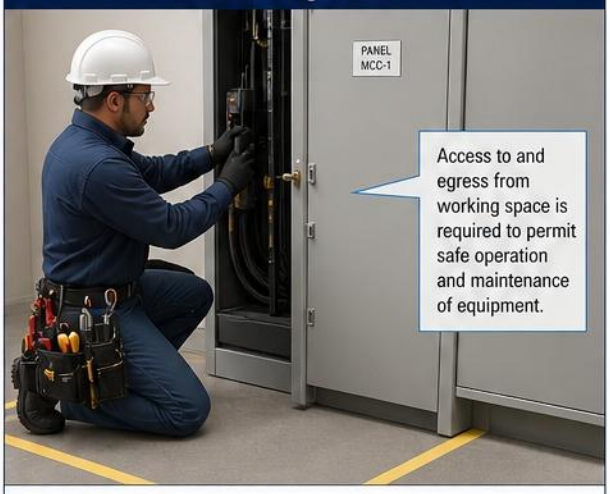
The means to lock the disconnect in the open position must be an integral part of the enclosure, or be an accessory that is not readily removed.

Part II. Not Over 1000V

110.26 Working Spaces About Electrical Equipment

A working space must be provided and maintained to allow safe access to and egress from electrical equipment. ▶ Figure 110–79

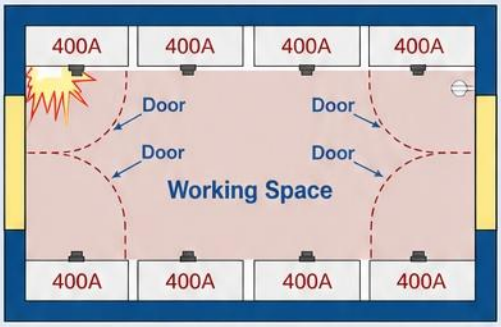
Figure 110–79 Working Space About Electrical Equipment Access to and Egress From 110.26



Access to and egress from working space is required to permit safe operation and maintenance of equipment.

Panels, switchboards, and other equipment enclosures must be arranged so that personnel can reach and leave the working space. Reaching into or leaving this area is considered restricted if one or more doors of simultaneously accessible enclosures limit the working space to less than 24 in. wide and 6½ ft high when the doors are at any position, including fully open, or if the doors can be opened more than 90 degrees. Figure 110–80.

Figure 110–80 Working Space Around Electrical Equipment — Access to and Egress From Impeded Access 110.26



Access to and egress from the working space is considered impeded if one or more simultaneously opened equipment doors limit the working space to less than 24 in. wide and 6½ ft high when such doors are at any position or can be opened more than 90 degrees.

Author's Comment:

- This rule is intended to prevent workers from becoming trapped between equipment doors during work in the installation. If an arc-flash incident occurs, adequate egress must be available so workers can reach a safe location.

(A) Working Space. Equipment that is likely to need inspection, adjustment, servicing, or maintenance while energized must be provided with working space as specified in 110.26(A)(1), (2), (3), and (4). Figure 110–81.

Author's Comment:

- Always consult the authority having jurisdiction (AHJ) to determine what equipment requires a clear working space.

When expressly permitted, smaller clear working spaces are allowed in locations where exposed live parts operate not more than 30V rms, 42V peak, or 60V dc.

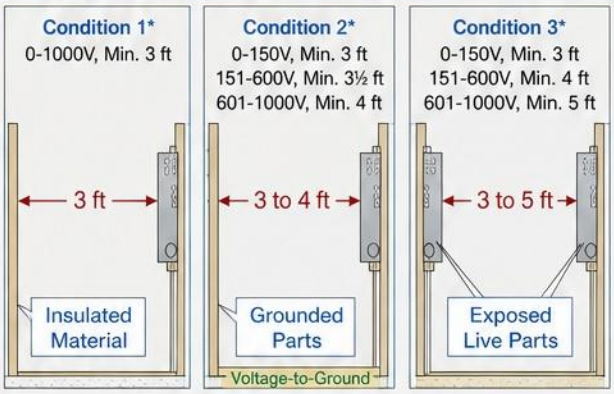
(1) Depth of Working Space. The depth of working space cannot be less than the distances listed in Table 110.26(A)(1). Figure 110–82.

The depth of working space must be measured from the enclosure front cover. Figure 110–83.

Figure 110–81 Working Space When Required 110.26(A)

Equipment that is likely to require examination, adjustment, servicing, or maintenance while energized must have working space provided in accordance with 110.26(A)(1), (2), (3), and (4).

Figure 110–82 Working Space — Depth 110.26(A)(1)



The depth of working space cannot be less than the distances contained in Table 110.26(A)(1).

Figure 110–83 Working Space — Depth Measurement 110.26(A)(1)

Depth of working space must be measured from the enclosure front cover.

Table 110.26(A)(1) Working Space

Voltage to Ground	Condition 1	Condition 2	Condition 3
0–150 Vac or Vdc	3 ft	3 ft	3 ft
151–600 Vac or Vdc	3 ft	3½ ft	4 ft
601–1000 Vac 601–1500 Vdc	3 ft	4 ft	5 ft

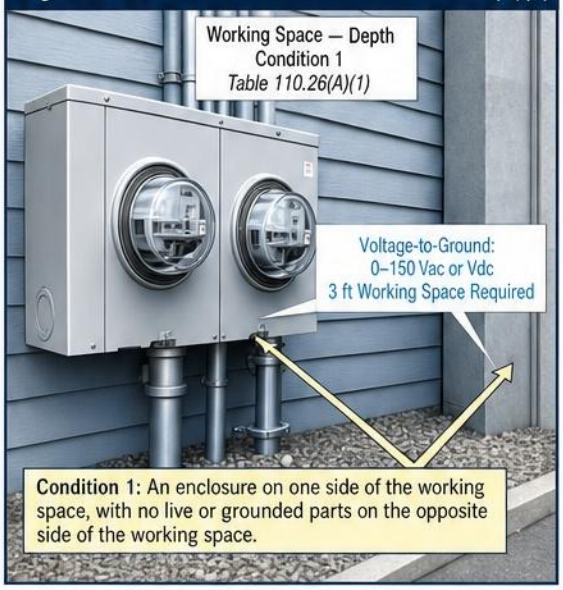
See Figure 110–84, Figure 110–85, and Figure 110–86.

Condition 1: An enclosure (including live parts) on one side of the working space, with no live or grounded parts on the opposite side of the working space.

Condition 2: An enclosure (including live parts) on one side of the working space, with grounded parts on the opposite side. Concrete, brick, tile, and similar surfaces are considered grounded.

Condition 3: Enclosures (including live parts) on both sides of the working space.

Figure 110–84 110.26(A)(1)



(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 renewable, adjustable, or serviceable parts are accessible from the front.

See Figure 110–87.

Figure 110–85 110.26(A)(1)

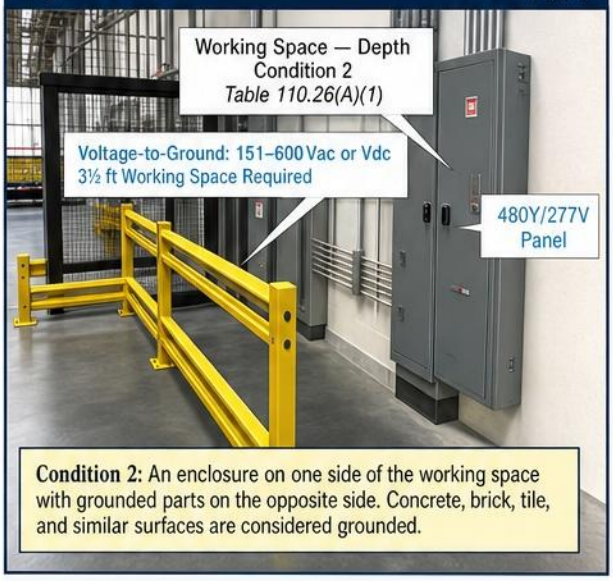


Figure 110–86 110.26(A)(1)

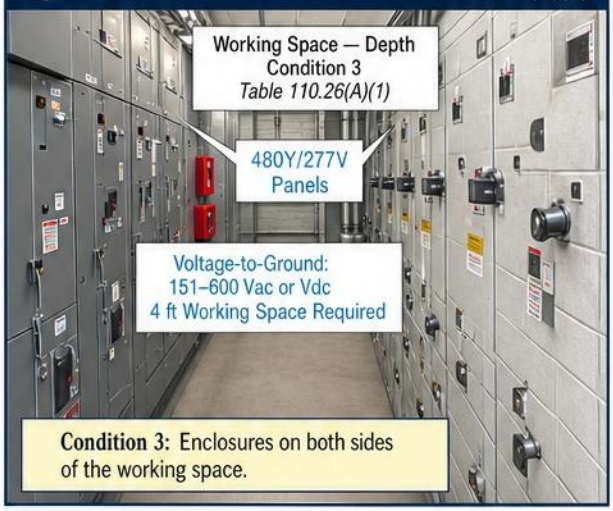
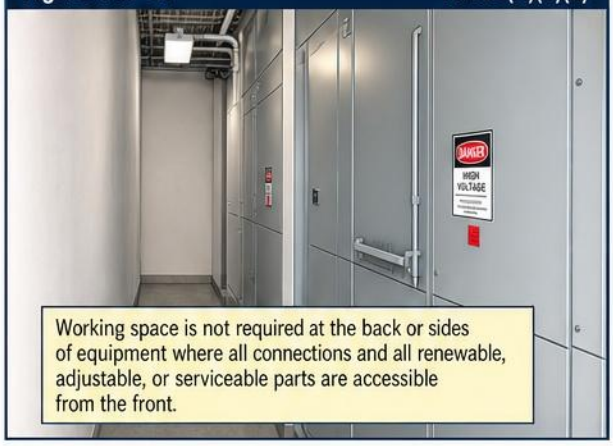


Figure 110–87 110.26(A)(1)(a)



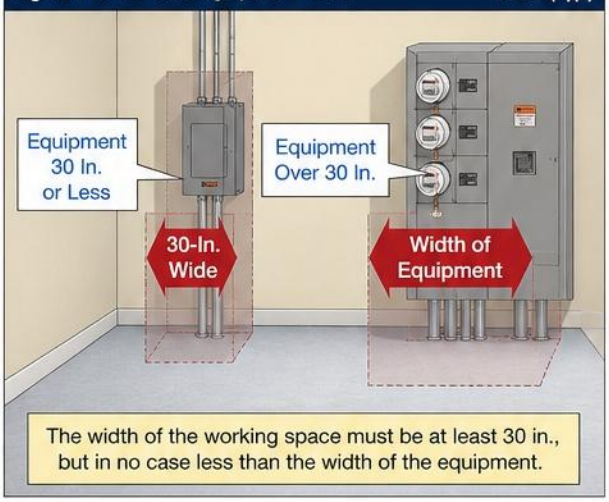
AUTHOR'S COMMENT:

- Locations that require access to the rear or sides of equipment for field connections must be identified by the manufacturer on the equipment face. See 408.18(C).

(c) Existing Buildings. When electrical equipment is replaced, Condition 2 working space dimensions are allowed in place of Condition 3 dimensions between dead-front switchboards or panelboards, but only if authorized or qualified personnel who will service the installation are present. These panelboards must be installed on opposite sides of the aisle from each other so that maintenance and inspection can be performed safely without both sides being exposed at the same time.

(2) Width of Working Space. The working space must be at least 30 in., but never less than the width of the equipment. ▸Figure 110–88

Figure 110–88 Working Space — Width 110.26(A)(2)

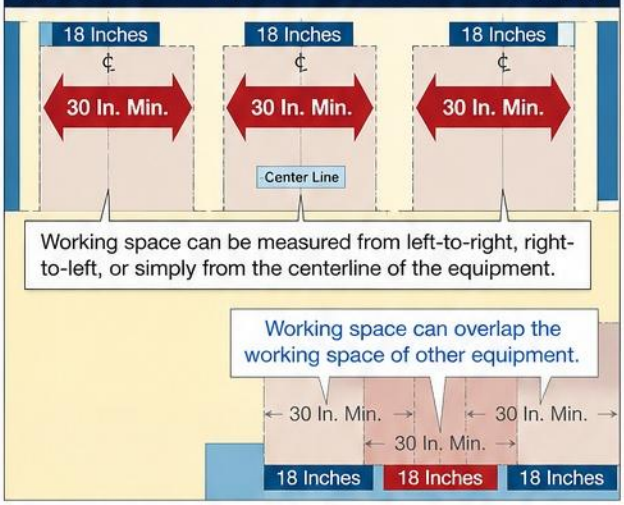


AUTHOR'S COMMENT:

- Working space width may be measured from left-to-right, right-to-left, or from the centerline of the equipment. It can overlap the working space of other electrical equipment. ▸Figure 110–89 and ▸Figure 110–90

The working space must have sufficient width, depth, and height to allow equipment doors to open at least 90 degrees. ▸Figure 110–91

Figure 110–89 Working Space — Width Measurement 110.26(A)(2)



Working space width may be measured in either direction from the centerline. Overlap with adjacent equipment is permitted.

Figure 110–90 Working Space — Width, Equipment Overlapping 110.26(A)(2)

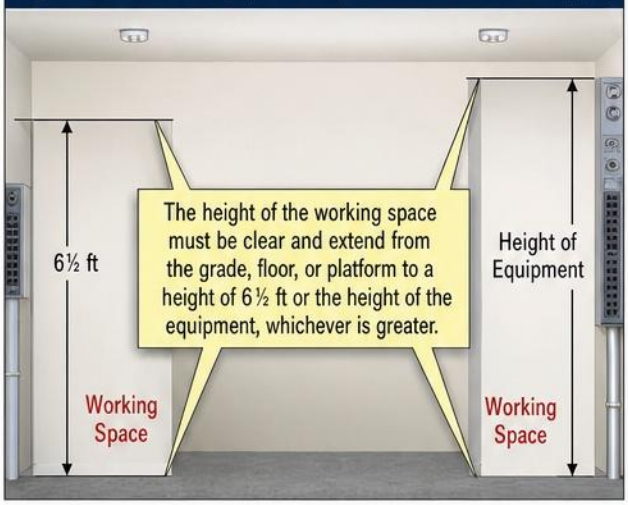
Working space is permitted to overlap the working space of other equipment.

Figure 110–91 Working Space — Width Doors Open 90 Degrees 110.26(A)(2)

Doors must be able to open a minimum of 90 degrees within the required working space.

(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, whichever is greater.

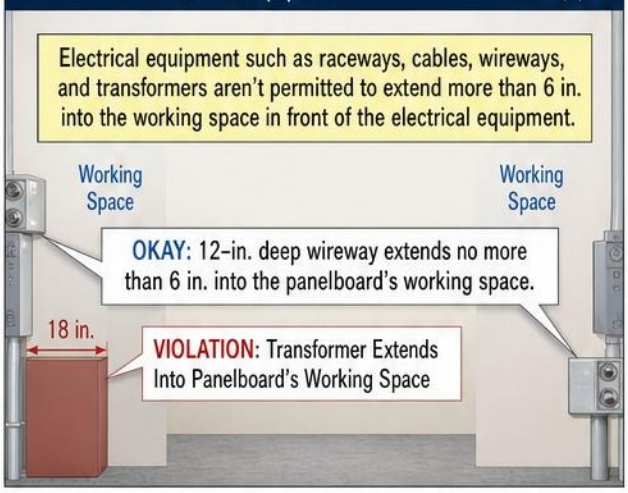
Figure 110–92 Working Space – Height 110.26(A)(3)



The working space must be clear from the grade, floor, or platform to a height of 6½ ft or to the height of the equipment, whichever is greater.

Electrical equipment such as raceways, cables, wireways, transformers, and support structures (including concrete pads) is not permitted to extend more than 6 in. into the working space in front of the electrical equipment. **Figures 110–93, 110–94,** and **110–95**

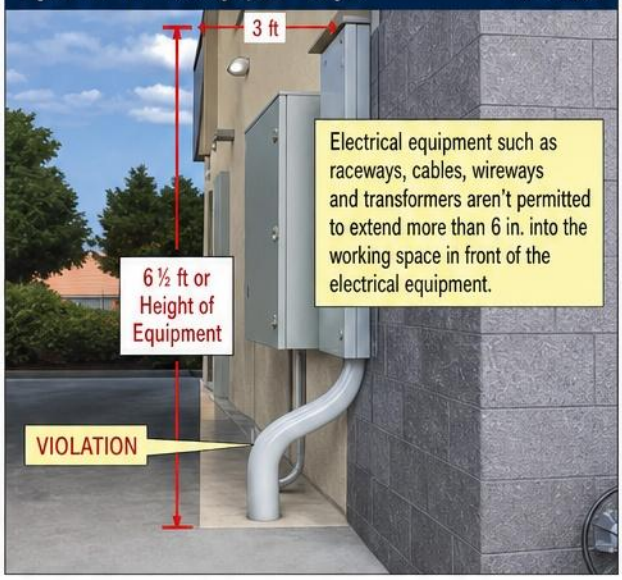
Figure 110–93 Working Space – Height Electrical Equipment 110.26(A)(3)



Raceways, cables, wireways and transformers aren't permitted to project more than 6 in. into the working space in front of the electrical equipment.

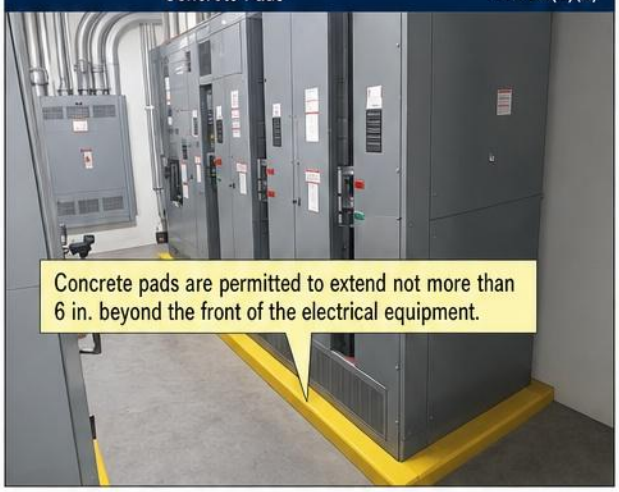
Ex 2: The minimum height of working space does not apply to a service disconnect or panelboards (rated 200A or less) in an existing dwelling unit where the height of the working space is less than 6½ ft.

Figure 110–94 Working Space – Height 110.26(A)(3)



Electrical equipment such as raceways, cables, wireways and transformers aren't permitted to extend more than 6 in. into the working space in front of the electrical equipment.

Figure 110–95 Working Space – Height Concrete Pads 110.26(A)(3)



Concrete pads are permitted to extend not more than 6 in. beyond the front of the electrical equipment.

Ex 3: Meters are permitted to be in the required working space but must also maintain the clearance requirements of this Code section.

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

(1) Suspended Ceiling and Crawl Space.

Suspended Ceiling. Equipment above a suspended ceiling must have an access opening not smaller than 22 in. × 22 in.

Crawl Space. Equipment installed in a crawl space must have an accessible opening not smaller than 22 in. × 30 in.

(2) The width of the working space must be a minimum of 30 in., but in no case be less than the width of the equipment

(3) The working space must permit equipment doors to open 90 degrees.

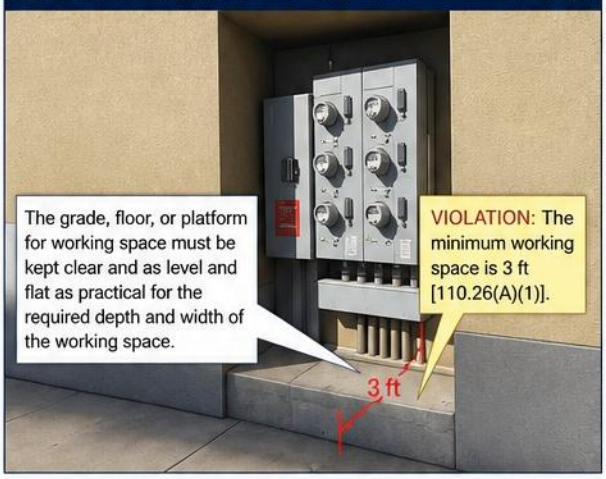
(4) The working space in front of equipment must comply with the depth requirements of Table 110.26(A)(1), and be unobstructed to the floor by fixed cabinets, walls, or partitions; horizontal ceiling structural members are permitted in this space, provided the location of weight-bearing structural members does not result in a side reach of more than 6 in. to work within the enclosure.

Author's Comment:

- The requirements of 110.26(A)(4) are appliable to installations (such as duct heaters and fan coil units) above the suspended ceiling where workers are using ladders and where workspace is usually limited.

(6) Grade, Floor, or Working Platform. The grade, floor, or platform within the working space must be kept clear and as level and flat as practical as determined by the AHJ for the required depth and width of the working space. Figures 110–96

Figure 110–96 Grade, Floor, or Working Platform 110.26(A)(6)

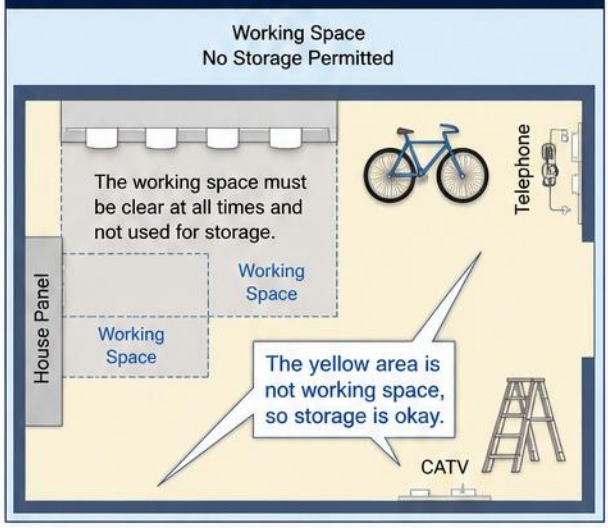


The working surface must be level, clear, and flat to provide the required depth and width of working space.

(B) Clear Working Space. The working space must be clear at all times and not used for storage. Figures 110–97 and 110–98

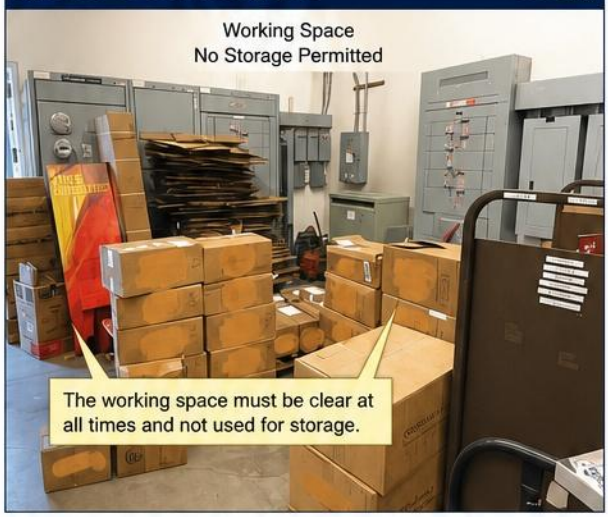
CAUTION: It is extremely dangerous to service energized parts in the first place, and unacceptable to subject oneself to additional dangers by working around bicycles, boxes, crates, appliances, and other impediments.

Figure 110–97 Clear Working Space 110.26(B)



Only the designated working space must be kept clear; storage is allowed outside the working space.

Figure 110–98 Clear Working Space 110.26(B)



Obstructions and stored items violate the requirement for a clear working space.

(C) Entrance to and Egress from Working Space.

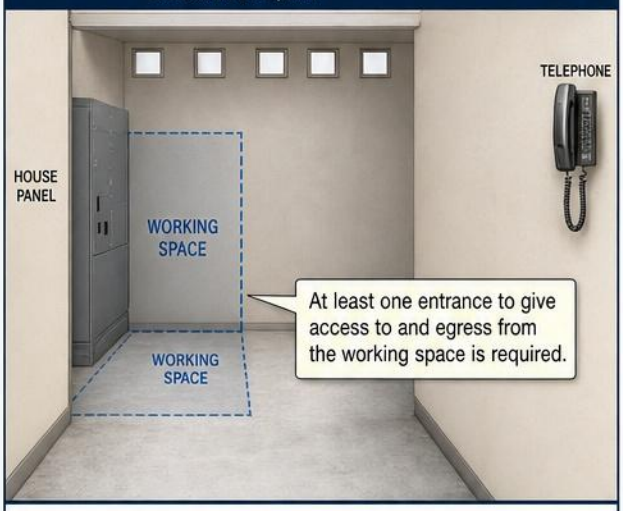
(1) Minimum Required. At least one entrance to give access to and egress from the working space is required. Figure 110–99

(2) Large Equipment.

Two Egresses. For equipment containing overcurrent protection devices, switching devices, or control devices, an entrance to and egress from the required working space must be at least 24 in. wide and 6½ ft high at each end of the working space. This requirement applies to either of the following conditions:

(1) Where feeder equipment is rated 1200A or more, and is over 6 ft wide. Figure 110–100

Figure 110–99 *Access to and Egress from Working Space One Entrance Required* *110.26(C)(1)*



One entrance is provided to the working space.

Figure 110–100 *Access to and Egress from Working Space Feeder Equipment 1200A or More and Over 6 Ft Wide* *110.26(C)(2)(1)*

Where feeder equipment is rated 1200A or more and is over 6 ft wide, an entrance to and egress from the required working space must be at least 24 in. wide and 6½ ft high at each end of the working space.

(2) Where the building disconnect [225.33(A)] or the service disconnect [230.71(B)] has a combined ampere rating of 1200A or more, and the combined width is over 6 ft ▸ Figure 110–101

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

(a) ***Unobstructed Egress.*** The location permits a continuous and unobstructed way of egress travel. ▸ Figure 110–102

(b) ***Double Working Space.*** The required working space depth is doubled, and the equipment is located so that the edge of the entrance is no closer than the minimum distance required by 110.26(A)(1). ▸ Figure 110–103

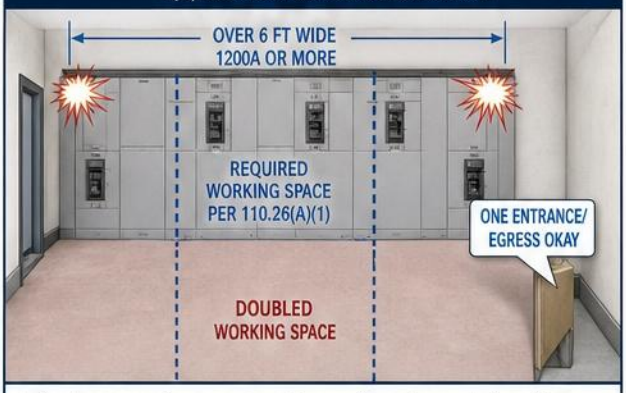
Figure 110–101 *Access to and Egress from Working Space Equipment Combined 1200A and Over 6 Ft Wide* *110.26(C)(2)(2)*

Where the building disconnect [225.33(A)] or the service disconnect [230.71(B)] has a combined ampere rating of 1200A or more, and the combined width is over 6 ft, an entrance to and egress from the required working space must be at least 24 in. wide and 6½ ft high at each end of the working space.

Figure 110–102 *Unobstructed Egress from Working Space Equipment Combined 1200A and Over 6 Ft Wide* *110.26(C)(2)(a)*

A single entrance for access to and egress from the required working space is permitted where the location allows a continuous and unobstructed way of egress travel.

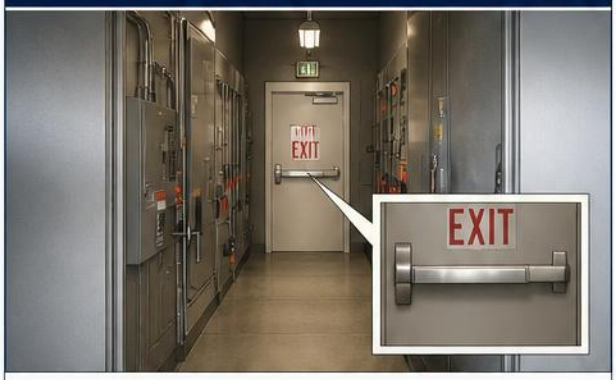
Figure 110–103 *Double Working Space Depth Equipment Combined 1200A and Over 6 Ft Wide* *110.26(C)(2)(b)*



A single entrance for access to and egress from the required working space is permitted where the required working space depth is doubled, and the equipment is located so that the edge of the entrance is no closer than the working space distance.

(3) Fire Exit Hardware on Personnel Doors. Equipment rated 800A or more that includes overcurrent protection devices, switching devices, or control devices must be installed with personnel doors intended for entry to and exit from the working space located no less than 25 ft from the nearest edge of that working space. The doors must be capable of opening at least 90 degrees in the direction of egress and must be equipped with listed panic or listed fire exit hardware. 110.26(C)

Figure 110–104 Working Space with Equipment Rated 800A or More Fire Exit Hardware on Personnel Doors 110.26(C)(3)



Doors within 25 ft from the nearest edge of the working space for equipment rated 800A or more must open at least 90 degrees in the direction of egress and be equipped with listed panic or fire exit hardware.

Author's Comment:

Electricians who have suffered burns on their hands in arc-flash or arc-blast events often struggle to open doors equipped with knobs that must be turned or that must be pulled open. Because this requirement is in the *NEC*, electrical contractors are responsible for ensuring panic hardware or listed fire exit hardware is installed where required, allowing doors to be pressed and open outward toward egress.

(D) Illumination of Working Space.

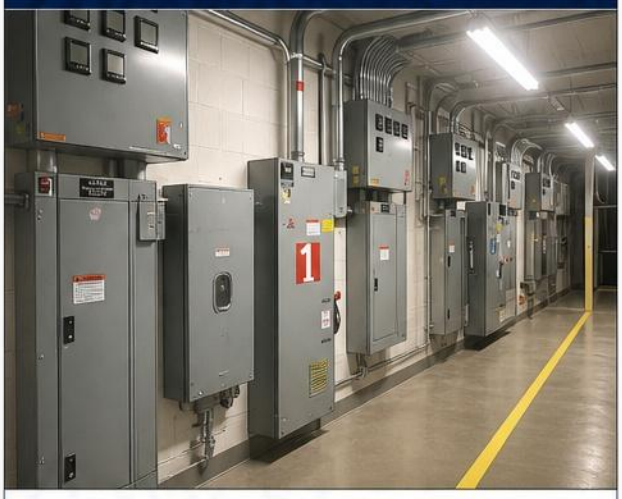
Working Space Indoors. Illumination is required for indoor working spaces about service equipment, switchboards, or enclosed panelboards. 110.26(D)

Automatic Means Not Permitted. Luminaires for indoor working spaces around service equipment, switchboards, or enclosed panelboards cannot be controlled, in its entirety, by an automatic means. 110.26(D)

Author's Comment:

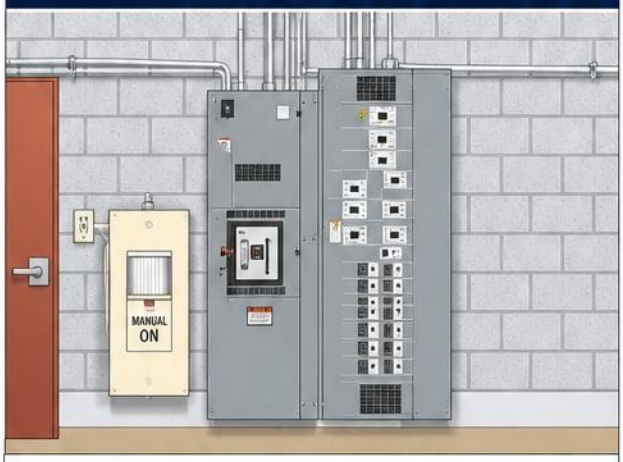
The Code does not identify the minimum foot-candles required to provide proper illumination. However, it is essential in electrical equipment rooms for the safety of those qualified to work on such equipment.

Figure 110–105 Illumination for Indoor Working Space 110.26(D)



Illumination is required for indoor working spaces about service equipment, switchboards, or enclosed panelboards.

Figure 110–106 Illumination for Indoor Working Space Automatic Control Not Permitted 110.26(D)



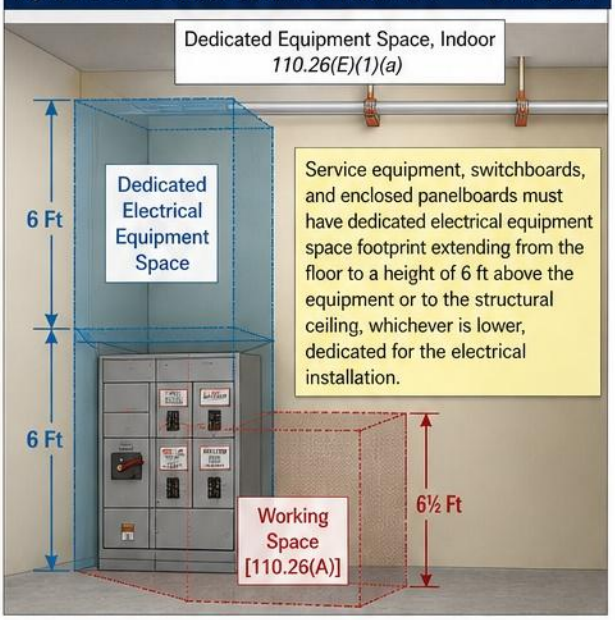
Luminaires for indoor working spaces around service equipment, switchboards, or enclosed panelboards cannot be controlled, in its entirety, by an automatic means.

(E) Dedicated Electrical Equipment Space. Service equipment, switchboards, and enclosed panelboards must have dedicated electrical equipment space and be protected from damage.

(1) Indoors. Service equipment, switchboards, and panelboard enclosures indoors must comply with the following:

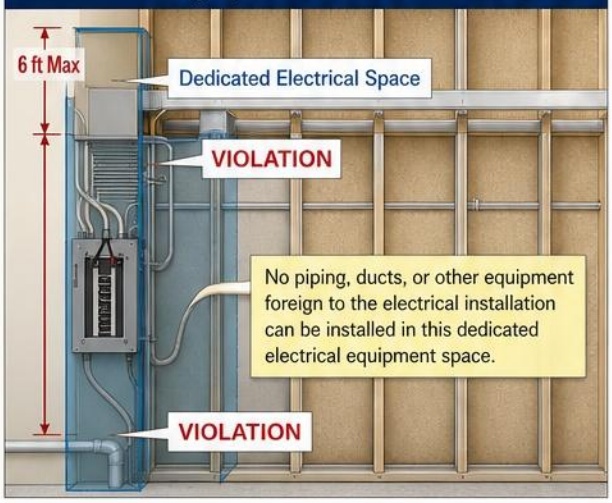
(a) Equipment Space. The footprint space width and depth of the equipment of the dedicated electrical space extending from the floor to a height of 6 ft above the equipment or to the structural ceiling whichever is lower must be dedicated for the electrical installation. ▸ Figure 110–107

Figure 110–107 Dedicated Equipment Space, Indoor 110.26(E)(1)(a)



No piping, ducts, or other equipment foreign to the electrical system can be installed in this dedicated electrical equipment space. ▸ Figure 110–108

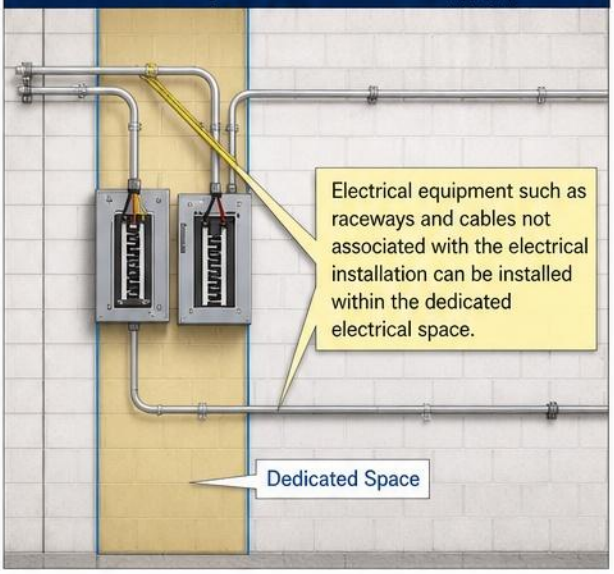
Figure 110–108 Dedicated Equipment Space, Indoor Foreign Systems Not Permitted 110.26(E)(1)(a)



Author's Comment:

- Electrical equipment such as raceways and cables not associated with the specific electrical installation can be within the dedicated electrical space of other equipment. ▸ Figure 110–109

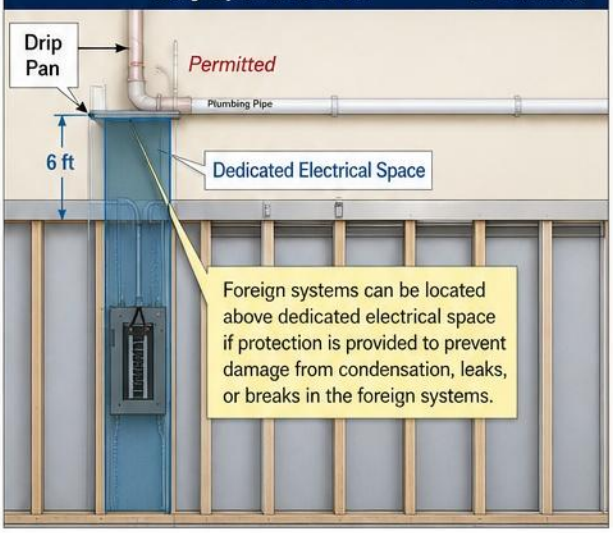
Figure 110–109 Dedicated Equipment Space, Indoor Raceways and Cables 110.26(E)(1)(a) Comment



Ex: Suspended ceilings can be within the dedicated equipment space.

(b) Foreign Systems. Foreign systems can be located above the dedicated equipment space if protection is provided to prevent damage to the electrical equipment from condensation, leaks, or breaks in the foreign systems. ▸ Figure 110–110

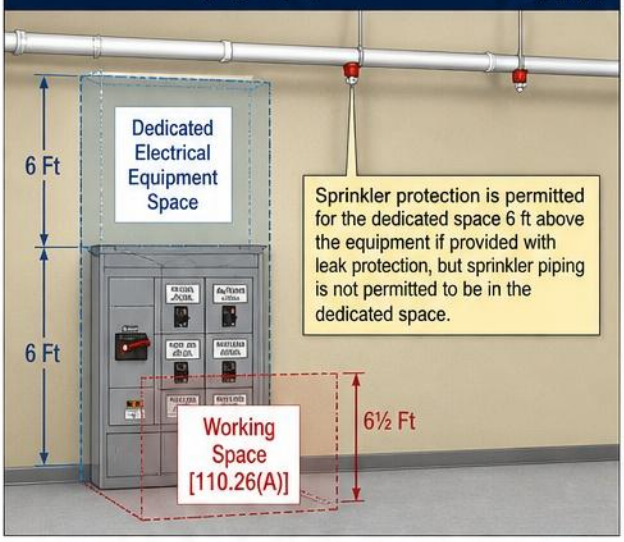
Figure 110–110 Dedicated Equipment Space, Indoor Foreign Systems Above 6 Ft 110.26(E)(1)(b)



(c) Sprinkler Protection. Sprinkler protection is permitted for the dedicated equipment space, but sprinkler piping is not permitted within the dedicated space. ▸ Figure 110–111

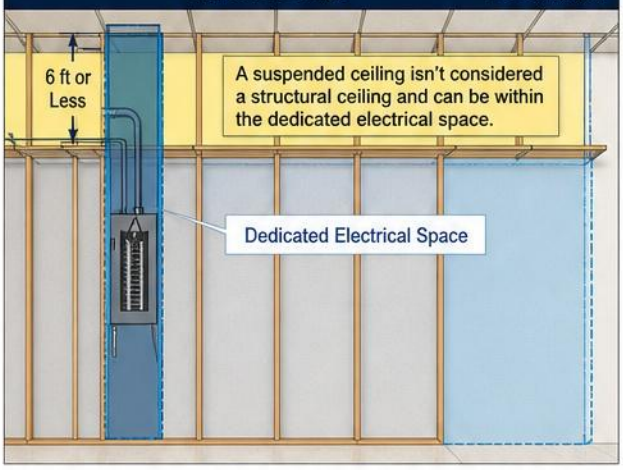
(d) Suspended Ceilings. A suspended ceiling is not considered a structural ceiling and can be within the dedicated electrical space. ▸ Figure 110–112

Figure 110–111 Dedicated Equipment Space, Indoor Springler Piping 110.26(E)(1)(c)



Sprinkler piping may be above the equipment with leak protection but must not occupy the dedicated space.

Figure 110–112 Dedicated Equipment Space, Indoor Suspended Ceilings 110.26(E)(1)(d)



A suspended ceiling may be inside the dedicated electrical space when its height is 6 ft or less.

(2) Outdoor. Outdoor installations for service equipment, switchboards, and enclosed panelboards must comply with the following:

(a) Installation Requirements.

(1) Be installed in identified enclosures.

(2) Be protected from accidental contact by unauthorized personnel and vehicular traffic. Figure 110–113

(3) Be protected from accidental spillage or leakage from piping systems.

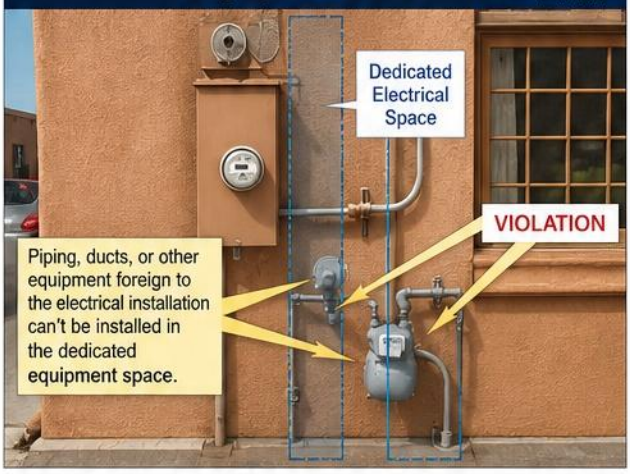
(b) Working Space. The working space includes the zone described in 110.26(A). Architectural attachments or other equipment are not permitted within this zone.

Figure 110–113 Dedicated Equipment Space, Outdoor Protection from Vehicle Traffic 110.26(E)(2)(a)(2)

Outdoor equipment must be shielded from the risk of vehicle impact.

(c) **Dedicated Equipment Space Outdoors.** The footprint area and depth of the outdoor dedicated equipment 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 110–114

Figure 110–114 Dedicated Equipment Space, Outdoor Foreign Systems Not Permitted 110.26(E)(2)(c)



No piping, ducts, or other non-electrical equipment may be placed in the dedicated outdoor space.

Example: Structural overhangs and roof extensions are permitted in this zone.

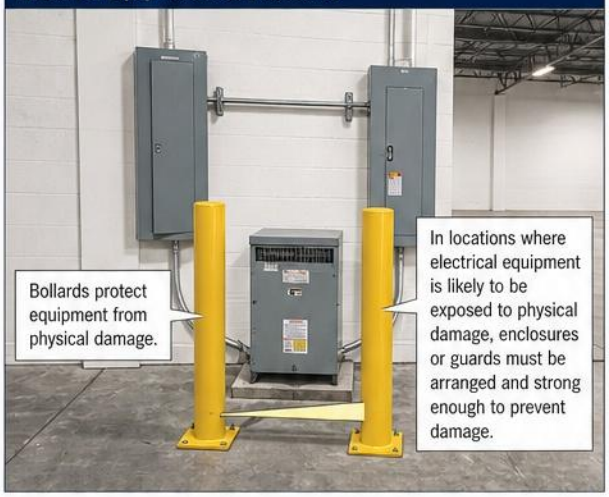
(F) LOCKED ELECTRICAL EQUIPMENT ROOMS OR ENCLOSURES

Electrical equipment rooms or enclosures that contain electrical apparatus and are secured by locks must be accessible to qualified persons.

110.27 Protection Against Physical Damage

(B) Physical Damage. In locations where electrical equipment is likely to be exposed to physical damage as determined by the AHJ, enclosures or guards must be arranged and strong enough to prevent damage.

Figure 110–115
Protection Against Physical Damage Electrical Equipment and Enclosures 110.27(B)



Bollards are installed to shield electrical equipment from impact and other physical hazards.

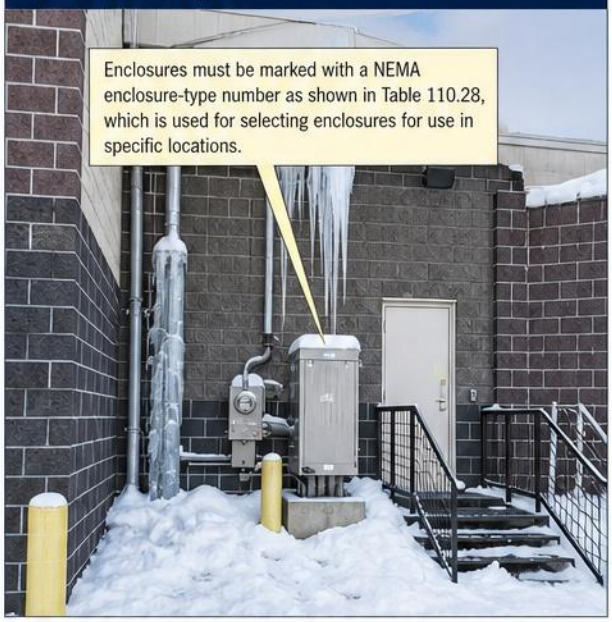
110.28 NEMA Enclosure Types

Enclosures must be marked with a NEMA enclosure-type number as shown in Table 110.28, which is used for selecting enclosures for use in specific locations.

Figure 110–116
NEMA Enclosure Types 110.28

Enclosures are marked with a NEMA enclosure-type number as shown in Table 110.28, which is used for selecting enclosures for use in specific locations.

Figure 110–117
NEMA Enclosure Types 110.28



NEMA enclosure-type markings help ensure the enclosure rating matches the environmental conditions where it is installed.

Note 1 to Table 110.28: Raintight is typically used in conjunction with Enclosure Types 3, 3S, 3SX, 3X, 4, 4X, 6, and 6P. Rainproof is typically used in conjunction with Enclosure Types 3R and 3RX. Watertight is typically used in conjunction with Enclosure Types 4, 4X, and 6.

Author's Comment:

- NEMA Type 3 enclosures are identified as rainproof, raintight, or watertight, and they are considered weatherproof. See Note 1 of Table 110.28.
- NEMA 3X, 3RX, 3SX, and 4X enclosures are suitable for a corrosive environment. See Table 110.28.

ANSI/NEMA 250-2020 Enclosures for Electrical Equipment

This *ANSI/NEMA Standards* publication covers the classification and description of enclosures for electrical equipment.

Type 1 Enclosures. This type of enclosure is constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts and inside the enclosure against ingress of solid foreign objects (falling dirt).

Type 2 Enclosures. This type of enclosure is constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts, protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt), and harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Figure 3 Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust), harmful effects on the equipment due to the ingress of water (rain, sleet, snow), and that will be undamaged by the external formation of ice on the enclosure.

Figure 3R Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt), harmful effects on the equipment due to the ingress of water (rain, sleet, snow), and that will be undamaged by the external formation of ice on the enclosure.

Figure 3S Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust), harmful effects on the equipment due to the ingress of water (rain, sleet, and snow), and external mechanisms remain operable when ice laden.

Figure 3X Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust), harmful effects on the equipment due to the ingress of water (rain, sleet, and snow), increased level of protection against corrosion, and that will be undamaged by the external formation of ice on the enclosure.

Figure 3RX Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt, harmful effects on the equipment due to the ingress of water (rain, sleet, and snow), and that will be undamaged by the external formation of ice on the enclosure which provides an increased level of protection against corrosion.

Figure 3SX Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust), equipment due to the ingress of water (rain, sleet, and snow), corrosion, and external mechanisms which remain operable when ice laden.

Figure 4 Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust), harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose-directed water), and that will be undamaged by the external formation of ice on the enclosure.

Figure 4X Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust), harmful effects due to the ingress of water (rain, sleet, snow, splashing water, and hose-directed water), corrosion, and that will be undamaged by the external formation of ice on the enclosure.

Figure 5 Enclosures 110.28

This type of enclosure is constructed for indoor use to provide a degree of protection to personnal against access to hazardous parts, equipment inside the enclosure against ingress of solid foreign objects (falling dirt, settling airborne dust, lint, fibers, and flyings), and harmful effects due to the ingress of water (dripping and light splashing).

Figure 6 Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt), harmful effects due to the ingress of water (hose-directed water and entry of water during eccasional temporary submersion at a limited depth), and that will be undamaged by the external formation of ice on the enclosure.

Figure 6P Enclosures 110.28

This type of enclosure is constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt), harmful effects due to the ingress of water (hose-directed water and entry of water during prolonged submersion at a limited depth), corrosion, and that will be undamaged by the external formation of ice on the enclosure.

Figure 12 Enclosures 110.28

This type of enclosure is constructed (without knockouts) for indoor use to provide a degree of protection to personnel against access to hazardous parts, to equipment inside the enclosure against ingress of solid foreign objects (falling dirt,

Equipment enclosures must protect against the entry of solid foreign objects (such as falling dirt, dust, lint, fibers, and flying particles), the harmful effects of water (including dripping and light splashing), and exposure to oil or non-corrosive coolants.

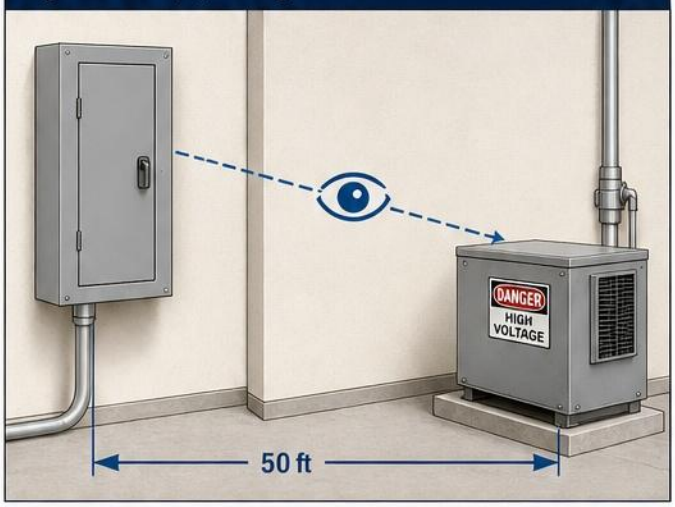
Type 12X Enclosures. These enclosures are designed for indoor use (with knockouts). They provide a level of protection that discourages personnel from gaining access to hazardous parts inside the enclosure and protects the equipment from solid foreign objects (falling dirt, dust, lint, fibers, and flying particles), the damaging effects of water (dripping and light splashing), and exposure to oil or non-corrosive coolants.

Type 13 Enclosures. These enclosures are intended for indoor use and provide protection that discourages personnel from accessing hazardous parts and protects the equipment from solid foreign objects (falling dirt, dust, lint, fibers, and flying particles), the harmful effects of water (dripping and light splashing), as well as from the impact of spraying, splashing, and seepage of oil and non-corrosive coolants.

110.29 In Sight From (Within Sight From, Within Sight)

When this Code requires that equipment be "in sight from," "within sight from," or "within sight of" a building, structure, or other equipment, the specified equipment must be visible and no more than 50 ft from that building, structure, or other equipment.

Figure 110.29(A) In Sight From 110.29



For "in sight from," the required equipment must be visible and located no more than 50 ft from the building, structure, or other equipment.

Figure 110.29(B) Within Sight From 110.29

For "within sight from," the required equipment must be visible through an opening (such as a window, door, or from a location) and located no more than 50 ft from the building, structure, or other equipment.

ARTICLE 120 Branch-Circuit, Feeder, and Service Load Calculations

Introduction to Article 120—Branch-Circuit, Feeder, and Service Load Calculations

This article includes the rules needed to determine demand loads for branch circuits, feeders, and services. The *Code* acknowledges that power demand does not occur simultaneously. This diversity in demand enables the use of the rules in this article to reduce the required sizes of circuits and equipment.

As you study Article 120, be sure to examine the illustrations and review the examples in Annex D to gain a full understanding of this article's requirements.

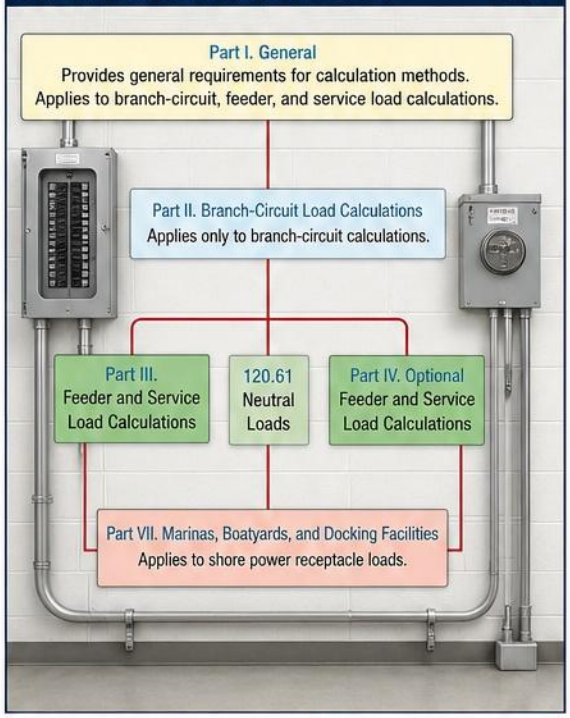
Part I. General

120.1 Scope

This article sets forth the requirements for determining demand loads for branch circuits, feeders, and services.

Note 2: See *NEC* Figure 120.1 for information on the organization of Article 120.

Figure 120–1 *NEC 120.1 Note 2*
Organization of Article 120, Load Calculations



This figure illustrates how Article 120 is organized and highlights the parts that apply to different types of load calculations.

120.3 Application of Other Articles

Table 120.3 lists references for branch-circuit calculations for specific equipment:

- Air-Conditioning Equipment—440.6, 440.21, 440.22, 440.31, 440.32, 440.62, and Part IV of Article 440
- Fixed Electric Space-Heating Equipment—424.5(B)
- Motors—430.6(A), 430.22, 430.24, 430.52, and 430.62
- Storage-Type Water Heaters—422.11(E)

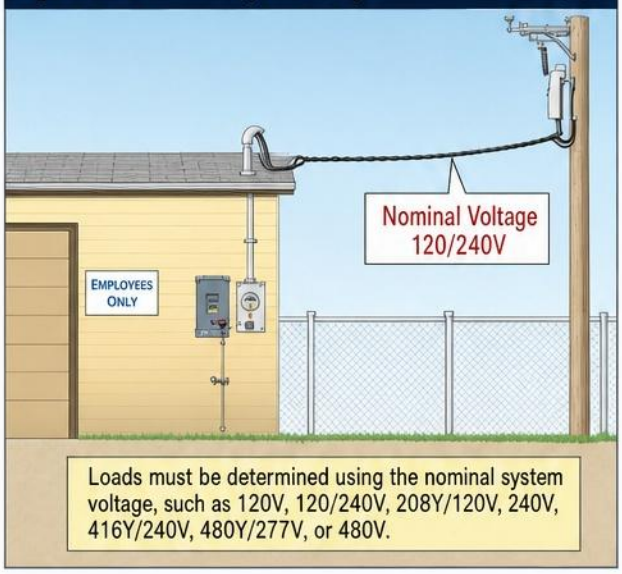
120.5 Load Calculations

(A) Voltage Used for Calculations. Branch-circuit, feeder, and service loads must be calculated using the *nominal system voltage*, such as 120V, 120/240V, 208Y/120V, 240V, 416Y/240V, 480Y/277V, or 480V.

Figure 120–2 *NEC 120.5(A)*
Nominal System Voltages

Loads are calculated based on the *nominal system voltage*, which may vary depending on the electrical system in use.

Figure 120-2 Nominal System Voltages 120.5(A)



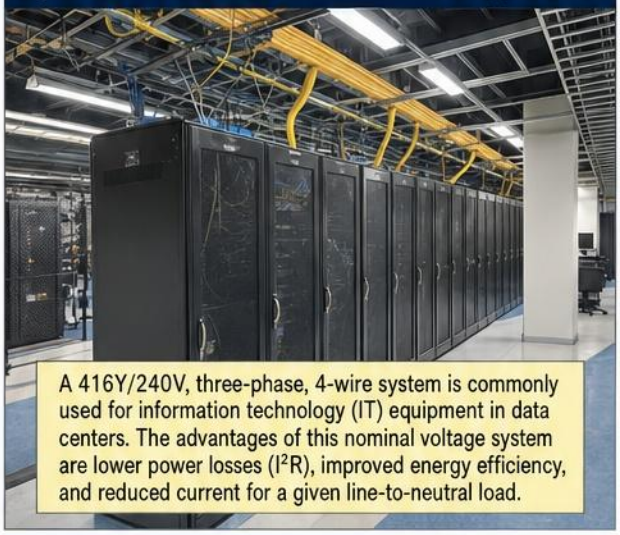
Author's Comment:

- When a voltage system has a "Y" contained in the voltage class (208Y/120V or 480Y/277V), it means that this voltage system is a three-phase wye system.

Author's Comment:

- A 416Y/240V, three-phase, 4-wire system is commonly used for information technology (IT) equipment in data centers. The advantages of this nominal voltage system are lower power losses (I^2R), improved energy efficiency, and reduced current for a given line-to-neutral load. Figure 120–3

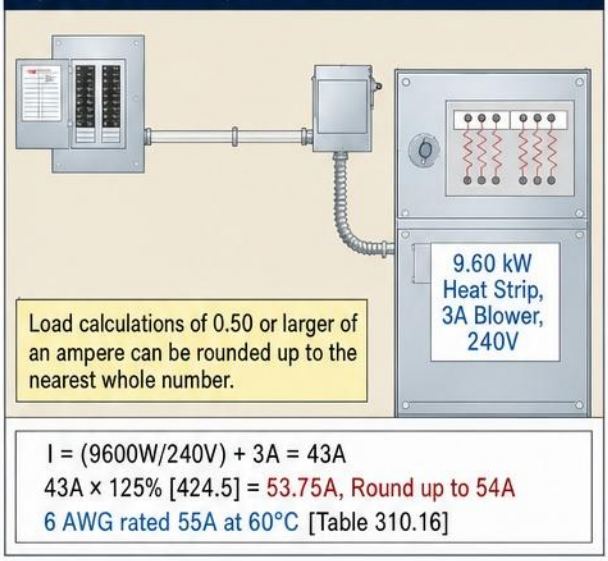
Figure 120-3 Data Centers 120.5(A) Comment



Voltage, Nominal. A value assigned for designating voltage classes (such as 120/240V, 208Y/120V, and 480Y/277V).

(B) Rounding Fractions of Amperes. Load calculations for branch-circuits, feeders, and services resulting in 0.50 or larger of an ampere can be rounded up to the nearest whole number. Load calculations resulting in less than 0.50 of an ampere can be rounded down to the nearest whole number. Figure 120–4

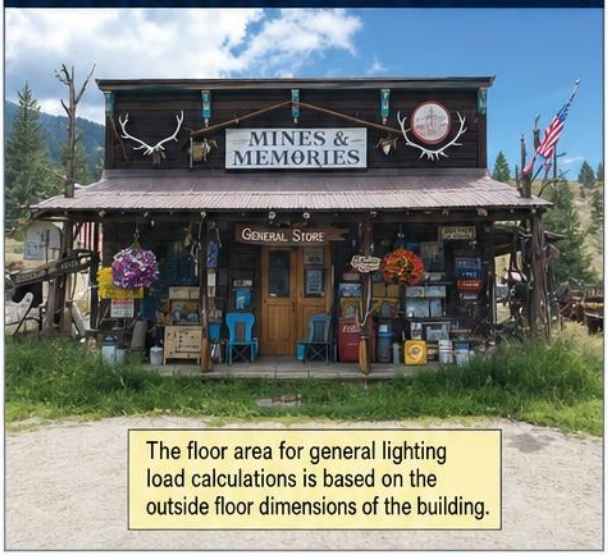
Figure 120-4 Rounding Fractions of Amperes 120.5(B)



(C) Building Floor Area.

Commercial. For commercial buildings, the floor area for general lighting load calculations is based on the outside floor dimensions of the building. Figure 120–5

Figure 120-5 General Lighting Commercial Floor Area 120.5(C)



Dwelling Units. For dwellings, the floor area is determined from the exterior dimensions, including the garage, but excluding detached garages, open porches, and unfinished spaces that are not intended for future use as habitable rooms or occupiable areas. ▶ Figure 120–6

Figure 120–6 Load Calculations, General Lighting Dwelling Unit Floor Area *120.5(C)*

Floor area is based on the exterior dimensions, including the garage, but excluding detached garages, open porches, and unfinished spaces that are not intended for future use as habitable rooms or occupiable areas.

(E) Continuous Loads. When calculating the service, feeder, or branch-circuit load, continuous loads must be determined in accordance with the requirements in Article 120, not at 125 percent of the continuous load factor.

Author's Comment:

- The load is determined in accordance with Article 120. For when to apply a 125 percent multiplying factor in sizing conductors and overcurrent protective devices for continuous loads, see 210.19(A)(1), 210.20(A), 215.4(A)(1), and 215.5.

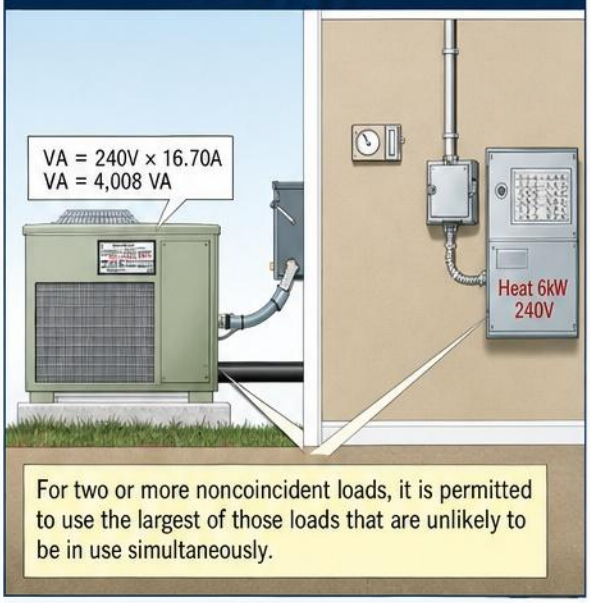
120.6 Noncoincident Loads

For two or more noncoincident loads, it is permitted to use the largest of these loads in the calculation.

Noncoincident loads are considered to be one of the following:

(1) Feeders or Services. The loads that are unlikely to be in use simultaneously. ▶ Figure 120–7

Figure 120–7 Noncoincident Loads—Feeders or Services 120.6



For two or more noncoincident loads, it is permitted to use the largest of those loads that are unlikely to be in use simultaneously.

(2) Branch Circuits, Feeders, or Services. The loads that are prevented from being in use simultaneously by listed equipment. ▶ Figure 120–8

Figure 120–8 Noncoincident Load—Branch Circuits, Feeders, or Services *120.6(2)*

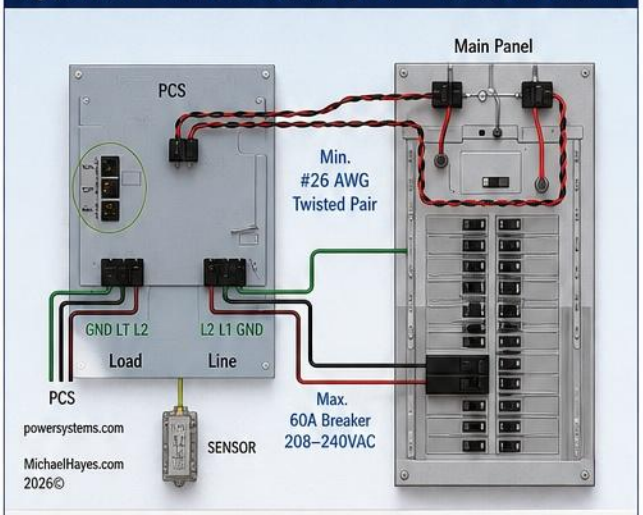
For two or more noncoincident loads, it is permitted to use the largest of those loads that are prevented from being in use simultaneously by listed equipment.

120.7 Power Control Systems (PCS)

Power control systems (PCS) are permitted to be used for branch-circuit, feeder, or service load calculations.

Power Control System (PCS). Equipment that monitors and controls power to prevent overload of an electrical service, conductor, or power distribution equipment. ▶ Figure 120–9

Figure 120–9 Power Control Systems (PCS) Article 100 Definition



Equipment that monitors and controls power to prevent overload of an electrical service, conductor, or power distribution equipment.

(A) PCS Requirements. The PCS shall comply with Article 130 Part II.

(B) PCS Control Setting. When used in load calculations, the control setting is not permitted to exceed 80 percent of the overcurrent protective device rating for the circuit being monitored by the PCS.

Figure 120–10 Load Calculations—Power Control Systems (PCS) 120.7(B)

The PCS control setting is not permitted to exceed 80% of the overcurrent protective device rating for the circuit being monitored by the PCS.

(C) Load Calculations Using PCS. The load on the branch circuit, feeder, or service must be the sum of the controlled loads. Controlled loads are determined in 120.7(C)(1), and noncontrolled loads are determined in 120.7(C)(2).

(1) Controlled Loads. Controlled loads must be based on the monitoring by the PCS to provide overload control. The PCS control configuration must comply with one or both of the following:

(1) If the PCS monitors only controlled loads, the control setting must be used in place of the controlled loads in load calculations.

(2) If the PCS monitors both controlled and noncontrolled loads, the minimum operating current of the controlled loads must be used in place of the controlled loads in load calculations.

Note: Minimum operating current is a value greater than or equal to zero representing the minimum current of the controlled loads.

(2) Noncontrolled Loads. Load calculations for loads not controlled by the PCS must comply with Article 120, Parts II through VII.

Note: See Informative Annex D Examples D14(a) through D14(d) for examples of load calculations with loads managed by PCSs.

Part II. Branch-Circuit Load Calculations

120.13 Dwelling Units—Branch Circuit Load

When sizing the number of branch circuits for dwelling units, the load is based on 3 VA per sq ft.

Figure 120–11 Branch-Circuit Load Calculations—Dwelling Units, Number of Circuits 120.13

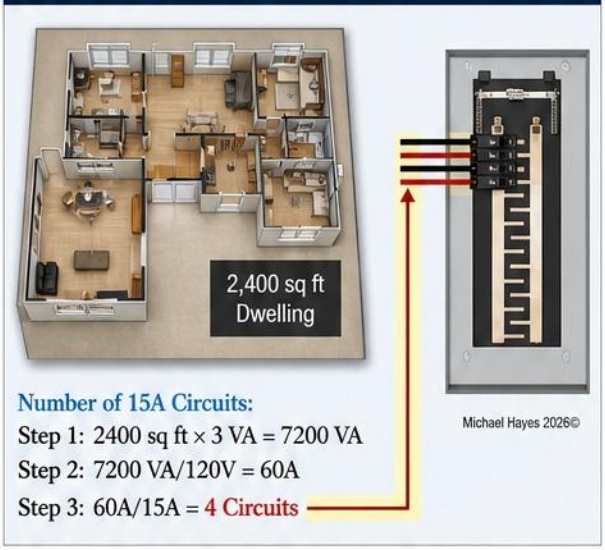
When sizing the number of dwelling unit branch circuits for general lighting and receptacles, the load is based on 3 VA per sq ft.

➤ Dwelling 15A Circuit [120.13] Example

Question: How many 15A, 120V general lighting and general-use receptacles circuits are required for a 2,400 sq ft dwelling unit? Figure 120–12

(a) Two circuits (b) Three circuits (c) Four circuits (d) Five circuits

Figure 120–12 | Dwelling 15A Circuit Example 120.13



Total general lighting and general-use receptacle load for a 2,400 sq ft dwelling requires four 15A, 120V circuits.

Solution:

Step 1: *Determine the total VA load.*

VA = 2,400 sq ft × 3 VA per sq ft [120.13]

VA = 7,200 VA

Step 2: *Determine the amperes.*

I = Volt-Amperes/Volts

I = 7,200VA/120V

I = 60A

Step 3: *Determine the number of circuits.*

Number of 15A Circuits = 60A/15A

Number of 15A Circuits = Four

Answer: *(c) Four circuits*

Author's Comment:

The *Code* does not limit the number of receptacle outlets on a general-purpose branch circuit in a dwelling unit.

➤ Number of Receptacles on a Dwelling Unit Circuit, Example

Question: What are the maximum number of 15A or 20A, 125V receptacles permitted on a 15A or 20A, 120V general-purpose branch circuit in a dwelling unit?

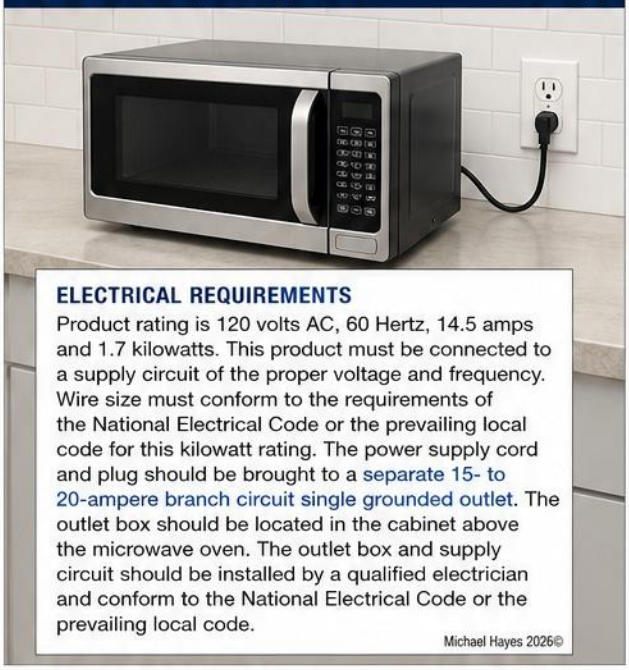
(a) 10 receptacles *(b)* 11 receptacles
(c) 12 receptacles *(d)* There is no limit

Answer: *(d) There is no limit*

120.14 BRANCH-CIRCUIT LOAD CALCULATIONS

(A) Specific Appliances. The branch-circuit load for a specific appliance is based on the ampere rating of the appliance. Figure 120–13

Figure 120–13 | Specific Appliances 120.14(A)



Branch-circuit load for a specific appliance is determined by the appliance's ampere rating.

(D) Luminaires. The branch-circuit load for a luminaire is not less than the VA rating of the luminaire. Figure 120–14

(F) Sign Outlet. The branch-circuit load for a sign is based on not less than 1200 VA for each commercial occupancy sign outlet required by 600.5(A)(2). Figure 120–15

Author's Comment:

Each commercial building or occupancy accessible to pedestrians must have a sign outlet at the entrance of each tenant space. The sign outlet must be supplied by a branch circuit rated at least 20A that serves no other loads.

Figure 120–14 Branch-Circuit Load Calculations *120.14(D)*

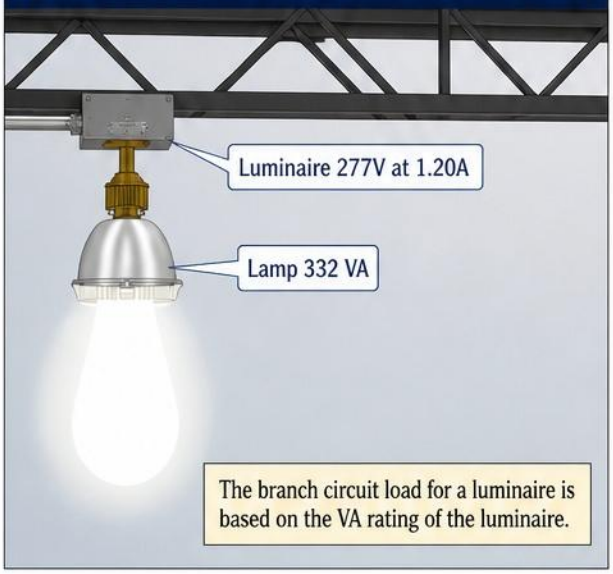


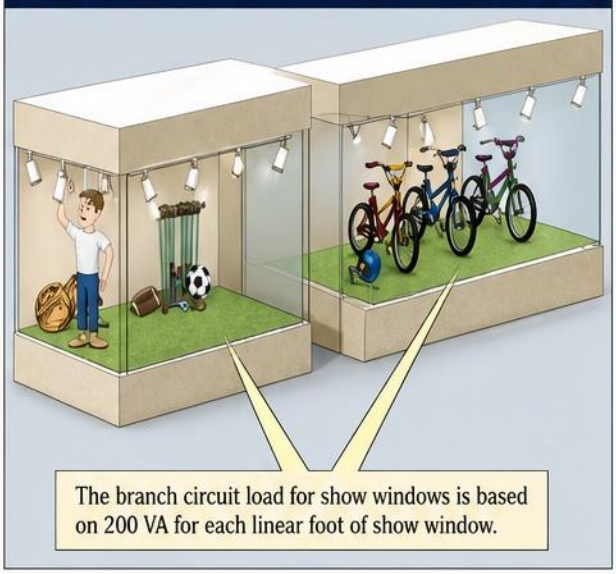
Figure 120–15 Load Calculations, Sign Outlet *120.14(F)*

(G) Show Window. The branch-circuit load for show windows is based on the following:

(1) 180 VA for each show-window receptacle outlet required by 210.62 [120.14(I)], or

(2) 200 VA for each linear ft of show window ▶ Figure 120–16

Figure 120–16 Load Calculation, Show Window 120.14(G)(2)

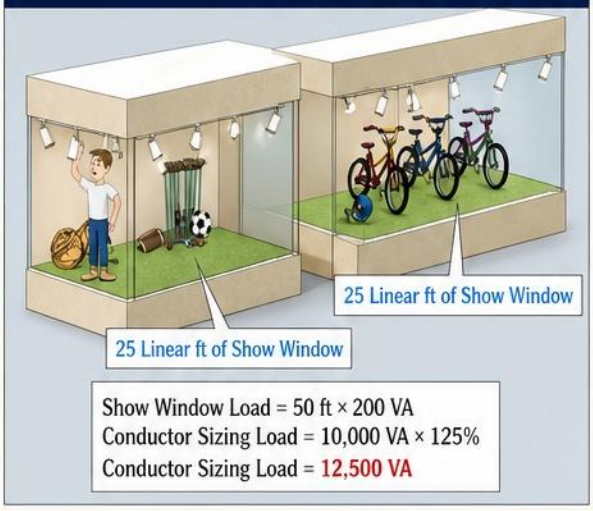


▶ Show Window Load [120.14(G)(2)] Example

Question: *What is the branch-circuit load for 50 linear ft of a show window?* ▶ Figure 120–17

(a) 5,000 VA (b) 10,000 VA (c) 15,000 VA (d) 20,000 VA

Figure 120–17 Load Calculations, Show Window Conductor Sizing *120.14(G)(2) and 210.19(A)(1) Example*



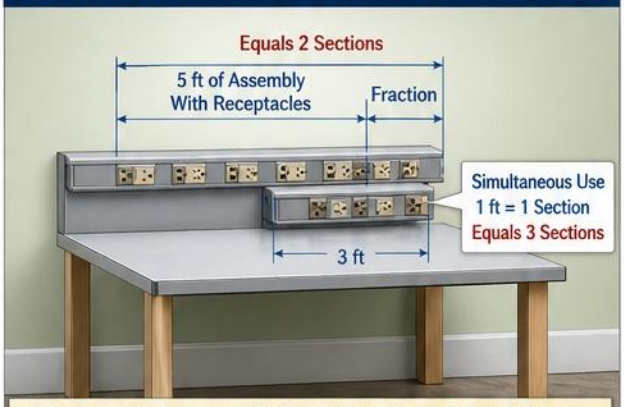
Solution:

50 Linear ft of Show Window × 200 VA per Linear ft = 10,000 VA

Answer: *(b) 10,000 VA*

(H) Fixed Multioutlet Assemblies. The branch-circuit load for fixed *multioutlet assemblies* in other than dwellings or guest rooms of hotels or motels is as follows: ▶ Figure 120–18

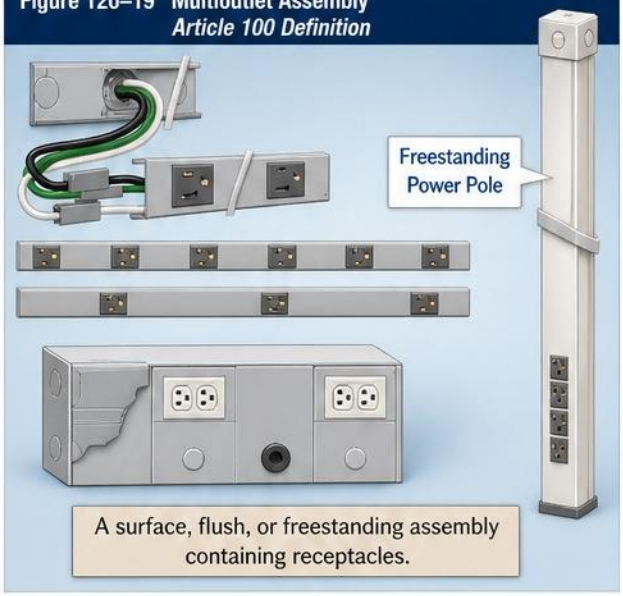
Figure 120–18 Fixed Multioutlet Assemblies 120.14(H)



Fixed multioutlet assemblies must be calculated as follows:
(1) Not used simultaneously, each 5 ft (or fraction of 5 ft) is considered 180 VA.
(2) Used simultaneously, each 1 ft (or fraction of 1 ft) is considered 180 VA.

Multioutlet Assembly. A surface, flush, or freestanding assembly containing receptacles.

Figure 120–19 Multioutlet Assembly *Article 100 Definition*



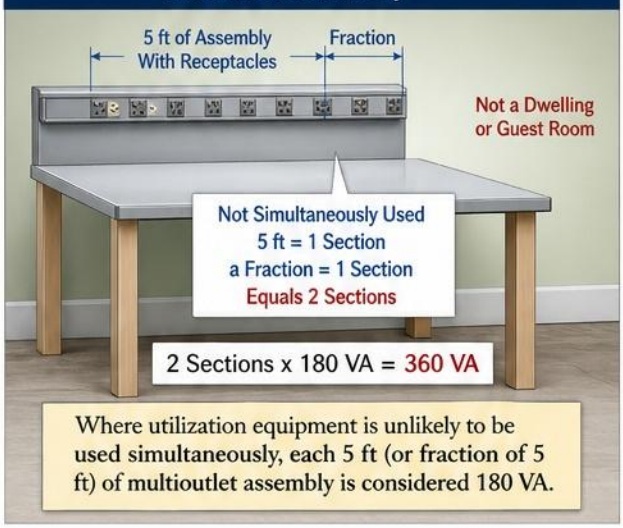
A surface, flush, or freestanding assembly containing receptacles.

(1) Where utilization equipment is unlikely to be used simultaneously, each 5 ft (or fraction of 5 ft) of multioutlet assembly is considered 180 VA.

(2) Where utilization equipment is likely to be used simultaneously, each 1 ft (or fraction of 1 ft) of multioutlet assembly is considered 180 VA.

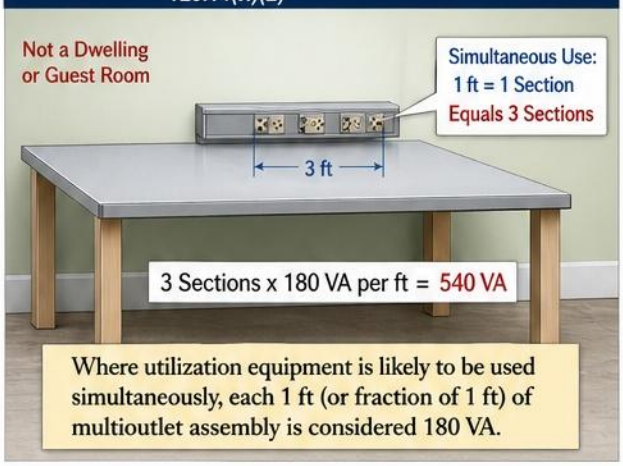
(I) Receptacle Outlets. In other than dwelling units, the branch circuit load for 15A or 20A, 125V general-use receptacle outlets is based on 180 VA per mounting yoke.

Figure 120–20 Multioutlet Assembly, Not Used Simultaneously 120.14(H)(1)



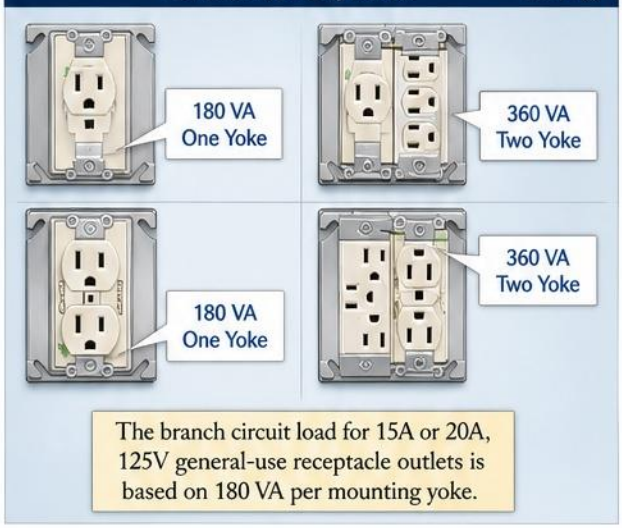
Where utilization equipment is unlikely to be used simultaneously, each 5 ft (or fraction of 5 ft) of multioutlet assembly is considered 180 VA.

Figure 120–21 Multioutlet Assembly, Used Simultaneously *120.14(H)(2)*



Where utilization equipment is likely to be used simultaneously, each 1 ft (or fraction of 1 ft) of multioutlet assembly is considered 180 VA.

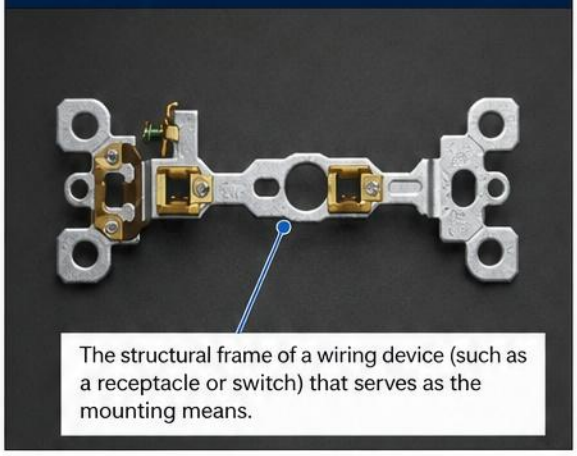
Figure 120–22 Receptacle Outlets, Commercial Occupancies 120.14(I)



The branch circuit load for 15A or 20A, 125V general-use receptacle outlets is based on 180 VA per mounting yoke.

Yoke (Strap). The structural frame of a wiring device (such as a receptacle or switch) that serves as the mounting means.
▶ **Figure 120–23**

Figure 120–23 *Article 100 Definition*
Yoke (Strap)



AUTHOR'S COMMENT:

Under the *NFPA Handbook* enhanced content, the maximum number of receptacles on a circuit for commercial occupancies is based on the circuit VA divided by 180 VA per receptacle.

NUMBER OF RECEPTACLES ON A COMMERCIAL CIRCUIT [120.14(I)] EXAMPLE

Question:
What is the maximum number of 15A or 20A, 125V receptacles permitted on a 20A, 120V general-purpose branch circuit in a commercial occupancy?
▶ **Figure 120–24**

(a) 10 receptacles (b) 11 receptacles
(c) 12 receptacles (d) 13 receptacles

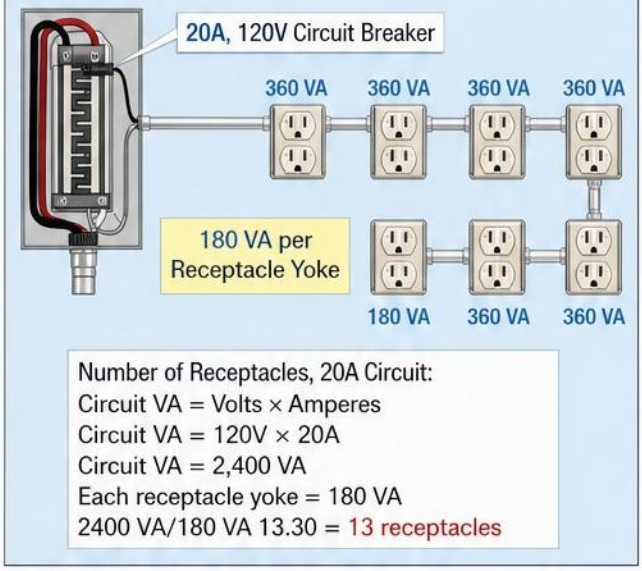
Solution:

Circuit VA = Volts × Amperes
Circuit VA = 120V × 20A
Circuit VA = 2,400 VA

Number of Receptacles = 2,400 VA / 180 VA
Number of Receptacles = 13.33 VA
Number of Receptacles = 13 receptacles

Answer: (d) 13 receptacles

Figure 120–24 **120.40**
Branch-Circuit Load Calculations
Receptacle Outlets, Commercial Occupancies
120.14(I) Example



Load calculation example for receptacle outlets in commercial occupancies. Each receptacle yoke is valued at 180 VA.

AUTHOR'S COMMENT:

General-purpose receptacles are not considered a continuous load according to Annex D load calculation examples.

PART III. FEEDER AND SERVICE LOAD CALCULATIONS

120.40 General

The calculated load of a feeder or service must not be less than the sum of the loads on the branch circuits supplied. These loads are determined by Article 120, Part II, after applying demand factors permitted or required by Article 120, Parts III, IV, V, VI, or VII.

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

Note 1: See Informative Annex D, Examples D1(a) through D10, for examples of feeder/service load calculations.

120.41 Dwelling Unit Load Calculations

General lighting and receptacle outlet loads for dwelling units must not be less than 2 VA per sq ft, based on the outside dimensions of the building in accordance with 120.5(C). This 2 VA per sq ft value includes the lighting and receptacle loads for the following:
▶ **Figure 120–25**

Figure 120–25 Dwelling Unit Standard Calculation General Lighting/Receptacle Loads *120.41*

General lighting and receptacle outlet loads are not less than 2 VA per sq ft, based on the outside dimensions of the dwelling in accordance with 120.5(C).

(1) General-use receptacle outlets rated 20A or less, including receptacles connected to the bathroom or garage circuits in accordance with 210.11(C)(3) and (C)(4)

(2) Receptacle outlets specified in 210.52(E) and (G) for outdoors, garages, and basements

(3) Lighting outlets specified in 210.70

The minimum lighting load is determined by using the minimum unit load and the floor area as determined in 120.5(C) for dwelling occupancies. Motors rated less than ½ hp and connected to a lighting circuit are considered part of the minimum lighting load.

120.50 Motor and Air-Conditioning Loads

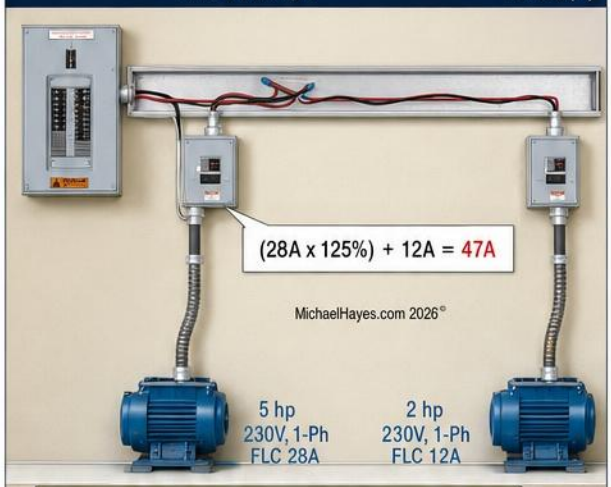
(A) Motor. Motor loads are calculated at not less than 125 percent of the largest motor full load current plus the sum of other motors full load currents [430.24]. See Figure 120–26.

(B) Air-Conditioning. Air-conditioning equipment loads are calculated at not less than 125 percent of the largest air-conditioning load [440.34]. See Figure 120–27.

120.51 Fixed Electric Space-Heating Load

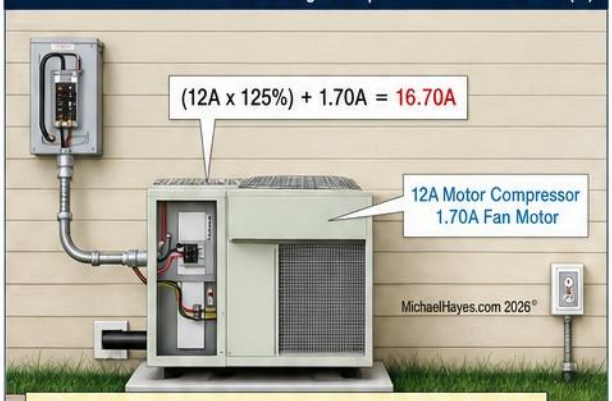
Fixed electric space-heating equipment loads are calculated at not less than 100 percent of the total connected load. *See Figure 120–28.*

Figure 120–26 Service and Feeder Load Calculations Motor Example *120.50(A)*



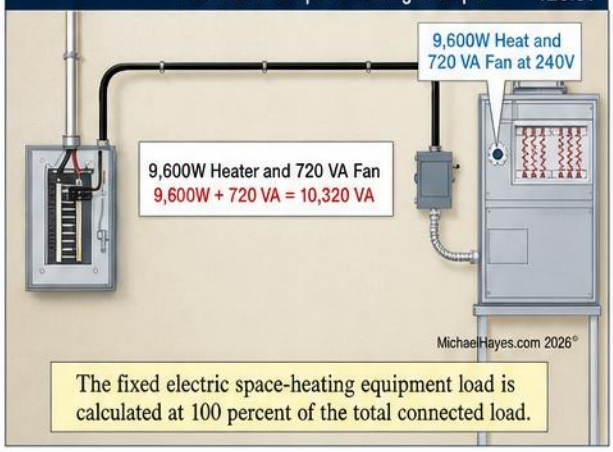
Motor loads are calculated at not less than 125% of the largest motor load FLC plus the sum of other motors FLCs [430.24].

Figure 120–27 Service and Feeder Load Calculations Air-Conditioning Example *120.50(B)*



The air-conditioning equipment load is calculated at 100% of the air-conditioning load [440.33].

Figure 120–28 Service and Feeder Load Calculations Fixed Electric Space-Heating Example *120.51*



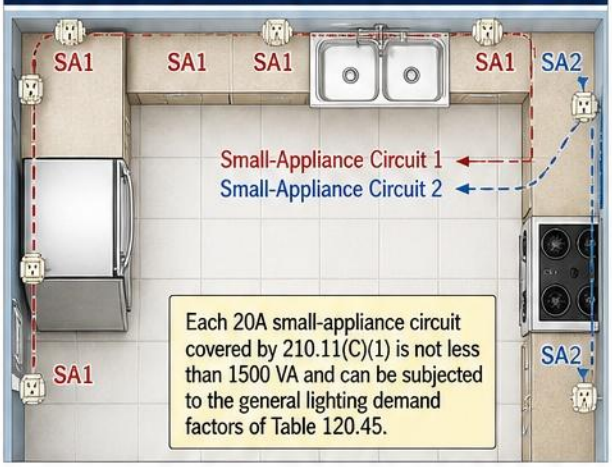
The fixed electric space-heating equipment load is calculated at 100 percent of the total connected load.

120.52 Dwelling Unit Small-Appliance and Laundry Loads

Table 120.45 applies to the small-appliance and laundry circuits as follows:

(A) Small-Appliance Demand Load. The load for each 20A small-appliance circuit covered by 210.11(C)(1) is not less than 1500 VA. This load can be subjected to the general lighting demand factors contained in Table 120.45. See Figure 120–29.

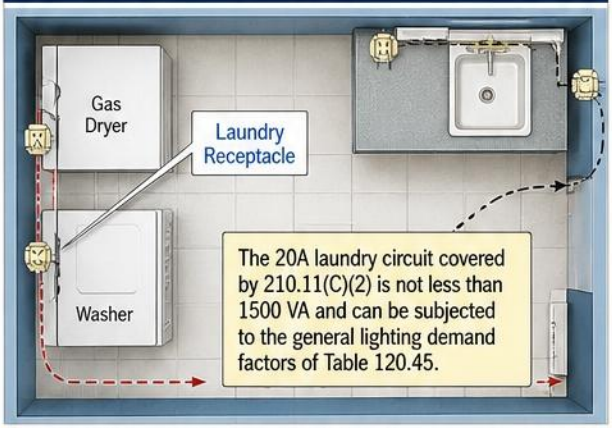
Figure 120–29 Small-Appliance Demand Load 120.52(A)



Two separate 20A small-appliance branch circuits (SA1 and SA2) serve the kitchen counter receptacles. Each circuit has a minimum load of 1500 VA and may be reduced using the demand factors from Table 120.45.

(B) Laundry Demand Load. The load for each 20A laundry circuit covered by 210.11(C)(2) is not less than 1500 VA. This load can be subjected to the general lighting demand factors contained in Table 120.45. See Figure 120–30.

Figure 120–30 Laundry Demand Load 120.52(B)



A single 20A laundry circuit serves the laundry receptacle and any other outlets in the laundry area. The minimum load is 1500 VA and may be reduced using Table 120.45 demand factors.

120.53 Dwelling Unit Appliance Demand Load

A demand factor of 75 percent is permitted to be applied to the total connected load of four or more appliances rated ¼ hp (or greater) or 500W (or greater) that are fastened in place. See Figure 120–31.

Figure 120–31 Appliance Demand Load 120.53

This demand factor does not apply to:

(1) Household electric cooking equipment that is fastened in place

(2) Clothes dryers

(3) Space-heating equipment

(4) Air-conditioning equipment

(5) Electric vehicle supply equipment (EVSE)

Not More than Four Appliances [120.53] Example

Question: *What is the conductor demand load for a dwelling unit containing a 1,000 VA waste disposal, 1,500 VA dishwasher, and 4,500 VA water heater? See Figure 120–32.*

(a) 6,000 VA (b) 7,000 VA (c) 8,000 VA (d) 9,000 VA

Solution:

Total Connected Load = 1,000 VA + 1,500 VA + 4,500 VA

Total Connected Load = 7,000 VA

Answer: *(b) 7,000 VA*

Figure 120–32 Dwelling Unit Standard Calculation Appliance Demand Load 120.53 Example 1

The connected load is determined by adding the loads of the waste disposal, dishwasher, and water heater. No demand factor is applied because there are only three fastened-in-place appliances.

▶ More than Four Appliances [120.53] Example

Question: *What is the conductor demand load for a dwelling unit containing a 1,000 VA waste disposal, 1,500 VA dishwasher, 1,800 VA microwave, and 4,500 VA water heater?*

(a) 6,600 VA (b) 10,400 VA (c) 11,250 VA (d) 12,450 VA

Solution:

Step 1: *Find the total connected appliance load from nameplate ratings.*

Total Connected Load = 1,000 VA + 1,500 VA + 1,800 VA + 4,500 VA
Total Connected Load = 8,800 VA

Step 2: *Find the total demand load at 75 percent (four units).*

Total Demand Load = 8,800 VA × 75%
Total Demand Load = 6,600 VA

Answer: *(a) 6,600 VA*

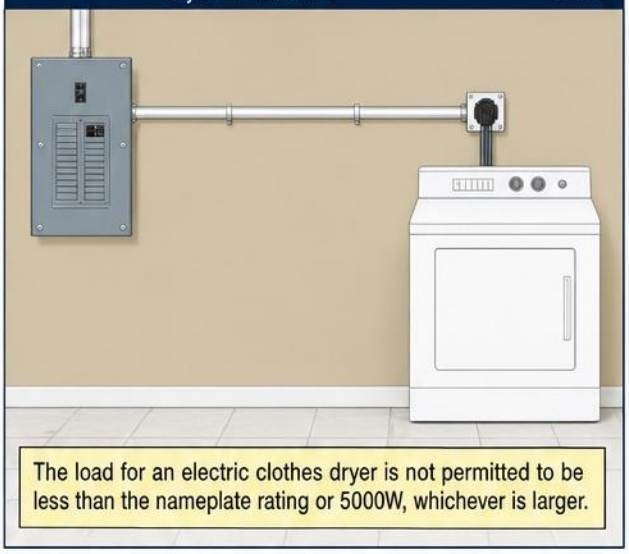
120.54 DWELLING UNIT CLOTHES DRYER DEMAND LOAD

The load for an electric clothes dryer is not permitted to be less than the nameplate rating or 5000W, whichever is larger. (Figure 120–33)

AUTHOR'S COMMENT

- A dryer outlet is not required to be installed in a dwelling unit. However, if it is installed, the load is not permitted to be less than 5000W or the nameplate (if larger).

Figure 120–33 Dwelling Unit Standard Calculation Dryer Demand Load 120.54



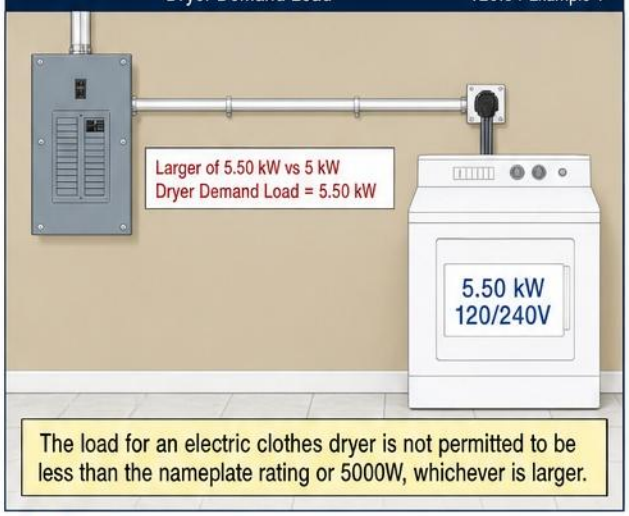
The dryer must be calculated using the larger of its nameplate rating or 5000W.

▶ Dryer Demand Load [120.54] Example

Question: *What is the service demand load for a 5.50 kW clothes dryer? (Figure 120–34)*

(a) 5 kW (b) 5.50 kW (c) 6 kW (d) 6.50 kW

Figure 120–34 Dwelling Unit Standard Calculation Dryer Demand Load 120.54 Example 1



Solution:

Dryer Demand Load = The larger of the nameplate rating or 5 kW.
Dryer Demand Load = 5.50 kW

Answer: *(b) 5.50 kW*

The use of the demand factors in **Table 120.54** is permitted.

Table 120.54 Demand Factors for Household Electric Clothes Dryers

Number of Dryers	Demand Factor (%)
1–2	100%
3–5	80%
6	75%
7	65%
8	60%
9	55%
10	50%
11	47%
12–23	47% minus 1% for each dryer exceeding 11
24–42	35% minus 0.5% for each dryer exceeding 23
43 and over	25%

120.55 Dwelling Unit Cooking Appliance Demand Load

The demand load for electric cooking equipment is established in accordance with 120.55 and Table 120.55 (including Table Notes).

Range 12 kW [Table 120.55 Column C] Example

Question: What is the service demand load for one 12 kW, 120/240V household range?

(a) 6 kW *(b) 8 kW* *(c) 10 kW* *(d) 12 kW*

Figure 120-35 **Table 120.55, Column C Example** 120.55

Answer: *(b) 8 kW [Table 120.55, Column C]*

Table 120.55 Note 1: For ranges rated more than 12 kW, the maximum demand in Column C must be increased 5 percent for each additional kilowatt of rating (or major fraction thereof), by which the rating of the range exceeds 12 kW.

Range over 12 kW [Table 120.55 Note 1] Example

Question: *What is the service demand load for one 14 kW range?*

▶ **Figure 120-36**

(a) 6.6 kW *(b) 8.8 kW* *(c) 11 kW* *(d) 12 kW*

Figure 120-36 **Table 120.55, Column C Example** 120.55

▶ ***Solution:***

Step 1: *Determine the Table 120.55 Column C demand load for one 14 kW range.*

Step 2: *For ranges rated more than 12 kW, the maximum demand in Column C must be increased 5 percent for each additional kilowatt of rating (or major fraction thereof), by which the rating of individual ranges exceeds 12 kW.*

A 14 kW range exceeds 12 kW by 2 kW. Therefore, Column C demand load must be increased by 5 percent for each kW (or major fraction thereof) a kilowatt that exceeds 12 kW.

Step 3: *Increase Column C by 10 percent.*

8 kW × 110% = 8.8 kW

Answer: *(b) 8.8 kW [Table 120.55 Note 1]*

Table 120.55 Note 4: The branch-circuit load for one range may be determined in accordance with Table 120.55.

Figure 120–37 Branch-Circuit Load for Range (Table 120.55 Note 4) Example 120.55

Question: What is the branch-circuit load for a 12 kW range?

(a) 6 kW (b) 8 kW (c) 10 kW (d) 12 kW

Solution:

From *Table* 120.55, *Column C* = 8 *kW*

P = 8 *kW*

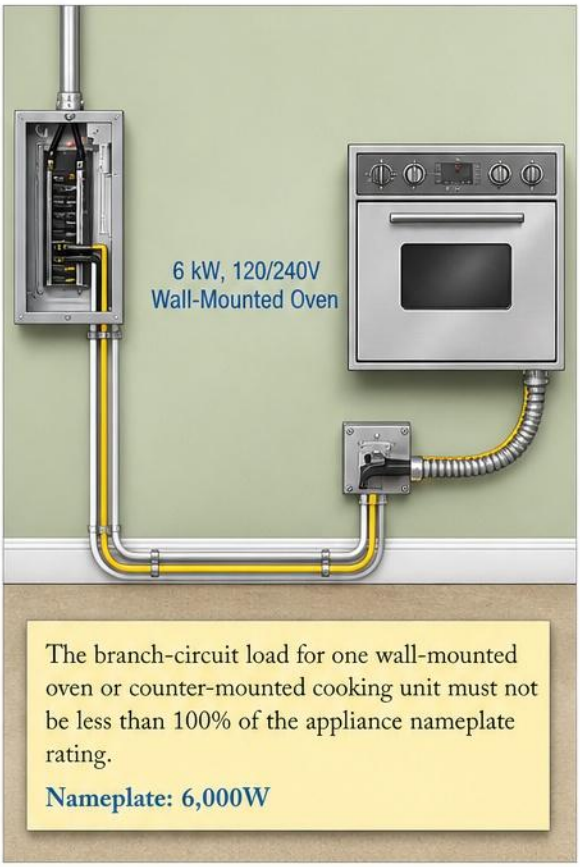
Answer: (b) 8 *kW*

Table 120.55 Note 5: The branch-circuit load for one wall-mounted oven or counter-mounted cooking unit must not be less than the nameplate rating (100 percent) of the appliance.

Figure 120–38 Branch-Circuit Load for Oven (Table 120.55 Note 5) Example 120.55

Question: What is the branch-circuit load for a 6 kW wall-mounted oven?

(a) 4 kW (b) 4.5 kW (c) 5 kW (d) 6 kW



Solution:

Answer: (d) 6 *kW*

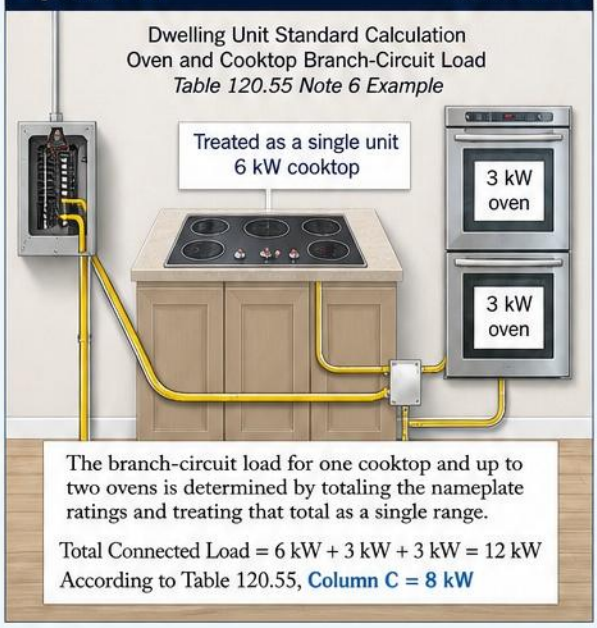
Table 120.55 Note 6: The demand load for a single branch circuit supplying one counter-mounted cooking appliance and up to two wall-mounted ovens is established by applying the nameplate ratings together. This produces a single range used to determine the load in accordance with Table 120.55 and its notes.

▶ Branch-Circuit Load for Oven and Cooktop [Table 120.55 Note 6] Example

Question: What is the branch-circuit load for a 6 kW counter-mounted cooking unit and two 3 kW wall-mounted ovens? Figure 120–39

(a) 6 kW *(b) 8 kW* *(c) 10 kW* *(d) 12 kW*

Figure 120–39 120.55 Note 6



Solution:

Step 1: *Determine the total connected load.*

Total Connected Load = 6 kW + 3 kW + 3 kW

Total Connected Load = 12 kW

Step 2: *Using Table 120.55, Column C, find the calculated kilowatt load for a single 12 kW rating.*

From Table 120.55, Column C = 8 kW

Answer: *(b) 8 kW*

120.57 Electric Vehicle Supply Equipment Load

The demand load for Electric Vehicle Supply Equipment (EVSE) is based on the nameplate rating of the equipment available at the time of calculation, or 7200 VA if the nameplate is not available. See Figure 120–40.

Figure 120–40 Load Calculations, Electric Vehicle Supply Equipment 120.57

The calculated load for each Electric Vehicle Supply Equipment (EVSE) is based on the nameplate rating of the equipment available at the time of calculation, or 7200 VA if the nameplate is not available.

▶ Electric Vehicle Supply Equipment Load [120.57] Example

Question: What is the service load for an EV charger (electric vehicle supply equipment) with a nameplate rating of 40A at 240V?

(a) 6,200 *VA* (b) 7,200 *VA*

(c) 8,600 *VA* *(d) 9,600 VA*

Solution:

Use the EVSE nameplate value of 40A.

40A × 240V = 9,600 VA

Answer: *(d) 9,600 VA*

120.61 Neutral Calculated Load

(A) Neutral Calculated Load. The neutral calculated load for feeders or services is the maximum calculated load between the neutral conductor and any one phase conductor.

AUTHOR'S COMMENT:

▶ Line-to-line loads do not place any load on the neutral conductor; therefore line-to-line loads are not considered in the neutral calculation.

(B) NEUTRAL CALCULATED LOAD REDUCTIONS.

(1) Electric Ranges, Ovens, or Cooking Units and Dryers.

Electric Ranges, Ovens, or Cooking Units. The neutral load for household electric ranges, wall-mounted ovens, or counter-mounted cooking units can be calculated at 70 percent of the cooking equipment demand load as determined in accordance with Table 120.55.

Dryers. The neutral load for household electric dryers can be calculated at 70 percent of the dryer calculated load as determined in accordance with Table 120.54.

(2) Over 200A Unbalanced Load. The calculated neutral load for a 3-wire, single-phase or 4-wire, three-phase system can be calculated at 70 percent for that portion of the unbalanced load over 200A.

AUTHOR'S COMMENT:

- In addition to the 70 percent demand factor contained in 120.61(B)(1), a further demand factor of 70 percent can be applied to that portion of the unbalanced load exceeding 200A. See Annex D, Example D4(a) Multifamily Dwelling.

PART IV. OPTIONAL FEEDER AND SERVICE LOAD CALCULATIONS

120.82 DWELLING UNIT OPTIONAL LOAD CALCULATIONS

(A) Feeder and Service Load. The demand load can be calculated by adding the loads from 120.82(B), (C), and (D).

Where the optional load calculation in 120.82(A) is used, the neutral load is permitted to be determined using the standard method of load calculation in accordance with 120.61.

(B) General Loads. The demand load must not be less than 100 percent of the first 8 kVA, plus 40 percent of the remaining kVA for the following loads:

(1) **General Lighting.** The general lighting load is based on 2 VA per sq ft for general lighting and general-use receptacles. The sq ft area is determined in accordance with 120.5(C).

(2) **Small-Appliance and Laundry Circuits.** Add 1500 VA for each 20A small-appliance circuit required by 210.11(C)(1)(a) with a minimum of two circuits per dwelling unit, and 1500 VA for each 20A laundry circuit required by 210.11(C)(2), with a minimum of one circuit per dwelling unit.

(3) **Appliances.** The nameplate rating of the following appliances:

a. Appliances that are fastened in place, permanently connected (hard-wired), or located on a specific circuit

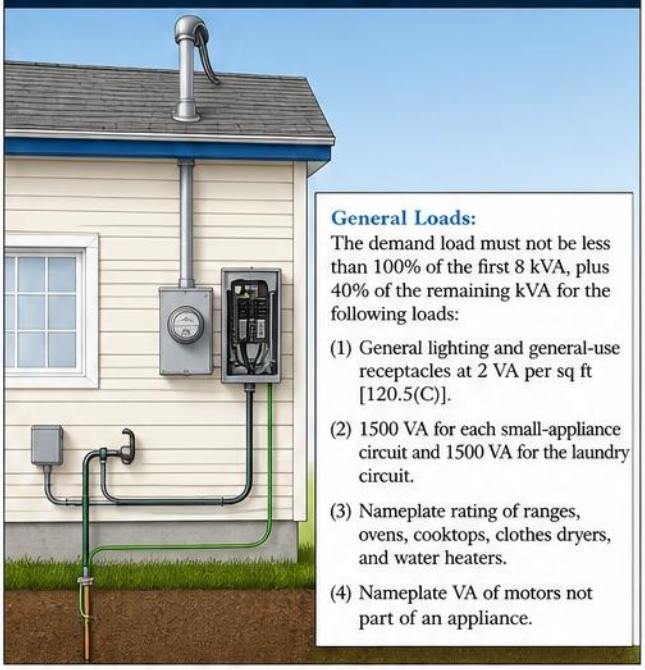
b. Ranges, wall-mounted ovens, and counter-mounted cooking units

c. Clothes dryers that are not connected to the laundry branch circuit

d. Water heaters

(4) **Motor VA.** The nameplate ampere or kVA rating of all permanently connected motors not included in 120.82(B)(3).

Figure 120–41 Dwelling Unit Optional Calculations — General Loads 120.82(B)



The optional calculation in 120.82(B) establishes minimum demand load criteria for general dwelling unit loads.

(C) Air-Conditioning and Heating Equipment. The larger of 120.82(C)(1) through (6):

(1) **Air-Conditioning Equipment.** Use 100 percent of the air-conditioning nameplate ratings.

(2) **Heat-Pump Compressor without Supplemental Heating.** Use 100 percent of the heat-pump nameplate rating.

(3) **Heat-Pump Compressor with Supplemental Heating.** Use 100 percent of the nameplate rating of the heat pump, and use 65 percent of the supplemental electric heating for central electric space-heating systems.

(4) **Space-Heating Units (Three Units or Less).** Use 65 percent of the nameplate ratings.

(5) **Space-Heating Units (Four or More Units).** Use 40 percent of the nameplate ratings.

(6) **Electric Thermal Storage and Other Heating.** Use 100 percent of the nameplate rating.

Figure 120–42 Dwelling Unit Optional Calculations A/C vs. Heating Loads 120.82(C)

The larger of:

(1) **A/C equipment.** 100% of the air-conditioning nameplate rating(s).

(2) **Heat-pump compressor** without supplemental heating. 100% of the heat-pump nameplate rating.

(3) **Heat-pump compressor** and **supplemental heating.** 100% of the nameplate rating of the heat pump and 65% of the supplemental electric heating.

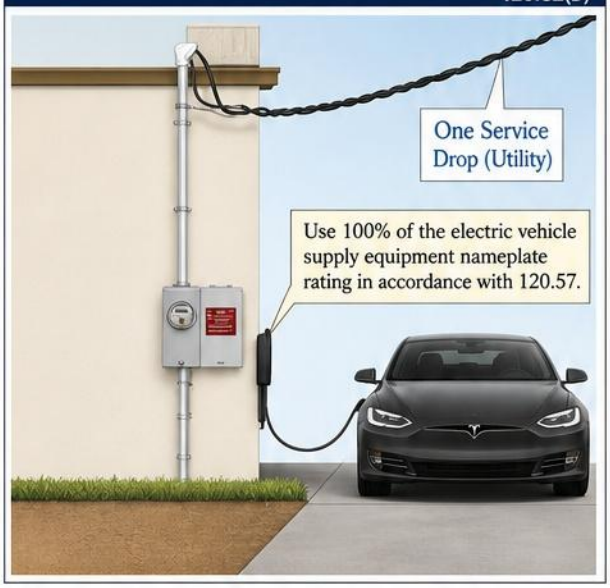
(4) **Space-heating units (3 units and fewer).** 65% of the space-heating nameplate rating(s).

(5) **Space-heating units (4 or more units).** 40% of the space-heating nameplate ratings.

This method compares the air-conditioning load to the heating load and uses the higher calculated value.

(D) Electric Vehicle Supply Equipment (EVSE). Use 100 percent of the electric vehicle supply equipment nameplate rating in accordance with 120.57.

Figure 120–43 Dwelling Unit Optional Calculations Electric Vehicle Supply Equipment 120.82(D)



The full nameplate rating of the EVSE is used for load calculations.

Sizing Service with Optional Method [120.82] Example

Question: Using the optional calculation method, what size service is required for a 1,500 sq ft dwelling unit that contains the following loads?

(a) *110A* (b) *125A* (c) *150A* (d) *175A*

- Dishwasher, *1,200 VA*
- Waste disposal, *900 VA*
- Cooktop, *6,000 VA*
- Oven, *3,000 VA*
- Dryer, *4,000 VA*
- Water heater, *4,500 VA*
- *Heat-pump compressor rated 28A at 240V, with supplemental electric heat having a rating of 7 kW*
- Electric vehicle charger, *9,600 VA*

Solution:

Step 1: *Determine lighting, receptacles, and small-appliance load [120.82(B)].*

Small-Appliance	*1,500 VA × 2*	*3,000 VA*
Laundry	*1,500 VA × 1*	*1,500 VA*
General Lighting	*1,500 sq ft × 2 VA/sq ft*	*3,000 VA*
Dishwasher	*1,200 VA × 1*	*1,200 VA*
Waste Disposal	*900 VA × 1*	*900 VA*
Cooktop	*6,000 VA × 1*	*6,000 VA*
Oven	*3,000 VA × 1*	*3,000 VA*
Dryer	*4,000 VA × 1*	*4,000 VA*
Water Heater	*4,500 VA × 1*	*+ 4,500 VA*
Calculated Load		*27,100 VA*
First 8,000 VA at 100%	*8,000 VA × 100%*	*8,000 VA*
Remainder at 40%	*19,100 VA × 40%*	*+7,640 VA*
Demand Load		*15,640 VA*

Step 2: *Determine largest of air-conditioning or heat [120.82(C)].*

Heat Pump Compressor at 100%	*240V × 28A*	*6,720 VA*
Supplemental Heat at 65%	*7,000 VA × 65%*	*+4,550 VA*
Demand Load		*11,270 VA*

Step 3: *Determine electric vehicle [120.82(D)].*

Electric Vehicle	*9,600 VA*	
Demand Load	*9,600 VA × 100%*	*9,600 VA*

Step 4: *Determine total demand load (Step 1 + Step 2 + Step 3).*

Step 1. General Lighting	*15,640 VA*
Step 2. AC/Heat	*11,270 VA*
Step 3. EVSE	*+9,600 VA*
Total Demand Load	***36,510 VA***

Step 5: Determine the service size in amperes.

I = Volt-Ampere/Volts

I = 36,510 VA/240V

I = 152A, 175A Service [240.6(A)]

Answer: *(d) 175A*

120.83 Existing Dwelling Unit Optional Load Calculation

This section is permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads if the dwelling unit is served by a 120/240V or 208Y/120V, 3-wire service or feeder.

The percentages listed in Table 120.83 must be used for existing and additional new loads. The larger connected load of air conditioning or space heating—but not both—must be used.

Load calculations include all of the following:

(1) General lighting and general-use receptacles at 2 VA/ft^2

(2) 1500 VA for each 2-wire, 20A small-appliance branch circuit and laundry branch circuit covered in 210.11(C)(1) and (2)

(3) The nameplate ratings of all of the following equipment:

a. Appliances that are fastened in place, permanently connected, or located to be on a specific circuit

b. Ranges, wall-mounted ovens, and counter-mounted cooking units

c. Clothes dryers

d. Water heaters

e. EVSEs supplied by individual branch circuits

Table 120.83 Existing Dwelling Unit Load Percentages

Load (kVA)	Percent of Load
First 8 kVA of existing and new load	100%
Remainder of existing load	40%
New EVSE	80%
New central electric resistance space heating	80%
All other new loads	50%

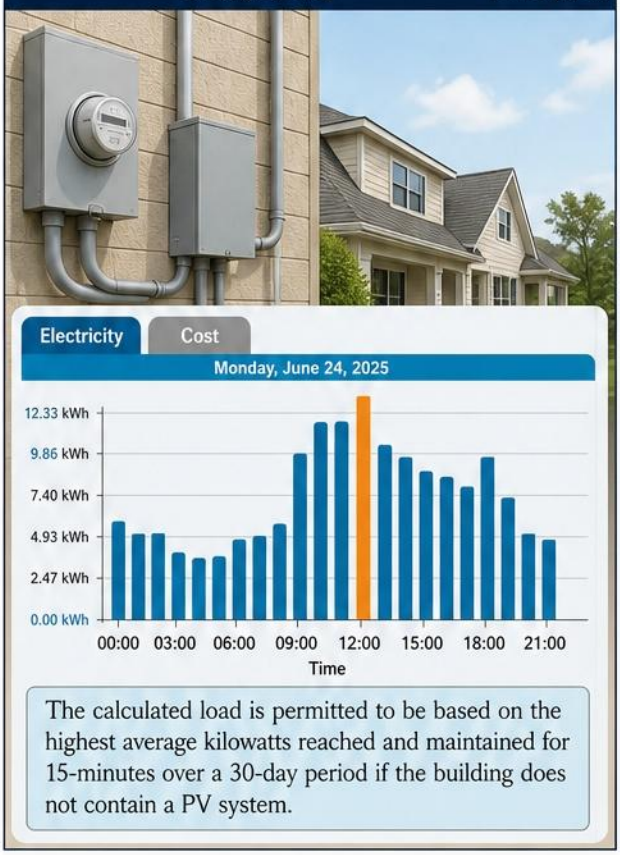
120.87 Determining Existing Loads

The feeder or service calculated load for an existing building can use actual maximum demand to determine the existing load as follows:

(1) Maximum Demand Data. The maximum demand data from the electric utility for a one-year period.

Ex: If the maximum demand data for a one-year period is not available, the calculated load is permitted to be based on the maximum demand (the highest average kilowatts reached and maintained for a 15-minute interval) recorded over a minimum 30-day period connected to the highest loaded phase, based on the initial loading at the start of the recording. This exception is not permitted if a building contains a PV system or peak load shedding. ▶ Figure 120–44

Figure 120–44 Feeder and Service Load Calculations Existing Building 120.87(1) Ex



(2) Calculated Load. The calculated load for an existing building must be no less than 125 percent of the load determined by 120.87(1), plus the new loads, minus any removed loads as calculated in Article 120.

230.71(A) Feeders From Other Systems

Feeders that supply power from one system to another must be protected to prevent the flow of current from the lower voltage system to the higher voltage system, unless the feeder is supplied from a current-limiting source.

Key Points

- A feeder that connects two systems operating at different voltages must be protected against reverse power flow from the lower voltage system back to the higher voltage system.
- This protection is not required if the feeder is supplied from a current-limiting source.
- The intent is to protect personnel, equipment, and the higher voltage system from unexpected energization and damage due to reverse current.

Understanding the Requirement

When a feeder supplies power from a lower voltage system to a higher voltage system, there is a risk that power could flow backward if a fault or other condition occurs. This reverse power can endanger workers and damage equipment. To prevent this, the NEC® requires suitable protection unless the source is inherently current-limiting.

Examples of preventive measures include:

- Properly sized overcurrent protection on the feeder at the lower voltage side.
- Use of listed reverse power relays or directional overcurrent relays.
- Automatic reclosers or circuit breakers with reverse power blocking.
- Current-limiting fuses at the source, where applicable.

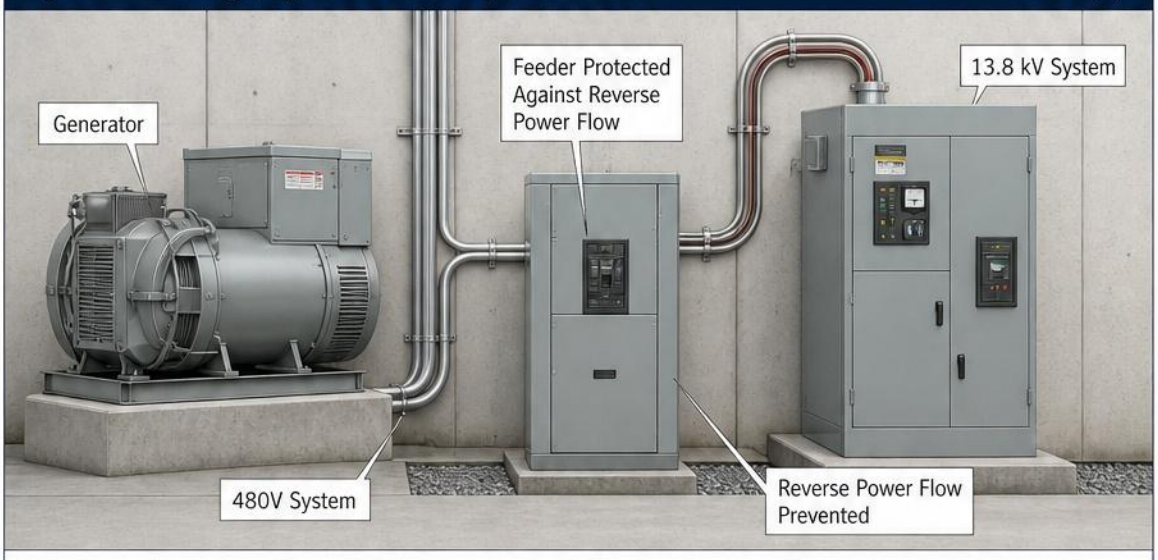
Application Examples

- **Generator Feeding Utility:** A generator operating at 480V feeds a 13.8 kV utility system. The feeder must be protected to prevent power from the utility backfeeding into the generator.
- **Solar Inverter to Medium Voltage:** An inverter at 480V supplies a medium-voltage network. Reverse power protection is required unless the inverter output is current-limited.
- **Battery System to Higher Voltage Bus:** A battery system at 600V DC feeds a 4160V DC bus. Reverse current protection is required to prevent current from the bus flowing back into the battery system.

Related Requirements

See also 230.71(B) for feeders employing current-limiting sources and 705.12(D) for interconnection of power production sources.

Figure 1 Feeder Supplying Power From One System to Another **230.71(A)**



A feeder supplying power from a 480V system to a 13.8 kV system is protected to prevent reverse current flow from the higher voltage system back into the lower voltage system, in accordance with 230.71(A).

ARTICLE 130 Energy Management Systems

Introduction to Article 130—Energy Management Systems

This article applies to the installation and operation of *energy management systems* (EMS). Energy management systems have become extremely popular and are used in electric vehicle supply equipment and anywhere load management is necessary. They adjust ampere settings, power monitoring devices for panelboards, lighting controls for building automation, load-shedding systems for an alternate power source, and so on.

Energy management ensures the electrical system does not overload a branch circuit, feeder, or service. It allows the electrical system to be sized based on the controlled or monitored current settings. Proper application of energy management systems may permit us to add additional loads to an existing installation without installing a larger service.

Energy Management System (EMS). A system that monitors and controls power within an electrical system.

Figure 130–1 Energy Management System (EMS) **130.1**

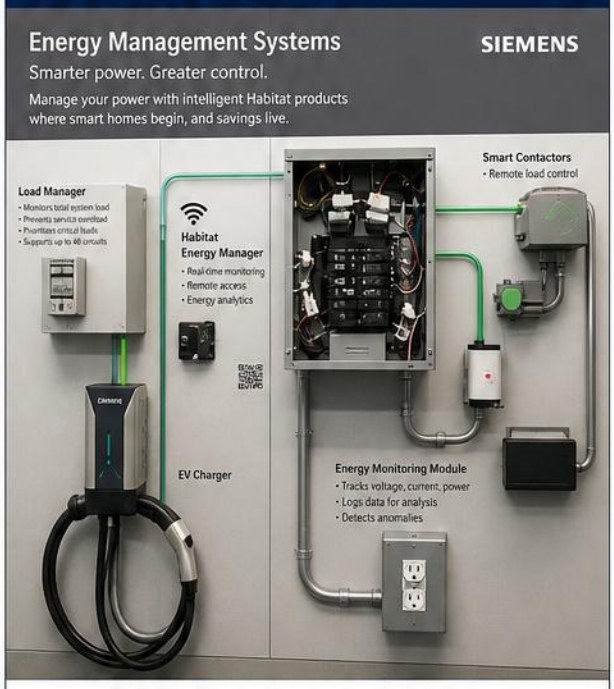
A system that monitors and controls power within an electrical system.

Part I. General

130.1 Scope

This article applies to the installation and operation of energy management systems.

Figure 130–2 Energy Management Systems **130.1**



Article 130 applies to the installation and operation of energy management systems.

130.2 Listing Requirements

Energy management systems (EMS) must be listed. Energy management systems that provide overload control must be listed and labeled as a *power control system*.

130.30 Load Management

Energy management systems are permitted to monitor and control electrical loads and sources in accordance with 130.30(A) through 130.30(C).

Load Management. The process within an energy management system that limits the total electrical load on an electrical supply system. This process sets a value by adjusting or controlling circuits supplying the load or individual loads.

(A) Load Shedding Controls. An energy management system is not permitted to override the load shedding controls put in place to ensure the minimum electrical capacity for the following:

(1) Fire pumps

(2) Emergency systems

(3) Legally required standby systems

(4) Critical operations power systems

(B) Disconnection of Power. An energy management system cannot disconnect power to the following:

(1) Elevators, escalators, moving walks, or stairway lift chairs

(2) Positive mechanical ventilation for hazardous (classified) locations

(3) Ventilation used to exhaust hazardous gas or reclassify an area

(4) Circuits supplying emergency lighting

(5) Essential electrical systems in health care facilities

(C) Capacity of Branch Circuit, Feeder, or Service. An energy management system cannot cause a branch circuit, feeder, or service to be overloaded.

Part II. Power Control Systems (PCS)

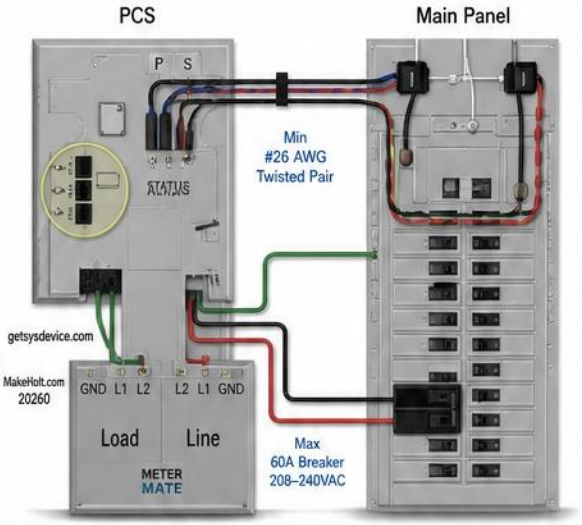
130.50 General

Part II contains the requirements for PCS of an energy management system. A PCS may control generation, energy storage, loads, circuit controllers, or other equipment to manage power. It may contain additional protective functions relative to EMS or grid interconnection functions.

Power Control System (PCS). Equipment that monitors and controls power to prevent overload of an electrical service, conductor, or power distribution equipment.

→ Figure 130–3

Figure 130–3 Power Control System (PCS) 130.50



Equipment that monitors and controls power to prevent overload of an electrical service, conductor, or power distribution equipment.

130.60 Conductors and Equipment

(A) Monitoring and Controls. The PCS must include monitoring and automatic controls to prevent the overload of conductors, power sources, and power distribution equipment associated with the PCS.

130.70 Settings

(A) Power Control System (PCS) Control Setting. The PCS control setting is considered a continuous load.

(B) Adjustable Settings. The adjustable settings for overload control must be set in accordance with its listing by a qualified person.

Qualified Person. A person with skills and knowledge related to the construction, operation, and installation of electrical equipment. This person must have received safety training to recognize and avoid the hazards involved with electrical systems.

Figure 130–4 Qualified Person **NEC 110.2(A)**

A person with skills and knowledge related to the construction, operation, and installation of electrical equipment. This person must have received safety training to recognize and avoid the hazards involved with electrical systems.

130.80 Marking and Documentation

(A) Marking. The power control system (PCS) must be field marked with the following:

(1) PCS control setting(s)

(2) Calculation date and identification of the qualified person determining the settings in other than one- and two-family dwellings

(3) Identification of loads and sources managed by the PCS

(4) The following or equivalent wording: "Circuits within this equipment are controlled by a power control system. The control settings shall only be changed by a qualified person"

The marking must be of sufficient durability to withstand the environment, cannot be handwritten, and must be permanently affixed to the equipment in accordance with 110.21(B). The marking must be located so they are clearly visible to qualified persons before examination, adjustment, or servicing of the equipment.

(B) Documentation. A list of the monitoring, control functions, and control equipment and associated settings that perform the overload control functions must be documented and readily available to qualified persons.

Note 1: Listed PCS may include specific hardware and software components that are detailed in the documentation included with the listing.

Note 2: A multisource PCS is rated for source control or source and load control. A single-source PCS is rated for load control only.

(C) Directory. Where the PCS is not within sight of the circuit overcurrent protective device, a label identifying the controlled device and associated circuits must be posted on the enclosure of the control device, disconnect, or branch-circuit overcurrent protective device.

ARTICLE 230
SERVICE

230.1 Scope

This article establishes the general requirements for conductors and equipment that deliver electric energy from the serving utility to the wiring system of the building or other structure.

230.2 Service-Entrance Conductors

Service-entrance conductors shall comply with 230.2(A) through (F).

(A) General. Service-entrance conductors must be sized in accordance with Article 310.

(B) Underground Installation. Service-entrance conductors installed underground shall comply with 230.2(B)(1) through (B)(5).

(1) Type. Underground conductors must be of the type USE or other listed types for direct burial.

(2) Depth of Cover. The conductors must be installed not less than 24 in. (600 mm) below grade.

(3) Protection. Where subject to physical damage, conductors must be installed in a raceway.

(4) Maximum Number of Bends. The conductors shall not have more than two bends between pull points.

(5) Other Uses. Conductors installed under a building or other structure in accordance with this section shall not be considered as underground branch circuits or feeders.

230.3 Service Equipment

Service equipment shall comply with 230.3(A) through (F).

(A) General. Service equipment shall be located as close as practical to the point of entrance of the service-entrance conductors.

(B) Location on or Attached to the Building. Service equipment shall be located on the outside of the building or other structure, or in other approved locations.

(C) Location Not Subject to Physical Damage. Service equipment shall be located or protected so that it is not subject to physical damage.

(D) Accessibility. Service equipment shall be readily accessible.

(E) Marking. Service equipment shall be durably marked to indicate its voltage, and to identify its purpose, unless the purpose is evident.

(F) Disconnecting Means. Service equipment shall be provided with a disconnecting means as required in 230.85.

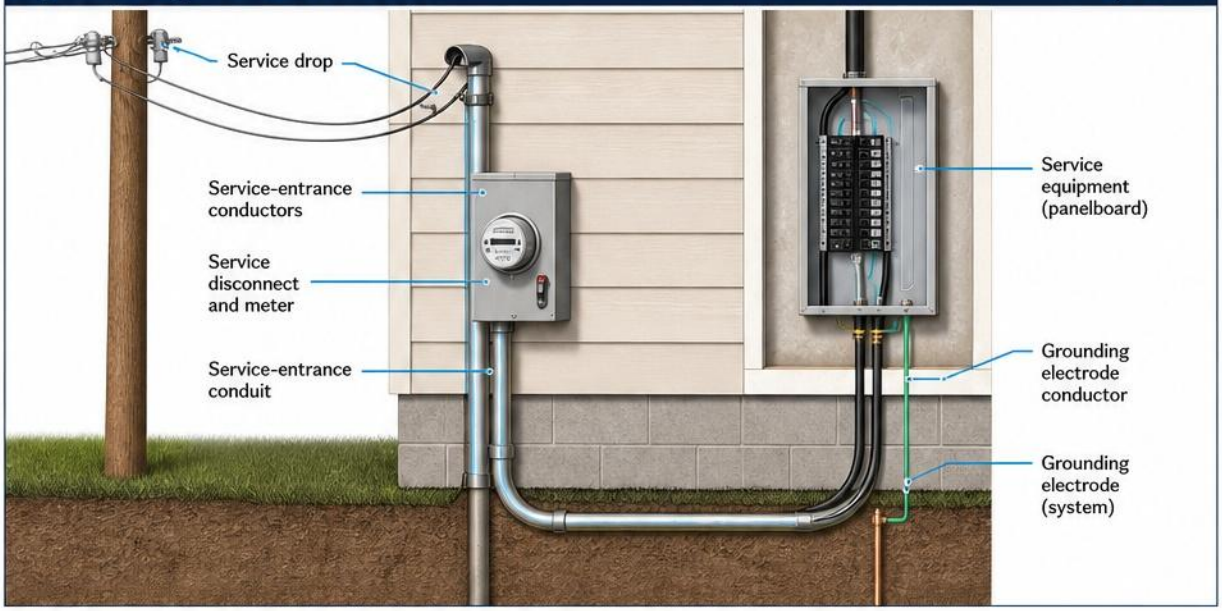
230.4 Service Identification

Service equipment, enclosures, and disconnecting means shall be legibly marked to show the available fault current from the serving utility in accordance with 230.4(A) and (B).

(A) Marking. The information shall be field marked by means of durable labels, tags, or other approved means.

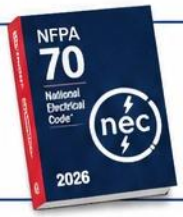
(B) Marking Locations. The marking shall be located at the service equipment, at the service point, and at each service disconnecting means.

Figure 230.1 Typical Service Installation 230.2, 230.3



A typical overhead service installation showing the service drop, service-entrance conductors, service disconnect and meter, service equipment (panelboard), and grounding electrode system.

CHAPTER 1 REVIEW QUESTIONS



Please use the 2026 *Code* book to answer the following questions.

1. An arc-fault circuit interrupter provides protection from the effects of arc-faults by recognizing unique characteristics associated with _____.

(a) overcurrent conditions
(b) arcing faults
(c) ground faults
(d) harmonic distortion

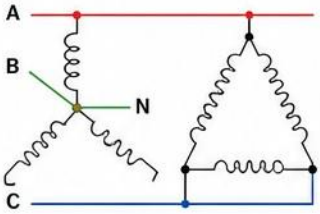
2. A component of the effective ground-fault current path that is the connection between the grounded circuit conductor and the supply-side bonding conductor or equipment grounding conductor of a _____ is the definition of a system bonding jumper.

(a) service disconnect
(b) separately derived system
(c) motor control center
(d) separate building disconnect

3. A location protected from weather and not subject to saturation with water or other liquids, but subject to moderate degrees of moisture defines a _____.

(a) dry location
(b) damp location
(c) wet location
(d) moist location

4. The _____ is the definition of neutral point.



(a) common point on a wye-connection in a polyphase system
(b) midpoint on a single-phase, 3-wire system
(c) midpoint of a single-phase portion of a 3-phase delta system
(d) any of these

5. A transformer is defined as equipment, either _____, that uses electromagnetic induction to convert current and voltage.

(a) single-phase or polyphase
(b) indoor or outdoor
(c) utility or consumer owned
(d) high- or low-voltage

6. The conductors and equipment permitted by the *NEC* shall be acceptable only if _____ by the authority having jurisdiction.

(a) labeled
(b) listed
(c) approved
(d) identified

7. Equipment intended to interrupt current at fault levels shall have an _____ at nominal circuit voltage at least equal to the available fault current at the line terminals of the equipment.

(a) interrupting rating
(b) overcurrent rating
(c) overload rating
(d) incident energy

8. Electrical equipment shall be installed _____.

(a) in a professional manner
(b) under the supervision of a licensed person
(c) in a skillful manner
(d) in a professional and skillful manner

9. Unused opernings shall be sealed to the wall of the equipment.

(a) taped over with electrical tape
(b) repaired by welding or brazing
(c) closed to afford protection substantially equivalent
(d) any of these

Figure 9 Seal Unused Openings — NEC 110.12

10. Internal parts of electrical equipment shall not be damaged or contaminated by foreign materials such as _____.

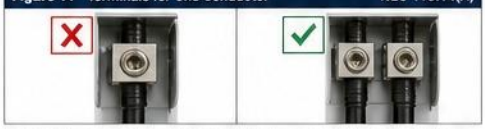
(a) paint, plaster
(b) cleaners
(c) abrasives
(d) any of these

Figure 10 Protect From Foreign Materials — NEC 110.12

11. Terminals are only suitable for one conductor unless the terminal is _____ for more than one conductor.

(a) labeled
(b) identified
(c) marked
(d) listed

Figure 11 Terminals for One Conductor — NEC 110.14(A)



12. Tightening torque values for terminal connections shall be as indicated on equipment or instructions and a(an) _____ means shall be used to achieve the indicated torque value.

(a) approved
(b) identified
(c) recognized
(d) standard

Figure 12 Tighten to Specified Torque — NEC 110.14(D)

13. Examples of approved means of achieving the indicated _____ values include torque tools or devices such as shear bolts or breakaway-style devices that demonstrate the proper torque has been applied.

(a) pressure
(b) torque
(c) tightening
(d) tension

Figure 13 Approved Torque Means — NEC 110.14(D)

14. Caution, warning, or danger hazard markings such as labels or signs shall be of sufficient durability to withstand the environment and warn of these hazards using effective _____.

(a) words
(b) colors
(c) symbols
(d) any combination of words, colors, or symbols

Figure 14 Durable Hazard Markings — NEC 110.21(B)

15. Caution, warning, or danger hazard markings such as labels or signs shall be permanently affixed to the equipment and shall not be _____.

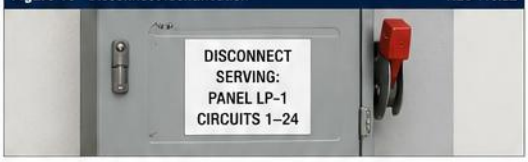
(a) handwritten
(b) engraved
(c) printed
(d) typed

Figure 15 Permanent Markings — NEC 110.21(C)

16. Each disconnecting means in other than one- or two-family dwellings shall be legibly marked to indicate its purpose and branch circuit source, unless the purpose and branch circuit source is _____.

(a) locked out and tagged
(b) not readily accessible
(c) evident
(d) less than 300 volts-to-ground

Figure 16 Disconnect Identification — NEC 110.22



17. The value of available fault current for use in determining appropriate minimum short-circuit current and interrupting ratings of service equipment is available from _____.

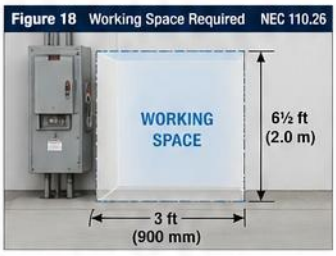
(a) the architect
(b) the engineer
(c) electric utilities
(d) the inspector

Figure 17 Available Fault Current Source — NEC 110.24

18. Working space is required for equipment operating at 1000V, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while _____.

(a) in use
(b) grounded
(c) operating
(d) energized

Figure 18 Working Space Required — NEC 110.26



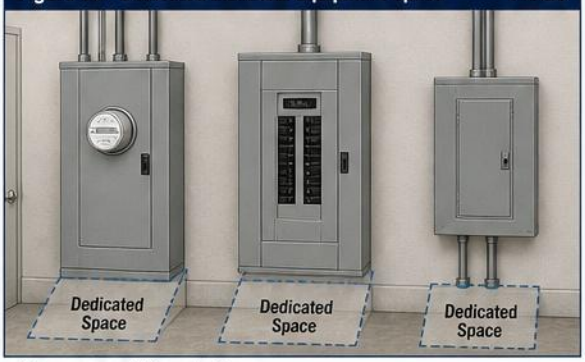
19. The required working space in front of equipment operating at 300V to ground, where there are enclosed live parts on one side and grounded parts on the other side, is _____.

(a) 3 ft
(b) 3½ ft
(c) 4 ft
(d) 4½ ft

Figure 19 Increased Working Space — NEC 110.26(A)(1)

20. Service equipment, switchboards, and enclosed panelboards shall have dedicated electrical equipment space and be _____.

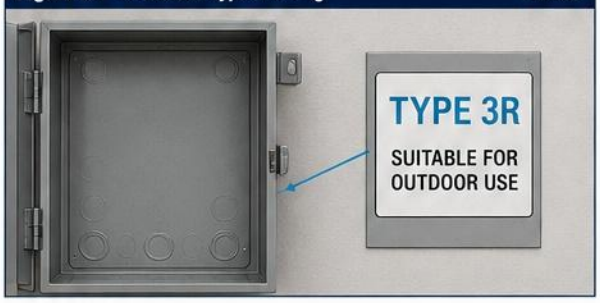
Figure 20 Dedicated Electrical Equipment Space 110.26



(a) protected from leakage
(b) protected from spillage
(c) protected from corrosion
(d) protected from damage

21. Enclosures shall be marked with an enclosure-type number and be suitable for the location in accordance with Table _____.

Figure 21 Enclosure Type Marking 110.26



(a) 110.26
(b) 110.28
(c) 110.31
(d) Annex C, Table C.1

22. The branch circuit load for outlets supplying luminaires shall be calculated not less than the maximum _____ rating of the equipment.

Figure 22 Luminaires Outlet Load 210.19(A)

(a) power
(b) true power
(c) voltage
(d) volt-ampere

23. Feeder and service loads for fixed electric space-heating loads shall be calculated at _____ of the total connected load.

Figure 23 Electric Space-Heating Load 220.60

(a) 75 percent
(b) 100 percent
(c) 115 percent
(d) 150 percent

24. For standard method dwelling unit load calculations, a demand factor of 75 percent of the total nameplate ratings can be applied if there are _____ or more appliances fastened in place.

Figure 24 Fastened-in-Place Appliances 220.53

(a) two
(b) three
(c) four
(d) five

25. For standard method dwelling unit calculations, the load for electric clothes dryers shall be nameplate rating or _____, whichever is larger, for each dryer served.

Figure 25 Electric Clothes Dryer 220.54

(a) 1500W
(b) 4500W
(c) 5000W
(d) 8000W

Notes

Article 100 Definitions

The NEC® uses precise terminology to ensure a common understanding of electrical concepts. Article 100 contains definitions of technical terms used throughout the Code.

Key Points

- Definitions in Article 100 are mandatory and apply throughout the NEC.
- Definitions are written in present tense and apply to both the singular and plural.
- When a term is defined in Article 100, that definition governs its use in the Code.

Article 110 Requirements for Electrical Installations

Article 110 sets forth general requirements that apply to all electrical installations unless modified by other articles in the Code.

110.1 Scope

These requirements cover the installation, alteration, and repair of electrical equipment and wiring in accordance with this Code.

110.2 Approval

Electrical equipment and materials shall be approved. Approval shall be in accordance with 110.2(A) through (D).

110.3 Installation and Use

Electrical equipment shall be installed and used in a neat and workmanlike manner.

110.4 Electrical Connections

Connections shall be clearly identifiable and accessible for inspection, operation, and maintenance.

110.5 Mechanical Execution of Work

Work shall be performed in a manner that assures the intended mechanical strength, durability, and reliable operation.

Article 210 Branch Circuits

Article 210 covers branch circuit requirements, including their conductors, ratings, overcurrent protection, and the number of outlets permitted on a circuit.

210.8 Ground-Fault Circuit-Interrupter Protection

Ground-fault circuit-interrupter (GFCI) protection is required for receptacles in specific locations as listed in 210.8(A) through (F).

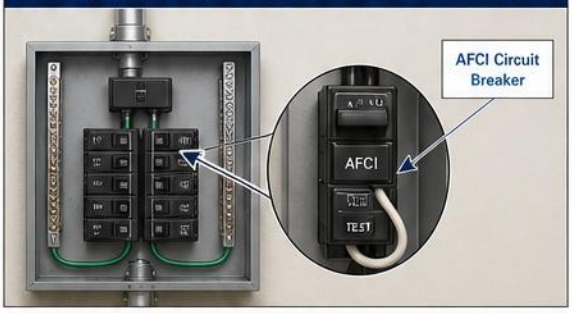
Figure 210.8(A)(1) Dwelling Unit Bathrooms **210.8(A)(1)**

GFCI protection is required for receptacles in bathrooms.

210.12 Arc-Fault Circuit-Interrupter Protection

Arc-fault circuit-interrupter (AFCI) protection is required for branch circuits supplying 120-volt, single-phase, 15- and 20-ampere outlets in dwelling units as specified in 210.12(A) through (C).

Figure 210.12 AFCI Protection for Dwelling Units **210.12**



AFCI protection is required for specified branch circuits in dwelling units.

Figure 250.32(A) Equipment Grounding Conductor **250.32(A)**

An equipment grounding conductor (EGC) provides a low-impedance path for fault current to facilitate operation of overcurrent devices.

CHAPTER

2 WIRING AND PROTECTION

INTRODUCTION TO CHAPTER 2—WIRING AND PROTECTION

Chapter 2 of the National Electrical Code® establishes requirements for the installation and protection of electrical wiring systems. The articles in this chapter address the proper identification of conductors, the conditions for installation and protection of circuits, and the methods used to safeguard people and property from electrical hazards.

Article 200—Use and Identification of the Grounded Conductors — Article 200

This article specifies the requirements for the use and identification of the grounded conductor, which in most cases is the neutral conductor.

Article 210—Branch Circuits — Article 210

This article contains the requirements for the installation, sizing, and protection of branch-circuit conductors between the final overcurrent protective device and the receptacle outlets, lighting outlets, or other outlets.

Article 225—Outside Branch Circuits and Feeders — Article 225

This article contains the requirements for outside overhead and underground wiring methods.

Article 240—Overcurrent Protection — Article 240

This article contains the requirements for overcurrent protection and ovdercurrent protective devices of conductors and equipment to protect against overload, short circuit, or ground fault.

Article 250—Grounding and Bonding — Article 250

This article covers the general requirements for bonding and grounding electrical installations. The terminology used in this article has been a source of much confusion over the years, so pay careful attention to the definitions (for example the term *ground*) pertaining to Article 250. Understanding the difference between bonding and grounding of electrical systems and equipment will help you correctly apply the provisions of this article.

Article 206—Non-Power-Limited Remote-Control and Signaling Circuits — Article 206

This article covers nonpower remote-control and signaling circuits that are not power-limited.

Article 215—Feeders — Article 215

This article contains the requirements for the installation, sizing, and protection of feeder conductors between the service disconnect, separately derived system, or other power supply, and the final branch-circuit overcurrent protective device.

Article 230—Services — Article 230

This article contains the requirements for the installation of service conductors and service equipment connecting the serving electric utility to the premises wiring system.

Article 242—Overvoltage Protection — Article 242

This article contains the requirements for the installation and connection of overvoltage surge-protective devices (SPD) to limit transient overvoltages. This is done by diverting or limiting surge current, which prevents its continued flow while remaining capable of repeating these functions.

Article 240 — Overcurrent Protection

General

Article 240 provides requirements for overcurrent protection of conductors and equipment to protect against damage due to excessive current.

Purpose

Overcurrent devices are intended to prevent the insulation of conductors from overheating, which can cause short circuits, fires, and equipment damage. They also help reduce hazards to people.

Types of Overcurrent Protection

Overcurrent protection is provided by fuses or *inverse time* circuit breakers. Fuses are one-shot devices that must be replaced after operation. Circuit breakers can be reset after they trip.

240.3 General

All conductors likely to be energized shall be protected against overcurrent in accordance with this article.

240.4 Overcurrent Protection of Equipment

Each piece of equipment shall be protected in accordance with its listing or labeling and this article.

240.6 Size of Overcurrent Protection

The overcurrent device shall not be rated higher than the ampacity of the conductors it protects, except as permitted in this article.

240.21 Branch Circuits

Branch-circuit conductors shall have an overcurrent device rated not higher than the ampacity of the conductors in accordance with 240.4(D), 240.4(E), and 240.4(G).

240.22 Feeder Circuits

Feeder conductors shall be protected by overcurrent devices in accordance with 240.4(B), 240.4(C), and 240.4(G).

240.24 Building or Other Structures

The service-entrance conductors and feeders shall be protected by overcurrent devices in accordance with 240.4(B), 240.4(C), 240.4(D), 240.4(E), and 240.4(G).

240.67 Selective Coordination

Where required or permitted by Chapter 2, selective coordination shall be provided in accordance with 240.67.

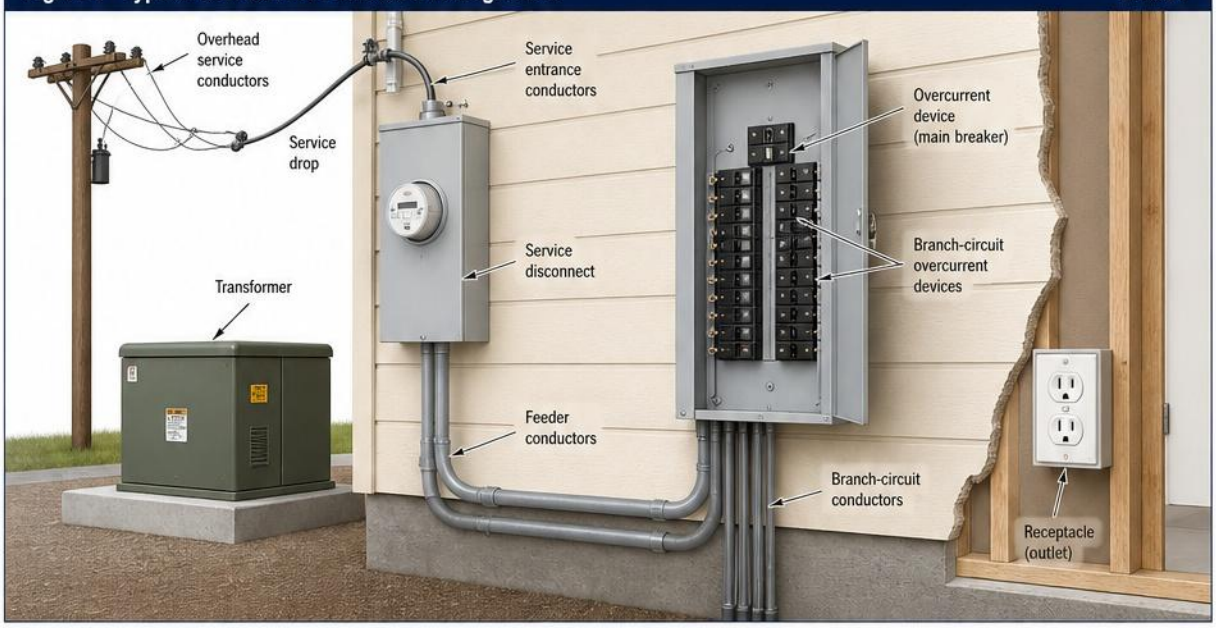
240.81 Surge Protection

Where surge arresters or surge protective devices are installed, they shall be installed in accordance with 240.81.

240.87 Arc-Fault Circuit Interrupter Protection

Arc-fault circuit-interrupter protection shall be provided in accordance with 240.87.

Figure 1 Typical Overcurrent Protection Arrangement **240.24**



Overcurrent protection devices are installed to protect conductors and equipment from damage caused by excessive current conditions such as overloads and short circuits.

ARTICLE 200

Use and Identification of Grounded Conductors

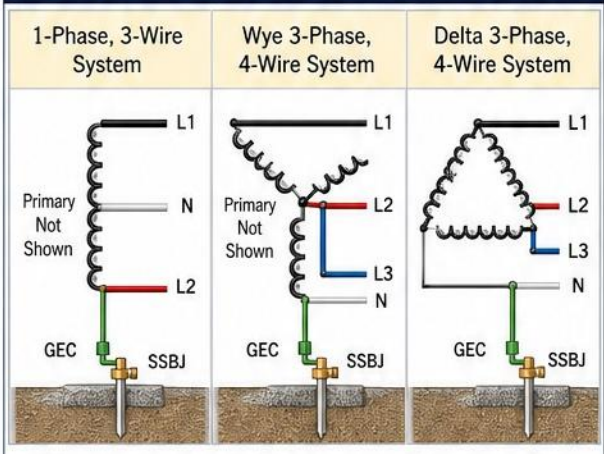
INTRODUCTION TO ARTICLE 200—USE AND IDENTIFICATION OF GROUNDED CONDUCTORS

Article 200 contains the requirements for the use and identification of grounded conductors. If the grounded conductor is connected to the neutral point of an electrical system, then it is referred to as the neutral conductor. Some electrical systems do not have a neutral conductor. For example, in a 3-phase, corner-grounded delta system, the grounded conductor is not a neutral conductor because it is not connected to a system neutral point. Whether it is referred to as the "grounded" conductor or as the "neutral" conductor, the white or gray marking on a circuit conductor indicates that it is a grounded conductor.

Grounded Conductor. The system conductor that is intentionally connected to the earth (ground).

▸ Figure 200–1

Figure 200–1 Grounded Conductor *NEC 200*

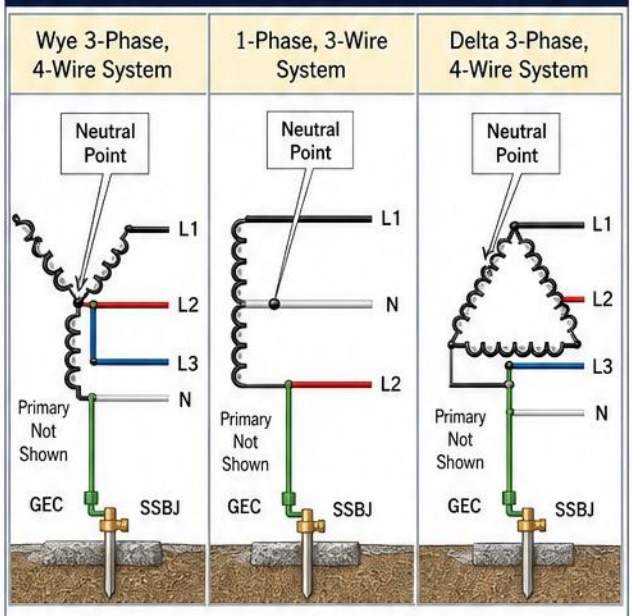


The system conductor that is intentionally connected to the earth (ground).

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

▸ Figure 200–2

Figure 200–2 Neutral Conductor *NEC 100 Definition*

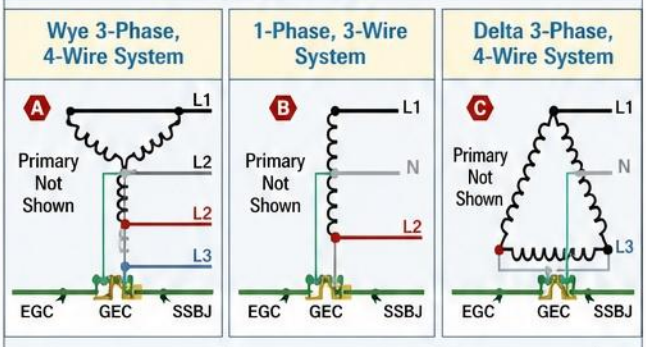


The conductor connected to the neutral point of a system intended to carry current under normal conditions.

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 200–3

Figure 200-3 Neutral Point *Article 100 Definition* **100.2**



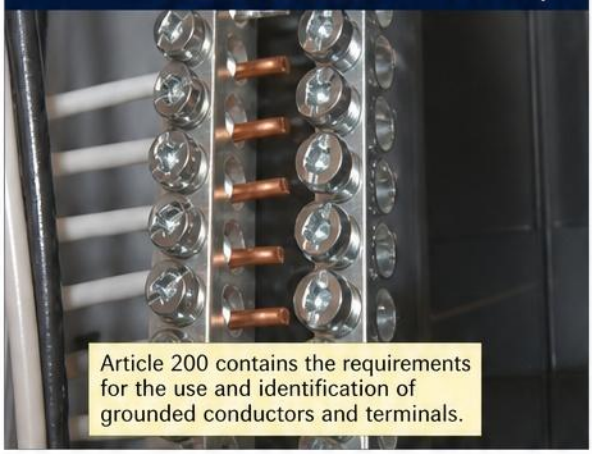
A – Common point of a wye 3-ph, 4-wire system.
B – Midpoint of a 1-ph, 3-wire system.
C – Midpoint of one phase of a delta 3-ph, 4-wire system.

The neutral point is the common node in various system configurations as defined in Article 100.

200.1 Scope

This section specifies the rules for using and marking grounded conductors and their connection points.

Figure 200-4 Use and Identification of Grounded Conductors **200.1 Scope**



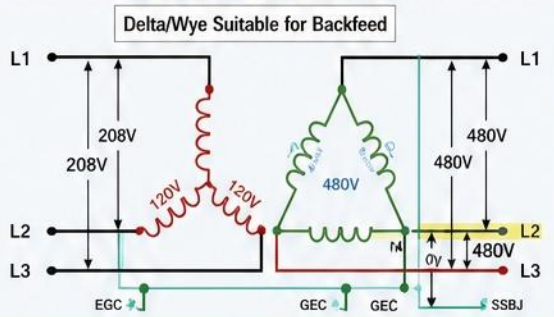
Article 200 addresses the proper use and labeling of grounded conductors and their terminals.

Author's Comment:

In a corner-grounded delta system, a bonding jumper is installed between one of the phase conductors to the transformer case (usually from the B-phase). This grounded-phase conductor acts as a grounded conductor, not a neutral conductor, since there is no neutral point in corner-grounded delta systems. When installing corner-grounded delta systems consider the following: **Figure 200-5**

- The voltage from the grounded-phase conductor to the transformer case will be 0V.
- The voltage between any two ungrounded conductors will be equal to the line-to-line voltage.
- The grounded-phase conductors must be identified in accordance with 200.7.
- The grounded-phase conductor can terminate to the neutral bus or terminal of a panelboard. It can also be terminated to an overcurrent protective device that opens all circuit conductors simultaneously in accordance with 240.22.

Figure 200-5 *Corner Grounded Delta System Grounded-Phase Conductor* **200.1 Comment**



When installing corner-grounded delta systems consider the following:
- The voltage from the grounded-phase conductor to the transformer case will be 0V.
- The voltage between any two ungrounded conductors will be equal to the line-to-line voltage.
- The grounded-phase conductors must be identified in accordance with 200.7.
- The grounded-phase conductor can terminate to the panelboard neutral terminal or to an overcurrent protective device per 240.22.

Key considerations for corner-grounded delta systems and the grounded-phase conductor.

200.4 General

(B) Continuity. The continuity of the neutral conductor is not permitted to be dependent on the metal of enclosures, raceways, or cable armor.

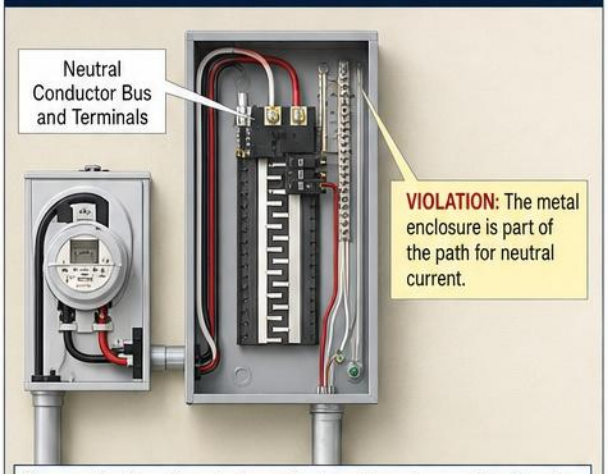
CAUTION: If the neutral conductor is connected at the equipment grounding terminal bar instead of the neutral terminal bar, neutral current will be present on the metal cabinet or enclosure.

200.6 Neutral Conductor

Neutral conductors must comply with the following:

(A) Installation. A neutral conductor cannot be used for more than one branch circuit. **Figure 200-7**

Figure 200–6 Continuity of Neutral Conductor 200.4(B)



The continuity of neutral conductors is not permitted to be dependent on the metal of enclosures, raceways, or cable armor.

Figure 200–7 Neutral Conductor Installation More than One Circuit 200.6(A)

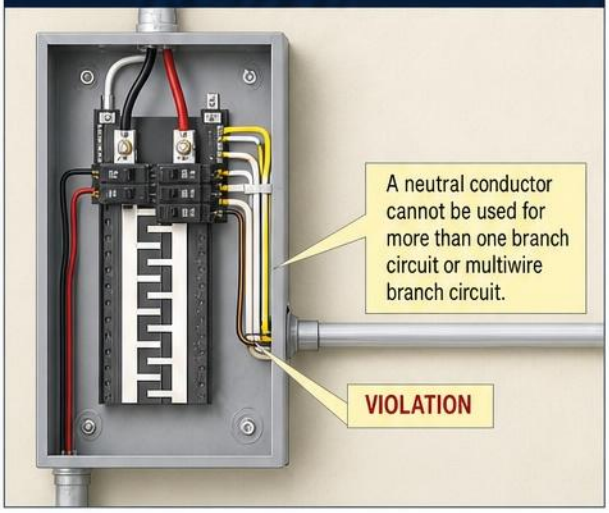


Figure 200–8 Neutral Conductor, Multiple Circuits Identified by Grouping 200.6(B)

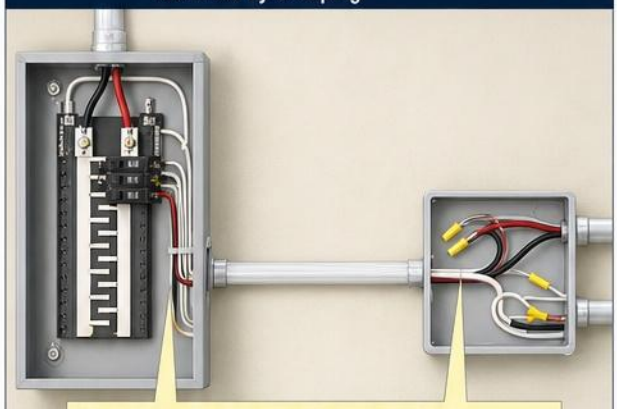
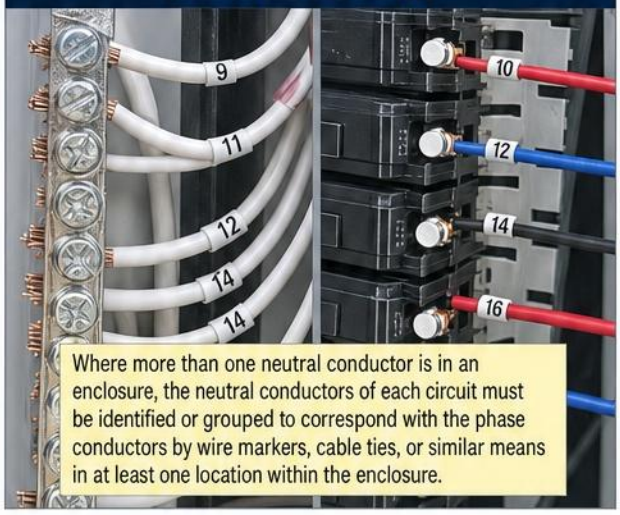


Figure 200–9 Neutral Conductor, Multiple Circuits Identified with Wire Markers 200.6(B)



(B) Multiple Circuits. Where more than one neutral conductor is in an enclosure, the neutral conductors of each circuit must be identified or grouped to correspond with the phase conductors by wire markers, cable ties, or similar means in at least one location within the enclosure. Figure 200–8 and Figure 200–9

Ex 1: Grouping of neutral conductors with its corresponding phase conductors is not required where the circuit conductors are contained in a single raceway or cable unique to that circuit, making the grouping obvious.

Ex 2: Grouping of neutral conductors with its corresponding phase conductors is not required if the circuit conductors pass through a box without any splices or terminations.

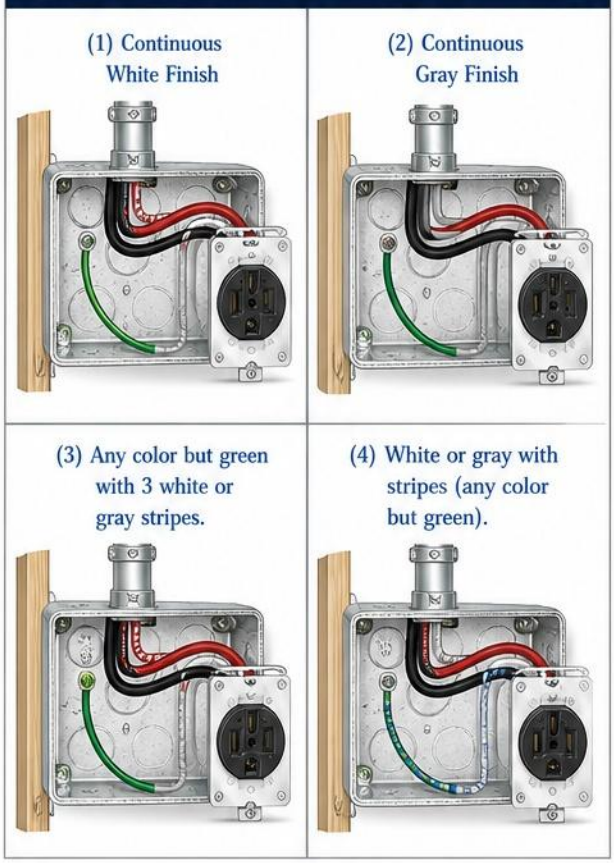
Author's Comment:

- Grouping all conductors associated with a circuit using cable ties or other means within the point of origination makes it easier to visually identify conductors of individual branch circuits.
- Grouping of circuit conductors assists in ensuring the correct neutral conductor is paired with the intended phase conductors at junction and splice points—particularly when connecting multiwire branch-circuit conductors to circuit breakers [210.4(D)].

200.7 Identification of Grounded Conductors

(A) 6 AWG or Smaller. The insulation of neutral and grounded-phase conductors 6 AWG and smaller must be identified by any of the following means: ▶ Figure 200–10

Figure 200–10 Neutral Conductor Identification 200.7(A)



(1) A neutral conductor with a continuous white outer finish

(2) A neutral conductor with a continuous gray outer finish

(3) A conductor of any color other than green that has three continuous white or gray stripes along its entire length

(4) A white or gray conductor whose outer covering includes colored tracer threads woven into the braid to identify the source of manufacture

(9) For conductors with a continuous white or gray outer finish, a single-colored stripe of a color other than green on other than green insulated conductor ▶ Figure 200–11

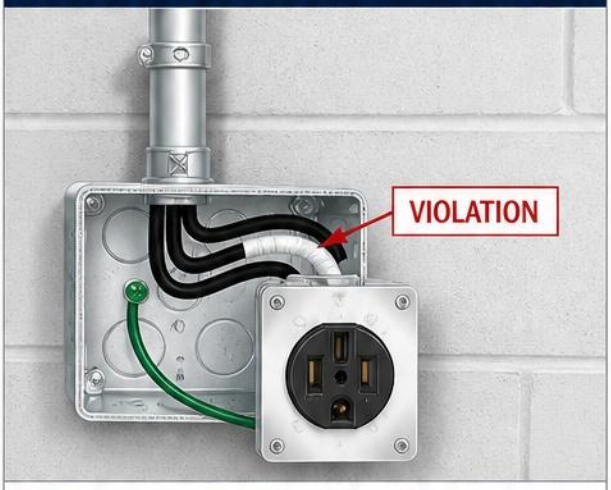
Author's Comment:

▶ Using white tape, paint, or other identification methods is not permitted for the insulation of neutral and grounded-phase conductors (6 AWG and smaller). ▶ Figure 200–12

Figure 200–11 Neutral Conductor Identification 200.7(A)(9)

Neutral conductors with a continuous white or gray outer finish may be identified by a single-colored stripe of any color other than green.

Figure 200–12 Neutral Conductor Identification 200.7(A) Comment



Applying white tape, paint, or other identification methods is not allowed for insulated neutral conductors that are 6 AWG and smaller.

(B) 4 AWG or Larger. Insulated neutral and grounded-phase conductors 4 AWG or larger must be identified by any of the following means: ▶ Figure 200–13 and ▶ Figure 200–14

(1) A neutral conductor with a continuous white outer finish along the conductor's length

(2) A neutral conductor with a continuous gray outer finish along the conductor's length

(3) A conductor with three continuous white or gray stripes along the conductor's entire length on other than green insulation

Figure 200–13 Neutral Conductor Identification 4 AWG or Larger 200.7(B)

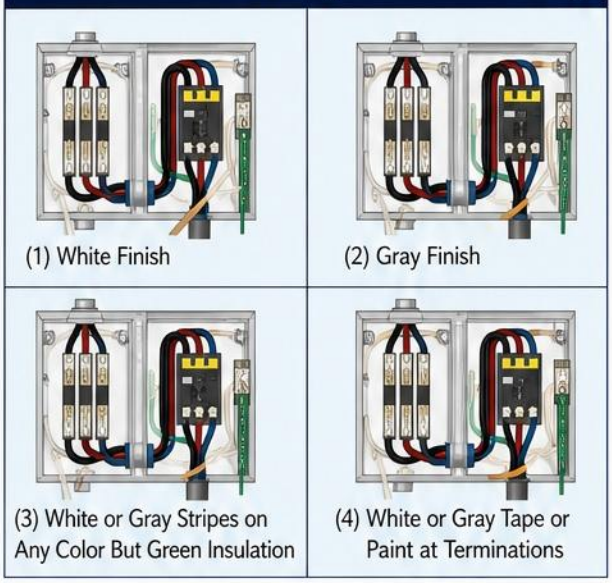
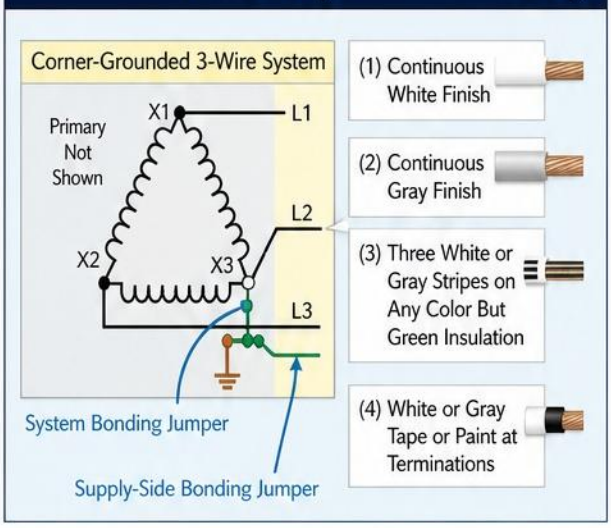


Figure 200–14 Grounded-Phase Conductor Identification 4 AWG or Larger 200.7(B)



(4) White or gray marking encircling the conductor's insulation at the conductor terminations as determined by the AHJ Figure 200–15.

(D) NEUTRAL CONDUCTORS OF DIFFERENT NOMINAL VOLTAGE SYSTEMS

When neutral conductors of different nominal voltage systems are installed in the same raceway, cable, or enclosure, each nominal voltage system neutral conductor must be identified in accordance with the following:

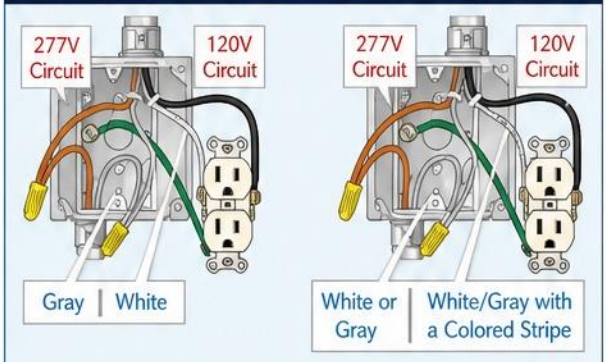
(1) One neutral conductor of a nominal voltage system must have a continuous white or gray outer finish along its entire length in accordance with 200.7(A) and (B)

Figure 200–15 Neutral Conductor Identification 4 AWG or Larger 200.7(B)(4)

An insulated neutral conductor 4 AWG or larger can be identified with white or gray marking encircling the conductor's insulation at the conductor terminations.

(2) The neutral conductor of the other nominal voltage systems must have an outer covering of white or gray along its entire length in accordance with 200.7(A) and (B), or have an outer covering of white or gray with a readily distinguishable color stripe (other than green) along its entire length Figure 200–16.

Figure 200–16 Neutral Conductor Identification Different Nominal Voltage Systems 200.7(D)



Neutral conductors of different nominal voltage systems installed in the same raceway, cable, or enclosure must be identified in accordance with 200.7(A) or (B).

(3) Other identification allowed by 200.7(A) or (B) that will distinguish each nominal voltage system neutral conductor

Author's Comment:

- The requirement to identify the neutrals by nominal voltage system only applies where there are neutrals from more than one nominal voltage system in a raceway, cable, or enclosure.

(E) Neutral Conductors in Multiconductor Cables.

Example 1: Neutral conductors contained within multiconductor cables are allowed to be reidentified at their terminations during installation by means of a distinctive white or gray marking, regardless of the conductor's size.

200.8 Use of White or Gray Color

(A) General. The following may be used solely for the neutral or grounded-phase conductor, except as permitted in 200.8(C):

(1) A conductor with a continuous white or gray outer covering

(2) A conductor with three continuous white or gray stripes

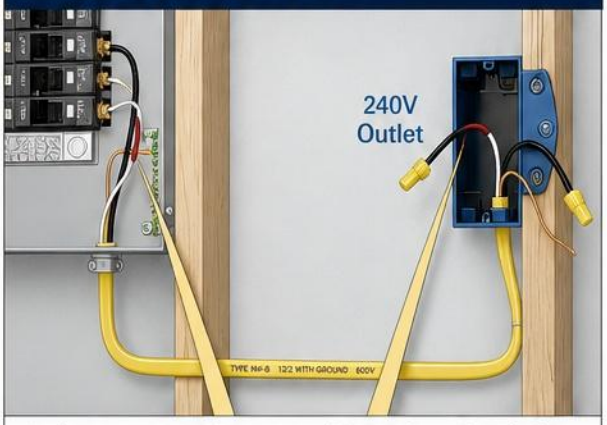
(3) Marking of a white or gray color at the termination

(C) Reidentification of White or Gray Conductor in Cables.

(1) Cable Assembly.

(a) Method. A white or gray conductor in a cable may be reidentified as a phase conductor by means of marking tape, paint, or other effective means (in a color other than green) applied at the terminations where the conductor is visible. See Figure 200–17.

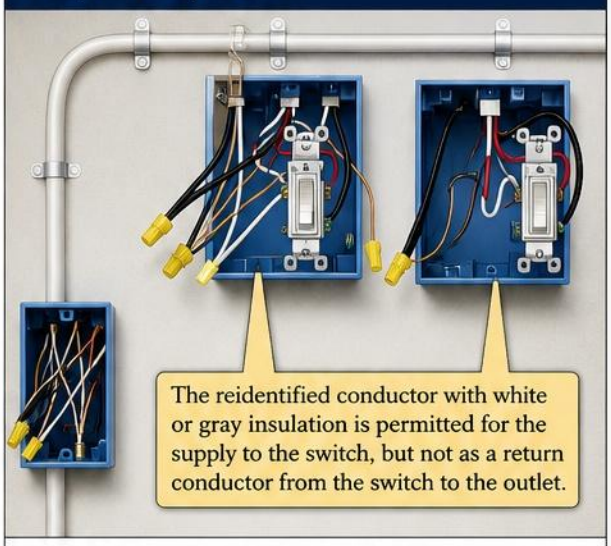
Figure 200–17 200.8(C)(1)(a)
White/Grey Conductor Use, in Cable Reidentification as Phase Conductor



A white or gray conductor in a cable may be reidentified as a phase conductor by means of marking tape, paint, or other effective means other than green at the termination where the conductor is visible.

(b) Single-Pole, 3-Way, and 4-Way Switches. For single-pole, 3-way, and 4-way switch loops, the reidentified conductor with white or gray insulation is permitted for the supply to the switch. It is not permitted for use as a return conductor from the switch to the outlet. See Figure 200–18.

Figure 200–18 200.8(C)(1)(b)
White/Grey Conductor Use in Cable 3-Way and 4-Way Switches



The white or gray conductor may be reidentified for the feed to the switch but cannot be used as the switched return from the switch to the outlet.

Author's Comment:

- The *NEC* does not permit the use of white or gray conductor insulation for phase conductors within a raceway—even if they are permanently reidentified. See Figure 200–19.

Figure 200–19 200.8(C)(1) Comment
White/Grey Conductor Use in Raceway Not Permitted as Phase Conductor

White or gray conductor insulation may not be used for phase conductors in a raceway, even if permanently reidentified.

200.10 Receptacle and Screw Shell Terminal

(B) Receptacles. Receptacles are required to have the neutral terminal identified by:

Figure 200–20.

Figure 200–20 Identification of Neutral Terminal on Receptacle **200.10(B)**

The neutral terminal is identified by the word "WHITE WIRE" molded into the device.

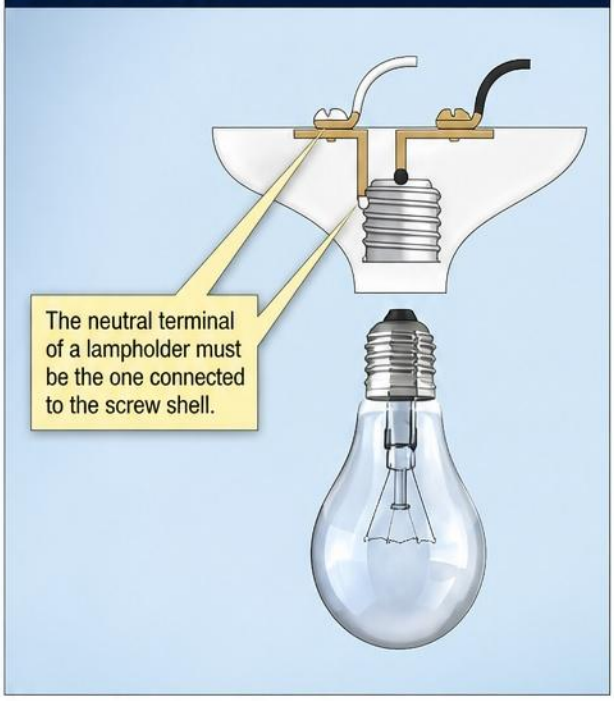
(1) A metal terminal or a terminal with a metal coating that is either white or silver and that is marked with the word "white" or the letter "W".

(2) If the terminal is not visible, the entrance hole for the conductor must be marked with the word "white" or the letter "W".

(C) Screw Shell. For devices with screw shells, the neutral terminal for the neutral conductor must be the one connected to the screw shell [410.90].

Figure 200–21.

Figure 200–21 Identification of Neutral Terminal on Screw Shell **200.10(C)**



The screw shell of the lampholder is the neutral terminal connection for the neutral conductor.

Notes

Article 250 — Grounds and Bonding

General. The purpose of Article 250 is to ensure effective protection of persons and property from electrical hazards by providing a low-impedance ground-fault current path.

GFCIs. Ground-fault circuit interrupters are required for specific personnel-protection applications in Article 210.

Equipment Grounding Conductor (EGC). An EGC is required in every branch circuit (250.118) and must be sized according to 250.122 based on the rating or setting of the overcurrent device.

Bonding vs. Grounding. Bonding connects metal parts together to ensure they remain at the same electrical potential. Grounding connects the electrical system to earth to stabilize voltage and facilitate the clearing of faults.

Service Equipment. The neutral conductor must be bonded to the equipment grounding conductor at the service disconnecting means only (250.24(A)(1)). Downstream from the service, the neutral and grounding conductors must be isolated from each other.

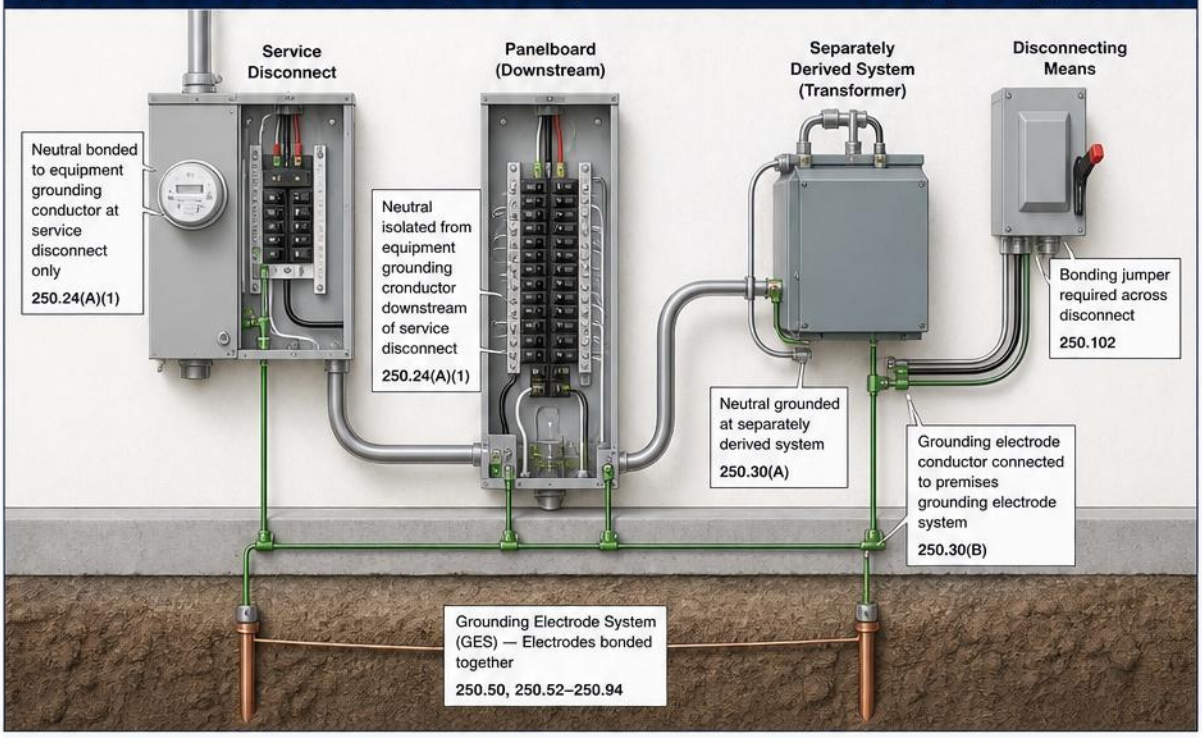
Grounding Electrode System. The grounding electrode system (GES) connects the electrical system to the earth. It must be installed in accordance with 250.50 and 250.52 through 250.94. Only one GES is required for a premises, and all electrodes must be bonded together.

Separately Derived Systems. Systems supplied by a separately derived source, such as a transformer, must have the neutral grounded (250.30(A)). The grounding electrode conductor from the derived system must be connected to the premises grounding electrode system (250.30(B)).

Equipment Bonding. All non–current-carrying metal parts of equipment, raceways, and metal enclosures must be bonded together (250.4(A)(1)), ensuring that fault current can return to the source on an effective path.

Bonding Jumpers. Bonding jumpers are required across service raceways, enclosures, disconnects, and other equipment likely to become energized (250.102).

Figure 250–1 Service Equipment, Grounding, and Bonding — 250.24(A), 250.30(A)(B), 250.50



The neutral is bonded to the equipment grounding conductor at the service only. All non–current-carrying metal parts are bonded, and the grounding electrode system connects the electrical system to the earth.

ARTICLE 206 Non-Power-Limited Remote-Control and Signaling Circuits

Introduction to Article 206—Non-Power-Limited Remote-Control and Signaling Circuits

Many remote-control and signaling circuits obtain their power from power-limited sources, but there are also remote-control and signaling circuits that are supplied by non-power-limited sources. This article sets out the rules for installing non-power-limited remote-control and signaling circuits.

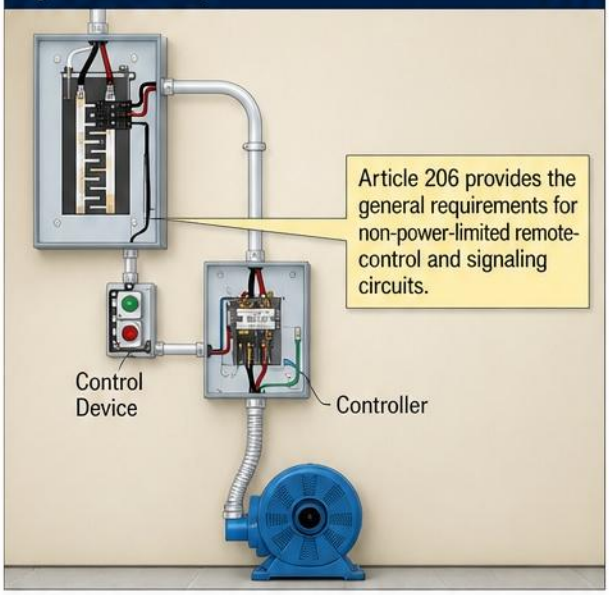
Remote-Control Circuit. An electrical circuit that controls any other circuit through a relay or an equivalent device.

206.1 Scope

This article specifies the general requirements for non-power-limited remote-control and signaling circuits.

▶ Figure 206–1.

Figure 206–1 Scope **206.1**

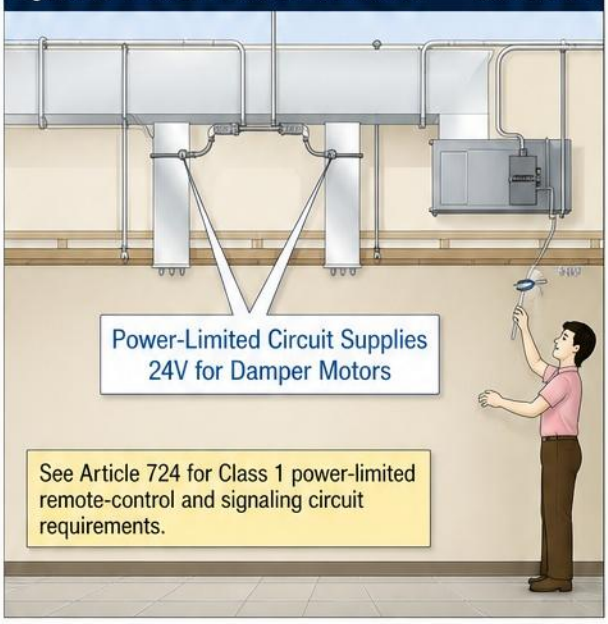


This figure shows an example of a non-power-limited remote-control circuit consisting of a control device, controller, and the controlled equipment.

Note 1: See Article 724 for Class 1 power-limited remote-control and signaling circuit requirements.

▶ Figure 206–2.

Figure 206–2 Class 1 Power-Limited Circuits **206.1 Note 1**



This figure illustrates a Class 1 power-limited circuit supplying 24V to damper motors.

Note 2: See Article 725 for Class 2 power-limited remote-control and signaling circuit requirements.

▶ Figure 206–3.

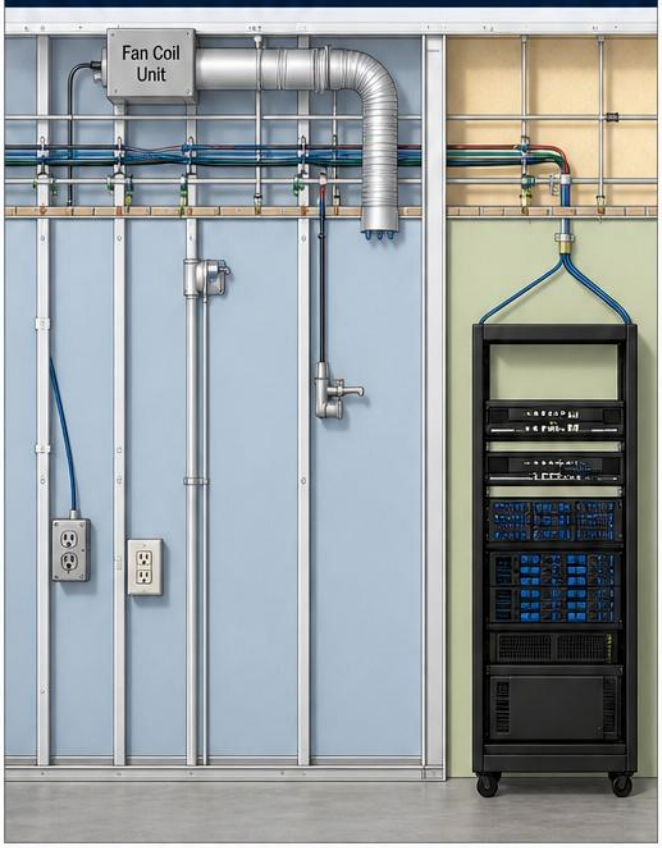
206.4 Installation

Non-power-limited remote-control and signaling circuits must be installed in accordance with 300.4 through 300.25.

(A) Sizes and Use.

(3) Ampacity Calculation. Conductors can be installed without applying the ampacity adjustment and correction factors specified in 310.15.

Figure 206–3
Class 2 Power-Limited Circuits 206.1 Note 2



See Article 725 for Class 2 power-limited remote-control and signaling circuit requirements.

(B) INSULATION

(1) Rating. Conductors must have an insulation rated not less than 600V.

(3) Type. Conductors that are 18 AWG CU, 16 AWG CU, or 14 AWG CCA can be Type FEP, Type FEPB, Type FEPJ, Type FJP, Type FEPG, Type FEPB, Type FEP, Type FEPB, Type PTFE, Type RFEP-2, Type RFEPB-2, Type RFEP-3, Type SF-2, SFB-2, Type TF, Type TFB, Type TFFN, Type TFN, Type ZF, or Type ZFB.

(C) NON-POWER-LIMITED REMOTE-CONTROL AND SIGNALING CIRCUITS WITH POWER-SUPPLY CIRCUITS

Non-power-limited remote-control and signaling circuit conductors rated 1000V or less with power-supply circuits are permitted to occupy the same cable, enclosure, or raceway without a barrier if all conductors have an insulation rating equal to at least the maximum circuit voltage and the equipment powered is functionally associated.

(D) OVERCURRENT PROTECTION

Non-power-limited remote-control and signaling circuit conductors must have overcurrent protection in accordance with **240.4** or **240.5**.

ARTICLE

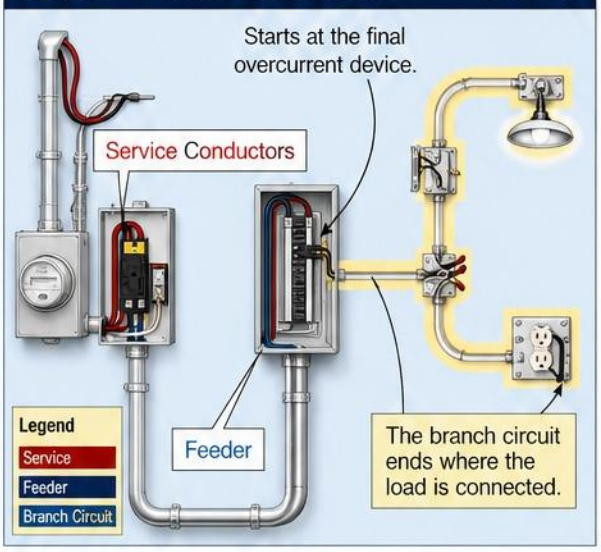
210 Branch Circuits

Introduction to Article 210—Branch Circuits

This article sets forth the general rules for *branch circuits* that extend from the last point of overcurrent protection to the outlets or utilization equipment. Because branch circuits serve most electrical installations, you must be familiar with these provisions. It is essential to know what a branch circuit is, where it begins, and where it ends in order to apply the rules correctly.

Branch Circuit. The circuit conductors located between the final overcurrent protective device (OCPD) that protects the circuit and the outlets.

Figure 210–1 Branch Circuit Definition **Article 100**



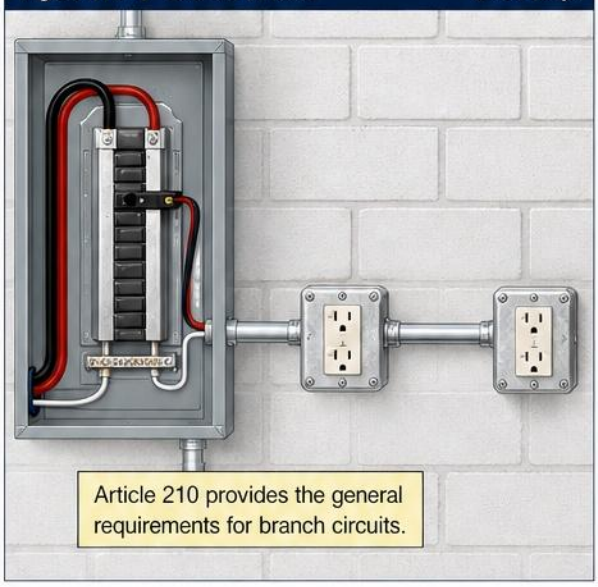
The conductors between the final overcurrent protective device and the receptacle outlets, lighting outlets, or other outlets.

PART I. GENERAL

210.1 Scope

This article specifies the general requirements applicable to branch circuits, including rules for conductor sizing, overcurrent protection, identification, GFCI/AFCI protection, and the requirements for receptacle and lighting outlets. [Figure 210–2]

Figure 210–2 Branch Circuits **210.1 Scope**



Author's Comment:

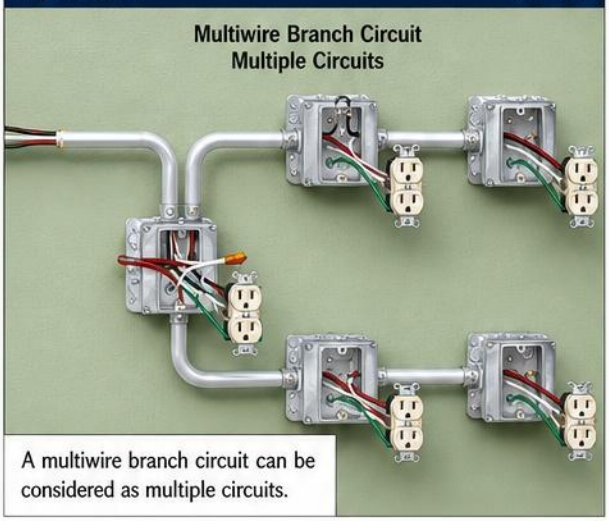
Article 210 sets out the general rules for branch circuits; however, equipment branch-circuit requirements are addressed in other articles.

- Air-conditioning [440.22 and 440.32]
- Motors [430.22]
- Electric space heating [424.5]
- Electric vehicles [625.40]
- Elevators [620.23 and 620.24]
- Signs [600.5]
- Information technology equipment [645.5]

210.4 Multiwire Branch Circuits

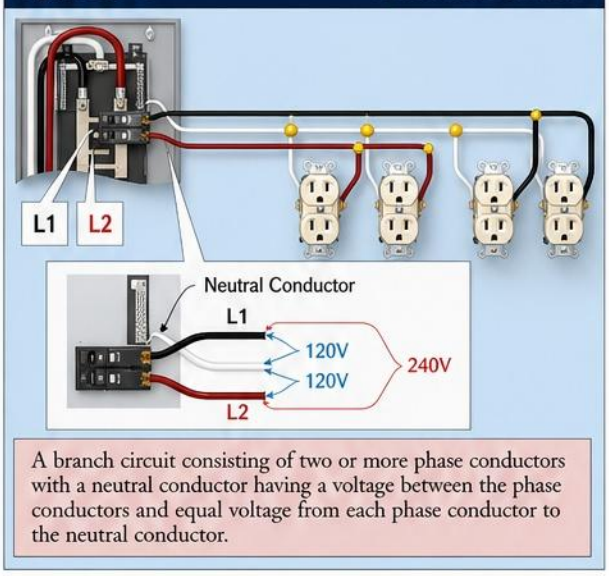
(A) General. A multiwire branch circuit can be considered as multiple circuits.

Figure 210–3 210.4(A)



Branch Circuit, Multiwire. A branch circuit consisting of two or more phase conductors with a neutral conductor having a voltage between the phase conductors and equal voltage from each phase conductor to the neutral conductor.

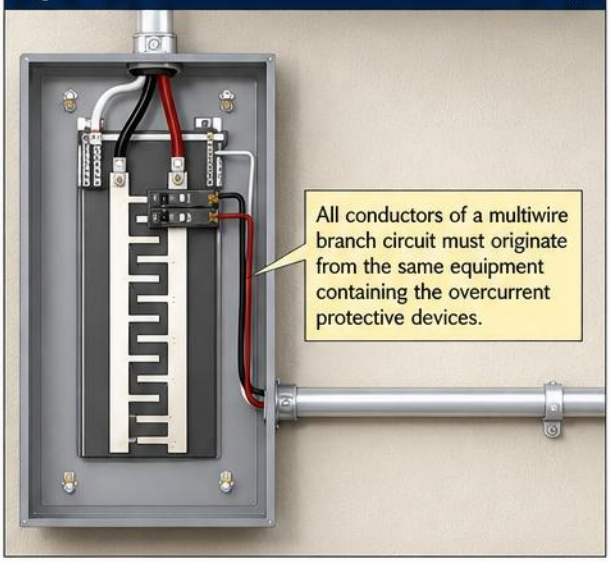
Figure 210–4 Article 100 Definition



All conductors of a multiwire branch circuit must originate from the same equipment containing the overcurrent protective devices.

Figure 210–5

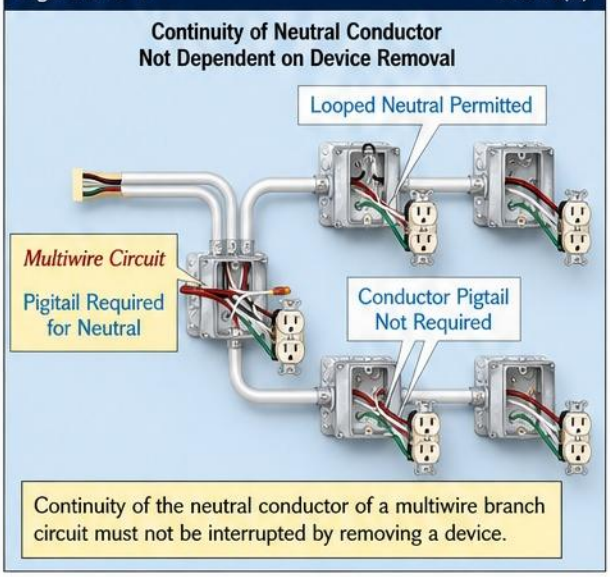
Figure 210–5 210.4(A)



Note 2: For the requirements relating to the continuity of the neutral conductor on multiwire branch circuits, see 300.15(B).

Figure 210–6

Figure 210–6 300.15(B)



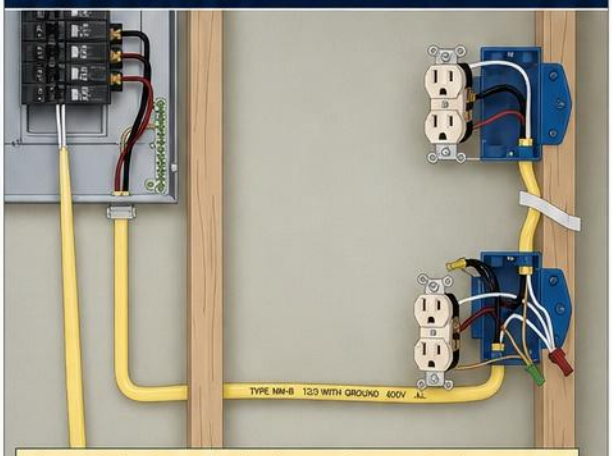
(B) Disconnecting Means. Each multiwire branch circuit must have a means to simultaneously disconnect all phase conductors at the point where the circuit originates.

Figure 210–7

Note: Individual single-pole circuit breakers with handle ties identified for the purposes of a circuit breaker with a common internal trip, can be used for multiwire branch circuits that serve only line-to-neutral loads [240.15(B)(1)].

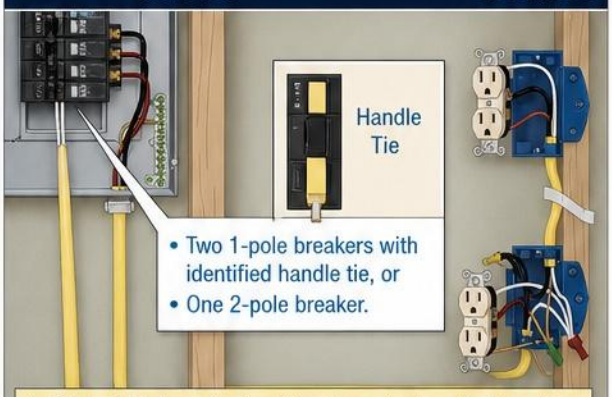
Figure 210–8

Figure 210–7 Multitwire branch circuit disconnecting means **210.4(B)**



A multitwire branch circuit must have a single means that simultaneously disconnects all ungrounded conductors at the location where the branch circuit originates.

Figure 210–8 Multitwire branch circuit disconnecting means note **210.4(B) Note**



Individual single-pole circuit breakers that are tied together with an identified handle tie, or a two-pole circuit breaker, may be used for a multitwire branch circuit that supplies only line-to-neutral loads [240.15(B)(1)].

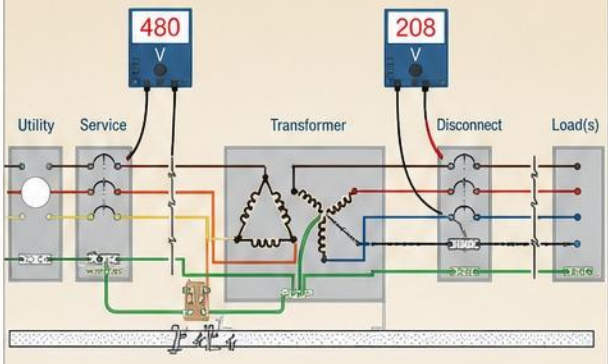
CAUTION: This rule exists to help prevent people from working on energized circuits they believe have been disconnected.

(C) Line-to-Neutral Loads. Multitwire branch circuits are permitted to supply only line-to-neutral loads.

Example 1: A multitwire branch circuit may supply individual utilization equipment that has line-to-line and line-to-neutral loads (range or clothes dryer).

Line-to-line. This is an electrical reference between two current-carrying conductors in a circuit other than a neutral conductor. ▸Figure 210–9

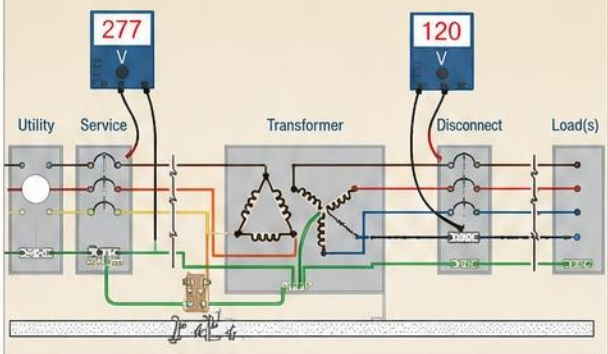
Figure 210–9 Line-to-line definition **Article 100**



Line-to-line is an electrical reference between two current-carrying conductors in a circuit other than a neutral conductor.

Line-to-neutral. This is an electrical reference between a current-carrying conductor and a neutral conductor or a neutral point in a circuit. ▸Figure 210–10

Figure 210–10 Line-to-neutral definition **Article 100**



Line-to-neutral is an electrical reference between a current-carrying conductor and a neutral conductor, or between a current-carrying conductor and a neutral point in a circuit.

(D) Grouping. The phase and neutral conductors of a multitwire branch circuit must be grouped or identified together by cable ties, wire markers, or comparable means within each enclosure as required by 200.6(B).

▸Figure 210–11 and ▸Figure 210–12

Figure 210-11 Multiwire Branch Circuit Identified by Grouping 210.4(D)

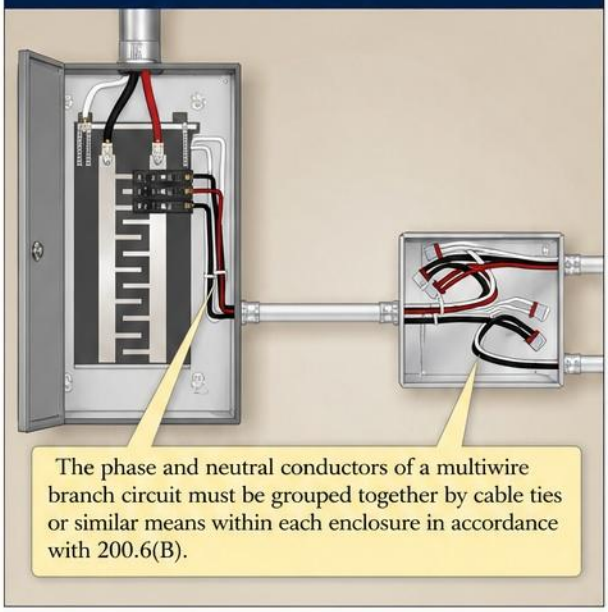
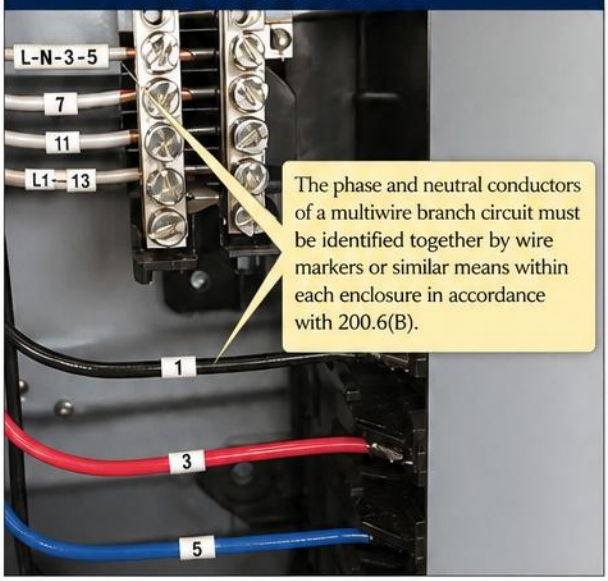


Figure 210-12 Multiwire Branch Circuit Identified with Wire Markers 210.4(D)



Author's Comment

- Grouping of phase and neutral conductors is not required where the conductors are contained in a single raceway or cable unique to that circuit which makes the grouping obvious [200.6(B) Ex 1].
- Grouping is not required if multiwire branch-circuit conductors pass through a box without splices or terminations [200.6(B) Ex 2].

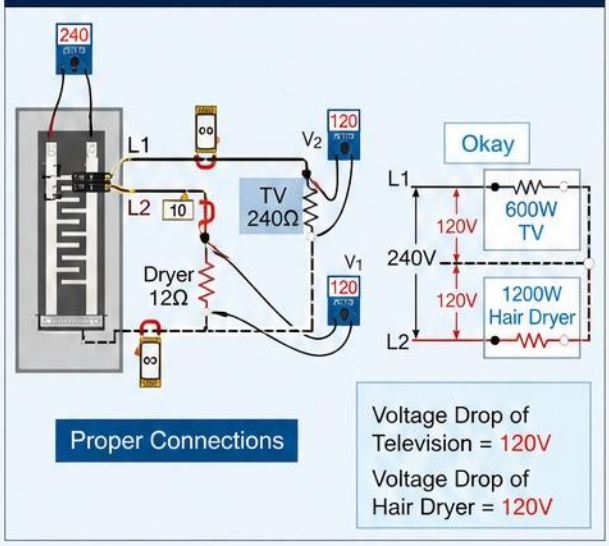
- Grouping multiwire branch-circuit conductors together by cable ties (or other means) at the point of origin makes it easier to visually identify the conductors of each multiwire branch circuit. The grouping ensures the correct neutral is paired with the intended circuit conductors at junction points and connecting the multiwire branch-circuit conductors to circuit breakers. If proper care is not exercised when making these connections, two circuit conductors can be accidentally connected to the same phase or line.

CAUTION: The opening of the phase or neutral conductor of a 2-wire circuit during the replacement of a device does not cause a safety hazard, so the pigtailing of these conductors is not required. If the continuity of the neutral conductor of a multiwire circuit is interrupted (opened), there could be a fire or destruction of electrical equipment resulting from overvoltage or undervoltage.

Hazard of an Open Neutral Example

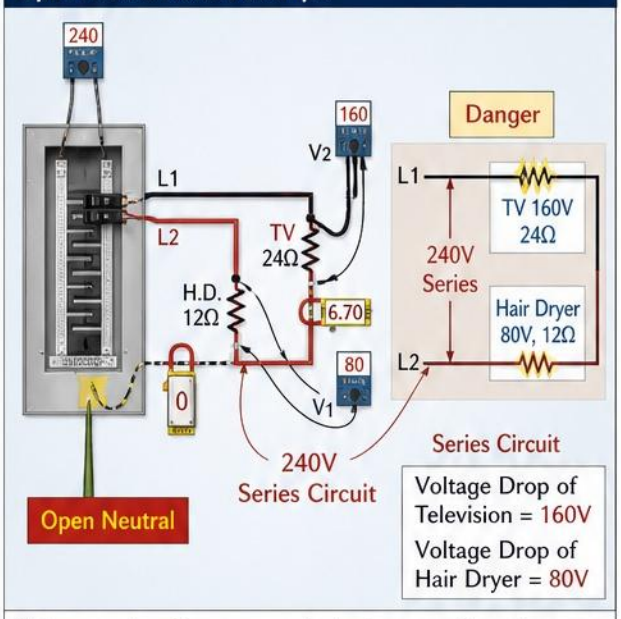
Example: A 3-wire, single-phase, 120/240V multiwire circuit supplies a 1,200W, 120V hair dryer, and 600W, 120V television. **Figure 210-13**

Figure 210-13 Multiwire Branch Circuit Proper Phase and Neutral Connection Example



If the neutral conductor of the multiwire circuit is interrupted, it will cause the 120V television to operate at 160V. It will consume 1,067W of power (instead of 600W) for only a few seconds before it burns up. **Figure 210-14**

Figure 210–14 Multiwire Branch Circuit Open Neutral Hazard Example 210.4



If the neutral conductor opens, the load currents from the two phases flow through each other in series. The current is additive, so insulation can be severely overheated.

Solution:

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

$R = E^2 / P$

R of the Hair Dryer $= 120^2 / 1{,}200W = 12\Omega$

R of the Television $= 120^2 / 800W = 24\Omega$

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

I = Volts / Resistance

Volts $= 240V$

$R = 36\Omega\ (12\Omega + 24\Omega)$

$I = 240V / 36\Omega$

$I = 6.70A$

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

Volts = I × R

$I = 6.70A$

$R = 12\Omega$ *for hair dryer and* 24Ω *for TV*

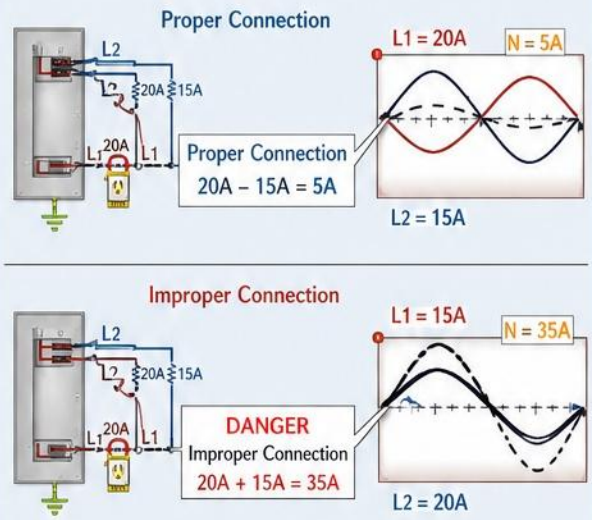
Voltage of Hair Dryer $= 6.70A \times 12\Omega = 80V$

Voltage of Television $= 6.70A \times 24\Omega = 160V$

WARNING: If the phase conductors are not kept in separate phases at the panelboard termination, the neutral conductor can be overloaded. This occurs because the current from the phase conductors is additive, which can damage insulation from excessive heat. Conductor overheating is known to shorten the service life of insulation, increasing the chance of arcing faults and potentially causing fires. While the duration that insulation can withstand is not precisely known, heat undeniably shortens its lifespan.

See **Figure 210–15.**

Figure 210–15 Multiwire Branch Circuit Overloaded Neutral Warning 210.4



If the phase conductors are not kept on separate phases at the panelboard termination, the neutral conductor can become overloaded. This can harm or destroy the neutral insulation due to excessive heat.

Author's Comment:

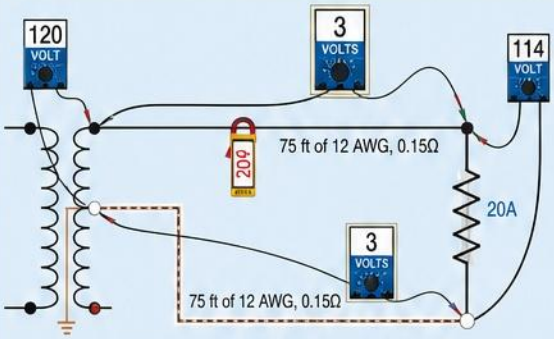
- Multiwire branch circuits can reduce circuit voltage drop by as much as 50 percent. A typical 2-wire circuit has current flow over both the phase and neutral conductors, so the circuit voltage drop includes the voltage drop of both wires. A balanced 3-wire, single-phase or 4-wire, three-phase multiwire branch circuit carries current only on the phase conductors, with no current on the neutral conductor. Therefore, the circuit voltage drop includes the voltage drop of only one conductor.

2-Wire Circuit Voltage Drop Example

Question: What is the voltage drop of two 12 AWG wires, each 75 ft long (0.15Ω), supplying a 2-wire, 20A load? ▶ Figure 210–16

(a) 2V (b) 3V (c) 4V (d) 6V

Figure 210–16 2-WIRE CIRCUIT VOLTAGE DROP EXAMPLE 210.4



$E_{VD} = I \times R$

I = 20A, R = 0.15Ω × 2 wires = 0.30Ω

E_{VD} = 20A × 0.30Ω

E_{VD} = 6V dropped on wires

A 2-wire circuit carries current through both the phase and neutral conductors. Therefore, the circuit voltage drop includes the voltage drop of both wires.

Solution:

$E_{VD} = I \times R$

$I = 20A$

$R = 0.15\Omega \times 2$ *wires*

$R = 0.30\Omega$

$E_{VD} = 20A \times 0.30\Omega$

$E_{VD} = 6V$

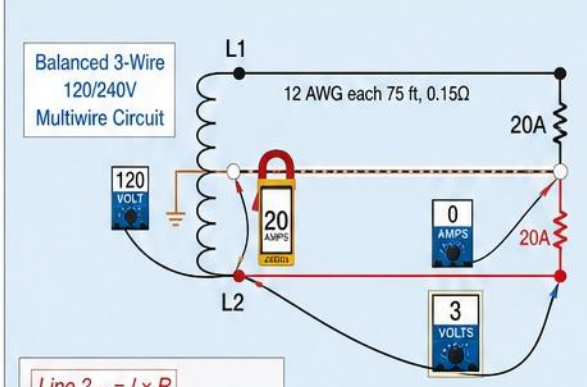
Answer: *(d) 6V*

Multiwire Circuit Voltage Drop Example

Question: *A multiwire circuit consists of 12 AWG each having a* length of seventy-five feet (0.15Ω): Line 1 current of 20A load, Line 2 current of 20A, Neutral current of 0A. What is the voltage drop of Line 2? ▶ Figure 210–17

(a) 2V (b) 3V (c) 4V (d) 6V

Figure 210–17 3-WIRE CIRCUIT VOLTAGE DROP EXAMPLE 210.4



$Line\ 2_{VD} = I \times R$

I = 20A, R = 0.15Ω

E_{VD} = 20A × 0.15Ω

E_{VD} = 3V dropped on wire

A balanced 3-wire, 1-phase multiwire branch circuit carries current on the phase conductors only. Therefore, the voltage drop on the wire includes the drop of one wire only.

Solution:

$Line\ 2_{VD} = I \times R$

I of Line 2 = 20A

R of Line 2 = 0.15Ω

$Line\ 2_{VD} = 20A \times 0.15\Omega$

$Line\ 2_{VD} = 3V$

Answer: *(b) 3V*

210.5 CONDUCTOR IDENTIFICATION

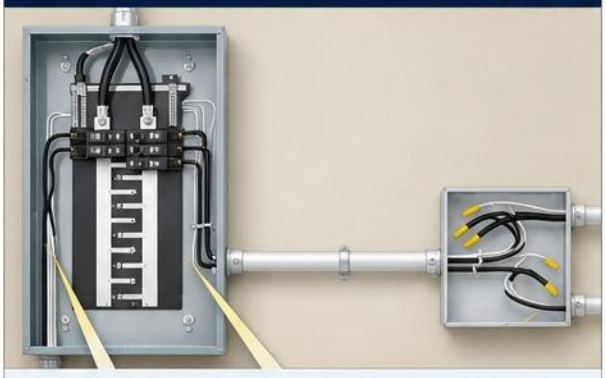
(A) NEUTRAL CONDUCTOR. The branch-circuit neutral conductor must be identified in accordance with 200.7.

(B) EQUIPMENT GROUNDING CONDUCTOR. The branch-circuit equipment grounding conductor must be identified in accordance with 250.119.

(C) IDENTIFICATION OF PHASE CONDUCTORS. Branch-circuit phase conductors must be identified as follows:

(1) SUPPLIED FROM ONE NOMINAL VOLTAGE SYSTEM. Where the premises wiring system has branch circuits supplied from one nominal voltage system, branch-circuit phase conductors must be identified in accordance with 310.6(A)(3). ▶ Figure 210–18

Figure 210–18 Branch Circuit Phase Conductor Identification Supplied from One Nominal Voltage System 210.5(C)(1)



Branch-circuit phase conductors must be identified in accordance with 310.6(A)(3).

(2) Supplied from More Than One Nominal Voltage System. Where wiring is supplied from more than one nominal voltage system, the branch-circuit phase conductors must be identified by phase and nominal voltage system at termination, connection, and splice points in accordance with 210.5(C)(2)(a) and (b).

(a) Means of Identification. Identification of the branch-circuit phase conductors can be by color coding, marking tape, tagging, or other means approved by the authority having jurisdiction (AHJ).
Figure 210–19

Figure 210–19 Branch-Circuit Phase Conductor Identification, Marking Supplied from More Than One Nominal Voltage System 210.5(C)(2)(a)

Branch-circuit phase conductor must be identified by color coding, marking tape, tagging, or other means approved by the authority having jurisdiction.

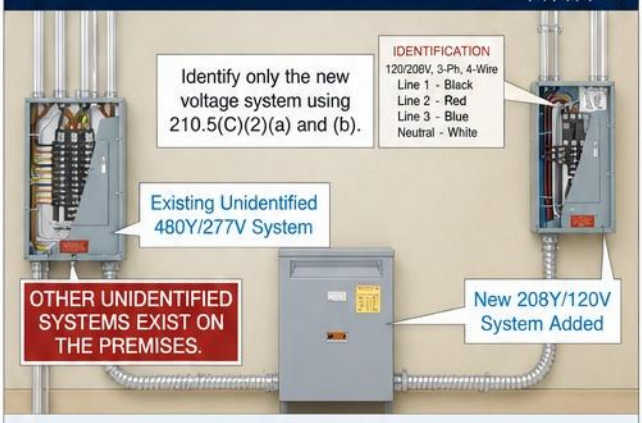
(b) Posting of Identification. Branch-circuit phase conductor identification must be readily available or posted at the enclosed panelboard. The identification is not permitted to be handwritten and must withstand the environment involved. Figure 210–20

Figure 210–20 Branch-Circuit Conductor Identification Posting of Identification Means, More Than One Voltage System 210.5(C)(2)(b)

Branch-circuit phase conductor identification must be readily available or posted at the enclosed panelboard, not permitted to be handwritten, and must withstand the environment involved.

Ex: Where a different voltage system is added to an existing installation, branch-circuit identification is only required for the new one. Each nominal voltage system distribution equipment must have a label with the words, "OTHER UNIDENTIFIED SYSTEMS EXIST ON THE PREMISES."
Figure 210–21

Figure 210–21 Branch-Circuit Phase Conductor Identification, Existing Supplied from More Than One Nominal Voltage System 210.5(C)(2)(b) Ex



Each nominal voltage system distribution equipment must have a label with the words "other unidentified systems exist on the premises."

Author's Comment:

- Branch-circuit phase conductors supplied from one nominal voltage system can be any color but white or green [310.6(A)(3)].

- The color scheme used must be maintained wherever phase conductors are terminated or accessible throughout the premises. This is especially important when identifying different system voltages and neutrals. Although the *NEC* does not mandate specific colors for phase conductors, electricians commonly use the following system.
  - 120/240V, single-phase—black, red, and white
  - 208Y/120V, three-phase—black, red, blue, and white
  - 240V/120V, three-phase (high-leg)—black, orange, blue, and white
  - 480Y/277V, three-phase—brown, orange, yellow, and gray; or brown, purple, yellow, and gray

Figure 210–22 Conductor Identification Practices 210.5(C) Comment

Although the *NEC* does not mandate a specific color code for phase conductors, electricians often use the following for power and lighting conductor identification:

- 120/240V, single-phase—black, red, and white
- 208Y/120V, three-phase—black, red, blue, and white
- 240V/120V, three-phase (high-leg)—black, orange, blue, and white
- 480Y/277V, three-phase—brown, orange, yellow, and gray; or brown, purple, yellow, and gray

210.6 Branch-Circuit Voltage

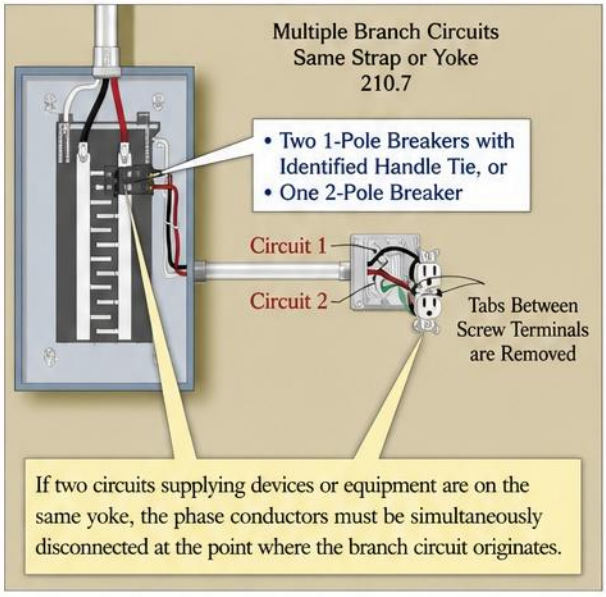
(A) Voltage Limitations. In dwelling units and hotel/motel guest rooms or suites, the voltage between conductors is not permitted to exceed 120V for:

(1) Luminaires

(2) Cord-and-plug-connected loads of 1440 VA (nominal or less) or less than ¼ hp

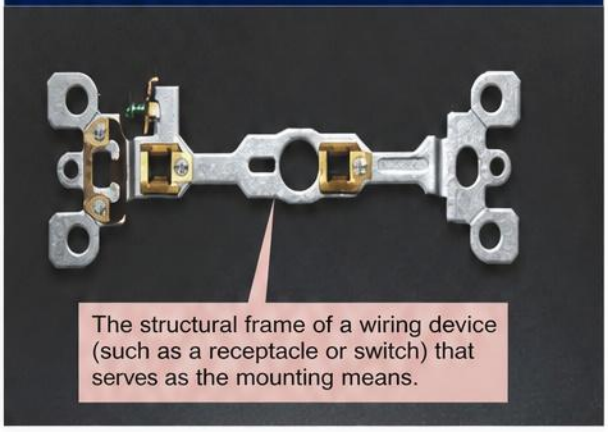
Figure 210–23 Multiple Branch Circuits 210.7

If two circuits supplying devices or equipment are on the same yoke, the phase conductors must be simultaneously disconnected at the point where the branch circuit originates.



Yoke (Strap). The structural frame of a wiring device (such as a receptacle or switch) that serves as the mounting means. 210–24

Figure 210–24 Yoke Article 100 Definition



Author's Comment:

- Individual single-pole circuit breakers with handle ties identified for the purpose or circuit breakers with a common internal trip can be used for this application [240.15(B)(1)].

210.8 GFCI PROTECTION

Class A GFCI protection is required in accordance with 210.8(A) through (F). Figure 210–25.

Figure 210–25 **210.8**

GFCI Device | GFCI Circuit Breaker

GFCI Receptacle | Faceless GFCI | 1-Pole GFCI Breaker | 2-Pole GFCI Breaker

Class A "GFCI" protection is required in accordance with 210.8(A) through (F).

Ground-Fault Circuit Interrupter (Class A). A device intended to protect people by de-energizing a circuit when ground-fault current exceeds the value for a Class A device (6 mA or higher). Figure 210–26.

Figure 210–26 **Article 100 Definition**

Ground-Fault Circuit Interrupter (Class A GFCI)

GFCI Device | GFCI Circuit Breaker

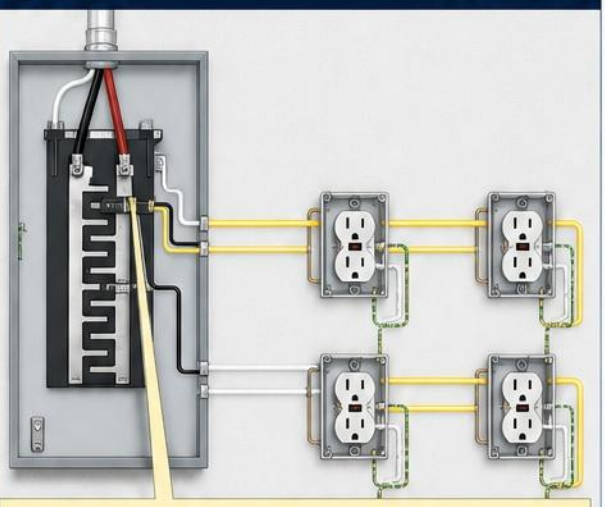
GFCI Receptacle | Faceless GFCI | 1-Pole GFCI Breaker | 2-Pole GFCI Breaker

A device intended to protect people by de-energizing a circuit when ground-fault current exceeds the value for a Class A device (6 mA or higher).

Author's Comment:

- The Consumer Product Safety Commission has reported a decrease in the number of electrocutions in the United States since the introduction of GFCI devices in the 1971 *NEC*.
- The GFCI protection required by 210.8(A) and (B) can be provided by using either a circuit breaker with GFCI protection or a receptacle with GFCI protection.
- The GFCI circuit breaker provides ground-fault protection starting at the breaker, so the entire circuit has ground-fault protection. A GFCI receptacle provides ground-fault protection for whatever is plugged into it and has load-side terminals that provide downstream protection for any other receptacles or devices on the circuit. Figure 210–27.

Figure 210–27 **210.8 Comment**

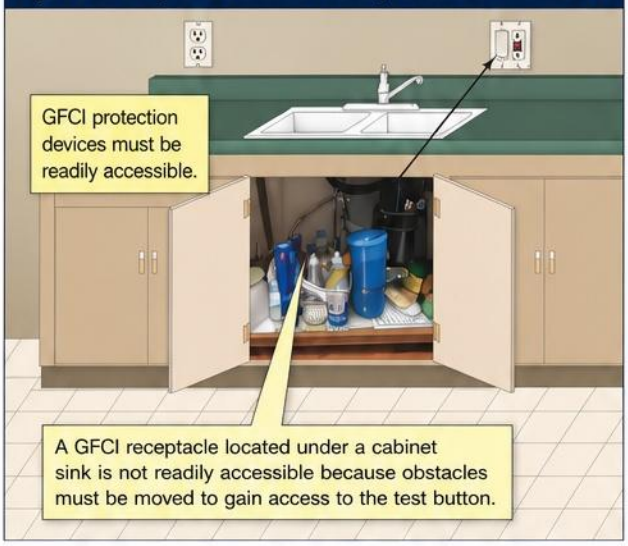


The GFCI circuit breaker provides ground-fault protection for the entire circuit has ground-fault protection. A GFCI receptacle provides ground-fault protection for whatever is plugged into it and has load-side terminals that provide downstream protection for any other receptacles on the circuit.

The GFCI device must be located at a readily accessible location. Figure 210–28.

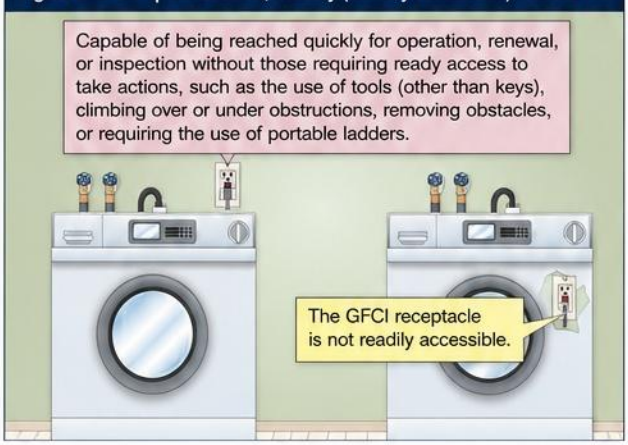
Accessible, Readily Accessible. Capable of being reached quickly for operation, renewal, or inspection without those requiring ready access to take actions, such as the use of tools (other than keys), climbing over or under obstructions, removing obstacles, or requiring the use of portable ladders. Figure 210–29 and Figure 210–30.

Figure 210–28 | GFCI Protection Readily Accessible 210.8



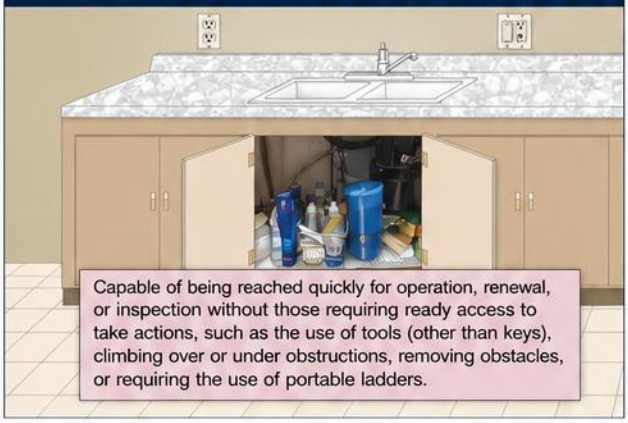
When a GFCI receptacle is installed under a cabinet sink, it is not considered readily accessible because items must be removed to reach the test button.

Figure 210–29 | Accessible, Readily (Readily Accessible) Article 100



This receptacle is outside the zone of ready access because it is not within quick reach for operation, renewal, or inspection without using tools or removing obstacles.

Figure 210–30 | Accessible, Readily (Readily Accessible) Article 100



The GFCI outlet is hidden behind cabinet contents and therefore is not readily accessible.

Author's Comment:

Manufacturers' instructions typically require the GFCI to be tested monthly. Because GFCIs can only be properly tested by pressing the GFCI test button, the receptacle must be in a readily accessible location. A GFCI outlet located under a cabinet sink is not readily accessible since it cannot be reached promptly without first clearing away obstructions. See Figure 210–31.

Figure 210–31 | GFCI Protection Testing 210.8

Manufacturers advise that GFCIs be tested monthly in accordance with their instructions.

Example: Rooftop GFCI receptacles only need to be readily accessible from the rooftop itself. See Figure 210–32.

Figure 210–32 | GFCI Protection Rooftop Receptacles 210.8 Ex

Access is considered sufficient when the GFCI outlet can be reached without leaving the rooftop.

For the application of 210.8(A)(9) and (11) or 210.8(B)(7), (14), and (16), the distance from receptacles is measured as the shortest path the power-supply cord connected to the receptacle will follow without piercing a floor, wall, ceiling, or fixed barrier.

Figure 210-33 GFCI Protection, Receptacle: How to Measure 210.8

Measured along the countertop surface—the shortest path to the wall receptacle without piercing any barriers.

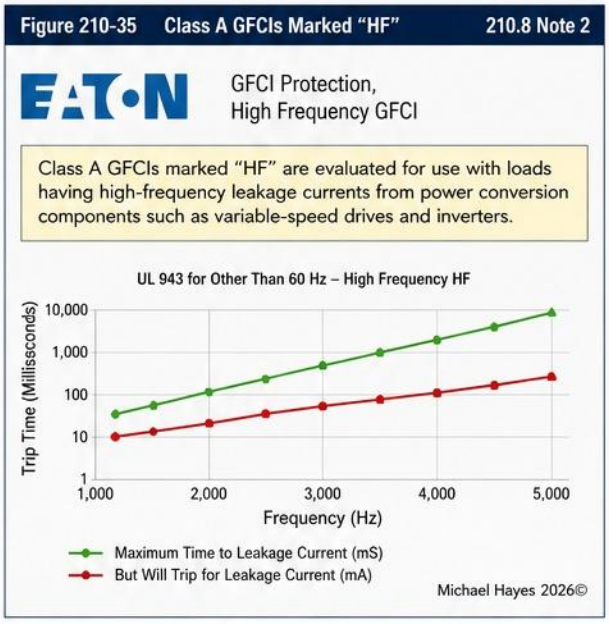
Figure 210-34 GFCI Protection, Receptacle: How to Measure 210.8

Measured from the edge of the opening to the receptacle along the shortest unobstructed path.

Figure 210-35 Note 2 High-Frequency Evaluation 210.8 Note 2

Class A GFCIs marked "HF" are evaluated for use with loads having high-frequency leakage currents from power conversion components such as variable-speed drives and inverters. See *UL 943, Ground-Fault Circuit-Interrupters*, for additional details.

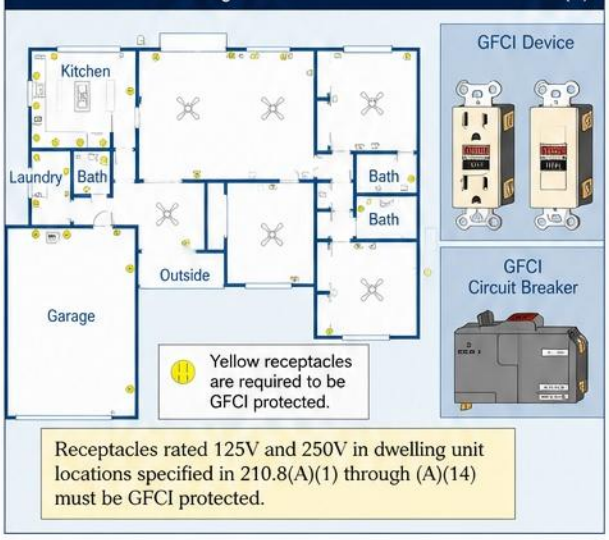
Figure 210-35 Class A GFCIs Marked "HF" 210.8 Note 2



Class A GFCIs marked "HF" are intended for use with equipment that can produce high-frequency leakage currents.

(A) Dwelling Units. Receptacles rated 125V or 250V in *dwelling unit* locations specified in 210.8(A)(1) through (A)(14) must be GFCI protected.

Figure 210-36 GFCI Protection, Receptacles: Dwelling Units 210.8(A)



Dwelling Unit. A single unit that provides permanent provisions for living, sleeping, cooking, and sanitation.

(1) Bathrooms. GFCI protection is required for all receptacles located in *bathrooms*.

Bathroom. An area including a sink with one or more of the following: a toilet, urinal, tub, shower, or bidet.

Figure 210–37 Dwelling Unit *Article 100 Definition*

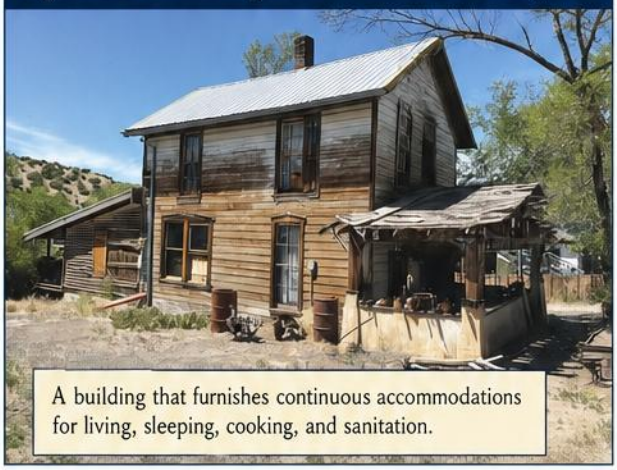


Figure 210–38 GFCI Protection for Receptacles in Dwelling Unit Bathrooms *210.8(A)(1)*

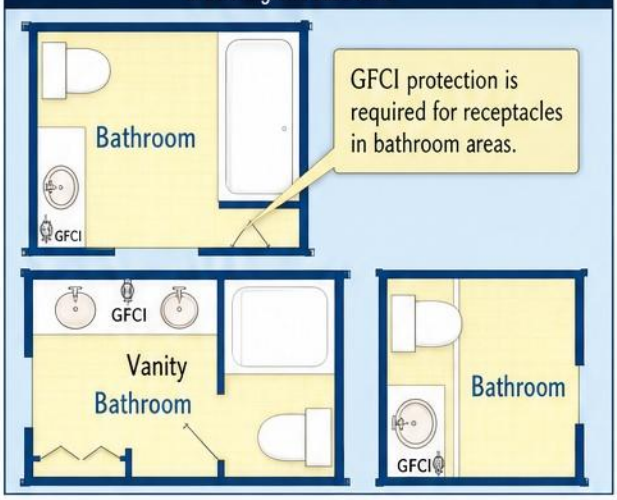
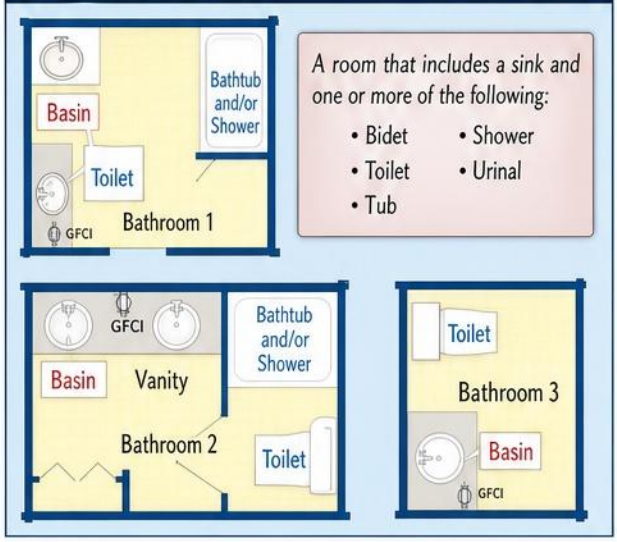
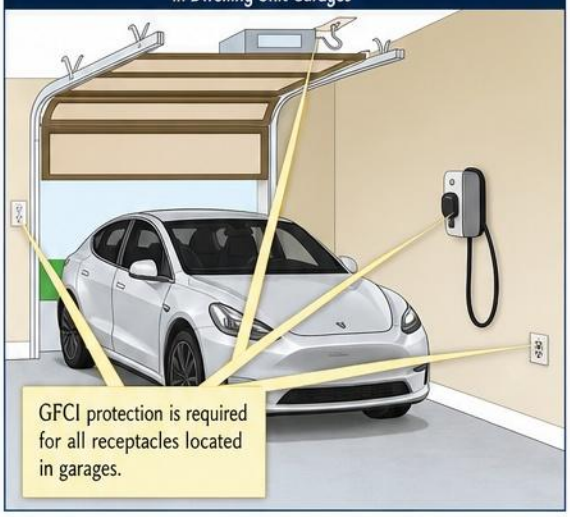


Figure 210–39 Bathroom *Article 100 Definition*



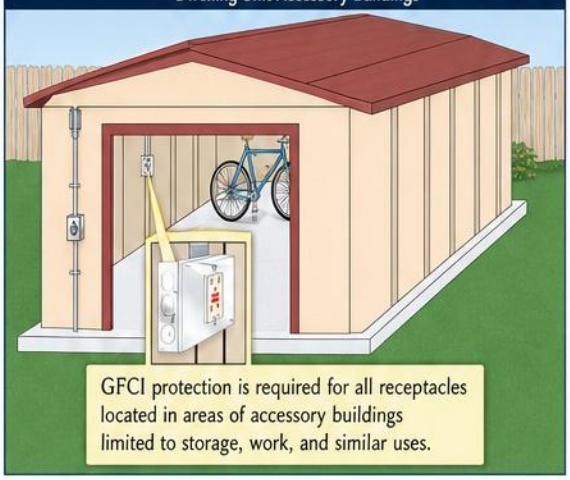
(2) Garages. GFCI protection is required for all receptacles located in garages.
210.8(A)(2)

Figure 210–40 GFCI Protection for Receptacles in Dwelling Unit Garages *210.8(A)(2)*



(3) Accessory Buildings. GFCI protection is required for all receptacles located in areas of accessory buildings limited to storage, work, and similar uses.
210.8(A)(3)

Figure 210–41 GFCI Protection for Receptacles in Dwelling Unit Accessory Buildings *210.8(A)(3)*



(4) Outdoors. GFCI protection is required for all receptacles located outdoors.
210.8(A)(4)

(5) Crawl Spaces. GFCI protection is required for receptacles in crawl spaces at or below grade.
210.8(A)(5)

(6) Basements. GFCI protection is required for all receptacles located in basements.
210.8(A)(6)

Figure 210-42 GFCI Protection, Receptacles Dwelling Unit Outdoors 210.8(A)(4)

GFCI protection is required for receptacles located outdoors.

Figure 210-43 GFCI Protection, Receptacles Dwelling Unit Crawl Spaces 210.8(A)(5)

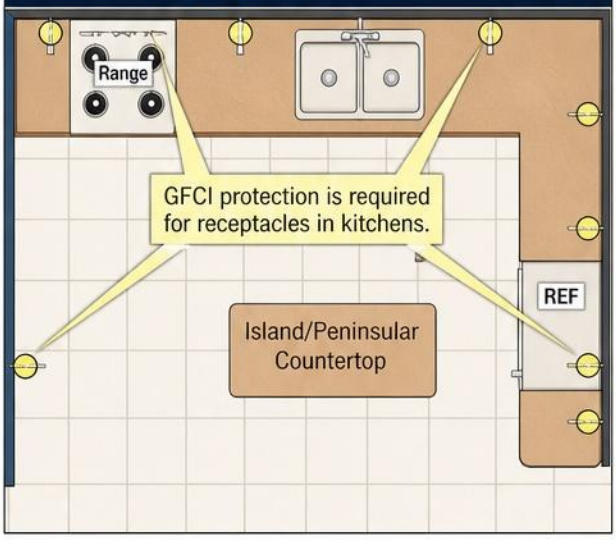
GFCI protection is required for receptacles in crawl spaces at or below grade.

Figure 210-44 GFCI Protection, Receptacles Dwelling Unit Basements 210.8(A)(6)

GFCI protection is required for receptacles in basements.

(7) Kitchens. GFCI protection is required for all receptacles located in kitchens. Figure 210-45

Figure 210-45 GFCI Protection, Receptacles Dwelling Unit Kitchens 210.8(A)(7)



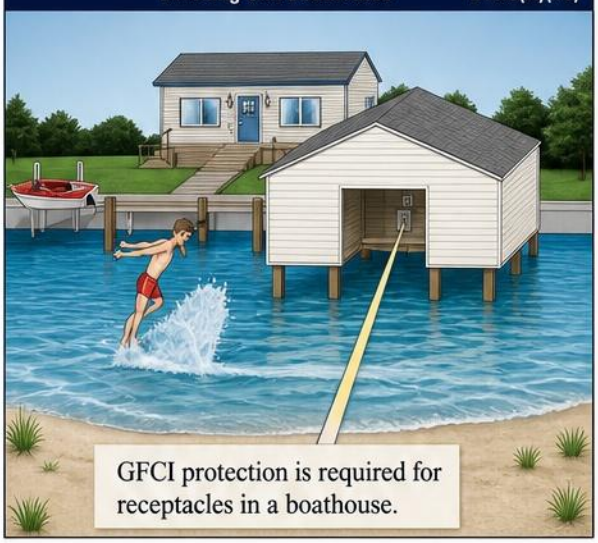
(8) Food Preparation Areas. GFCI protection is required for all receptacles located in areas with sinks and permanent provisions for food preparation, beverage preparation, or cooking.

(9) Sinks. GFCI protection is required for all receptacles located within 6 ft of the top inside edge of the bowl of a sink. Figure 210-46

Figure 210-46 GFCI Protection, Receptacles Dwelling Unit Sinks 210.8(A)(9)

(10) Boathouses. GFCI protection is required for all receptacles located in a boathouse. Figure 210-47

Figure 210-47 GFCI Protection, Receptacles Dwelling Unit Boathouses 210.8(A)(10)



Author's Comment

- The *Code* does not require a receptacle to be installed in a boathouse, but if there are any, they must be GFCI protected.

(11) Bathtubs or Shower Stalls. GFCI protection is required for all receptacles located within 6 ft of the outside edge of a bathtub or shower stall that are not within a bathroom. ■ Figure 210-48

Figure 210-48 GFCI Protection, Receptacle Dwelling Unit Shower Stalls 210.8(A)(11)

(12) Laundry Areas. GFCI protection is required for all receptacles located in the *laundry area.* ■ Figure 210-49

Laundry Area. An area containing a clothes washer or dryer. ■ Figure 210-50

Figure 210-49 GFCI Protection, Receptacles Dwelling Unit Laundry Areas 210.8(A)(12)

Figure 210-50 Laundry Area Article 100 Definition

(13) Indoor Damp Locations. GFCI protection is required for all receptacles located in damp indoor locations as determined by the AHJ.

(14) Indoor Wet Locations. GFCI protection is required for all receptacles located in indoor wet locations as determined by the AHJ.

Ex 1: GFCI protection is not required for a receptacle dedicated to fixed electric snow-melting equipment if the receptacle is not readily accessible and ground-fault protection of equipment (GFPE) is provided as required by 426.28. ■ Figure 210-51

Ex 2: GFCI protection is not required for a receptacle that only supplies a security system.

Ex 4: GFCI protection is not required for receptacles in exhaust fans, unless specified by the fan instructions or listing. ■ Figure 210-52

Figure 210–51 Dwelling Unit Outdoors 210.8(A)(1)

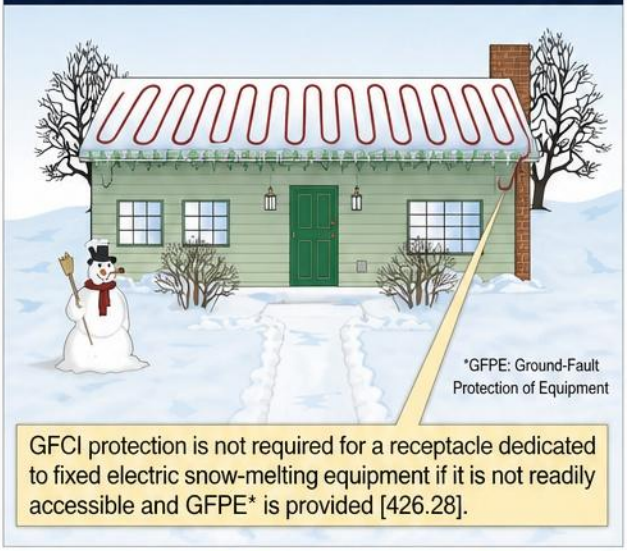


Figure 210–52 Dwelling Unit Exhaust Fans 210.8(A) Ex 4

Figure 210–53 Other Than Dwelling Unit, Bathrooms 210.8(B)(1)

Figure 210–54 Other Than Dwelling Unit, Kitchens 210.8(B)(2)

Author's Comment:

- Exhaust fans in the area directly above the footprint (width and depth of equipment) of a bathtub or shower must be GFCI protected in accordance with UL *Guide Information GPWX*.

(B) Other Than Dwellings. GFCI protection is required for 125V through 250V receptacles supplied by single-phase branch circuits 50A or less or three-phase branch circuits 100A or less rated 150V or less to ground in the following locations:

(1) Bathrooms. GFCI protection is required for receptacles located in bathrooms. Figure 210–53

(2) Kitchens. GFCI protection is required for 125V through 250V receptacles located in kitchens. Figure 210–54

Kitchen. An area with a sink and permanent provisions for food preparation and cooking. Figure 210–55

(3) Food Preparation Areas. GFCI protection is required for receptacles located in areas containing sinks with permanent provisions for food preparation, beverage preparation, or cooking.

(4) Buffet Serving Areas. GFCI protection is required for receptacles located in buffet serving areas with permanent provisions for food serving, beverage serving, or cooking.

(5) Rooftops. GFCI protection is required for 125V through 250V receptacles located on rooftops. Figure 210–56

(6) Outdoors. GFCI protection is required for 125V through 250V receptacles located outdoors. Figure 210–57 and Figure 210–58

Figure 210–55 Kitchen Article 100 Definition

A room or space containing a sink and permanently installed facilities for food preparation and cooking.

Figure 210–56 210.8(B)(5)
GFCI Protection, Receptacles Other Than Dwelling Unit, Rooftops

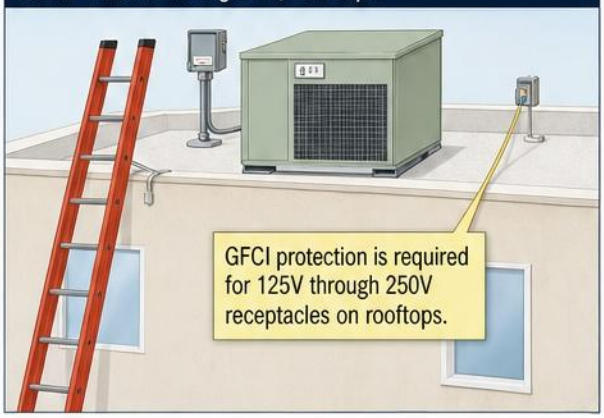


Figure 210–57 210.8(B)(6)
GFCI Protection, Receptacles Other Than Dwelling Unit, Outdoors

Figure 210–58 210.8(B)(6)
GFCI Protection, Receptacles Other Than Dwelling Unit, Outdoors

(7) Sinks. GFCI protection is required for 125V through 250V receptacles and cord-and-plug-connected fixed or stationary appliances within 6 ft from the top inside edge of the bowl of a sink. Figure 210–59.

Figure 210–59 210.8(B)(7)
GFCI Protection, Receptacles Other Than Dwelling Unit, Sinks

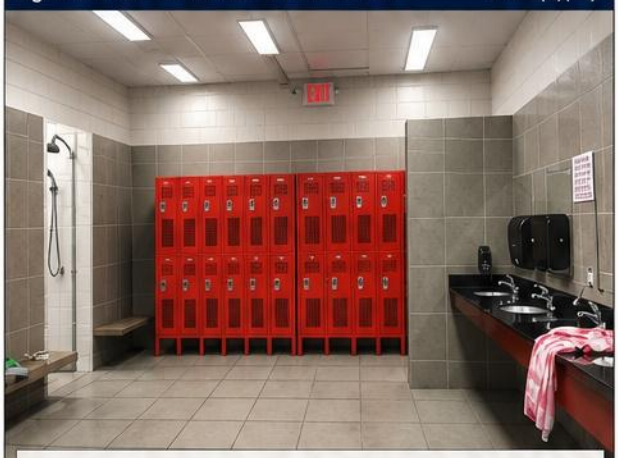
Author's Comment:
A defective appliance located next to a sink may create an electric shock hazard—regardless of whether the receptacle is within 6 ft or not.

(8) Indoor Damp Locations. GFCI protection is required for receptacles located in damp indoor locations as determined by the AHJ.

(9) Indoor Wet Locations. GFCI protection is required for all receptacles located in indoor wet locations as determined by the AHJ.

(10) Locker Rooms with Showers. GFCI protection is required for 125V through 250V receptacles located in locker rooms with showering facilities. (Figure 210–60)

Figure 210–60 Locker Rooms with Showers 210.8(B)(10)



GFCI protection is required for 125V through 250V receptacles in locker rooms with showering facilities.

(11) Garages and Similar Areas. GFCI protection is required for 125V through 250V receptacles located in garages, accessory buildings, and similar areas. (Figure 210–61)

Figure 210–61 Garages and Similar Areas 210.8(B)(11)

GFCI protection is required for 125V through 250V receptacles in garages, accessory buildings, and similar areas.

Garage. A building or portion of a building in which one or more vehicles can be kept for use, sale, storage, rental, repair, exhibition, or demonstration purposes. (Figure 210–62)

Figure 210–62 Garage *Article 100 Definition*

A building or portion of a building in which one or more vehicles can be kept for use, sale, storage, rental, repair, exhibition, or demonstration purposes.

(12) Crawl Spaces. GFCI protection is required for receptacles located in crawl spaces at or below grade level.

(13) Unfinished Areas of Basements. GFCI protection is required for receptacles located in unfinished areas of basements.

(14) Open Aquatic Tanks or Bowls. GFCI protection is required for receptacles within 6 ft from the top inside edge, rim, or conductive support framing of an open aquatic vessel or container, bait wells, and similar tanks or bowls for aquariums. (Figure 210–63)

Figure 210–63 Open Aquatic Tanks or Bowls 210.8(B)(14)

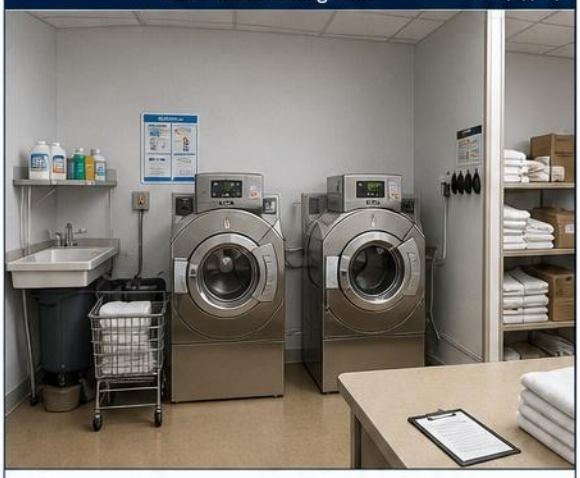
GFCI protection is required for receptacles within 6 ft from the top inside edge, rim, or conductive support framing of an open aquatic vessel or container, bait wells, and similar tanks or bowls for aquariums.

Author's Comment:

- The requirement for aquatic tanks does not apply to closed aquatic vessels or containers, bait wells, and similar tanks or bowls for aquariums.

(15) Laundry Areas. GFCI protection is required for 125V through 250V receptacles located in a laundry area.

Figure 210–64 Laundry Area Receptacles Other than Dwelling Units 210.8(B)(15)



GFCI protection is required for 125V through 250V receptacles in a laundry area.

(16) Bathtubs and Shower Stalls. GFCI protection is required for receptacles located within 6 ft of the outside edge of a bathtub or shower stall that are not in a bathroom.

(C) Crawl Space Lighting Outlets. GFCI protection is required for 120V lighting outlets in crawl spaces.

(D) Branch Circuits Supplying Specific Appliances. GFCI protection is required for the branch circuit or outlet for appliances rated 150V or less to ground (120V, 208V, 240V, 120/240V, 208Y/120V), 60A or less:

(1) Automotive vacuum machines

Figure 210–65 Automotive Vacuum Machines 210.8(D)(1)

GFCI protection is required for automotive vacuum machines rated 150V or less to ground and rated 60A or less either cord-and-plug or hardwired.

(2) Drinking water coolers and bottle fill stations

Figure 210–66 Drinking Water Coolers and Bottle Fill Stations 210.8(D)(2)

GFCI protection is required for drinking water coolers and bottle fill stations rated 150V or less to ground and rated 60A or less, either cord-and-plug or hardwired connected.

(3) High-pressure spray washing machines

(4) Tire inflation machines

Figure 210–67 Tire Inflation Machines 210.8(D)(4)

GFCI protection is required for tire inflation machines rated 150V or less to ground and rated 60A or less either cord-and-plug or hardwired.

(5) Vending machines

(6) Sump pumps

(7) Dishwashers

(8) Electric ranges

(9) Wall-mounted electric ovens

(10) Counter-mounted electric cooking units

(11) Clothes dryers

(12) Microwave ovens 210.8(D)(12)

Figure 210–68 Vending Machines 210.8(D)(5)

Figure 210–69 Sump Pumps 210.8(D)(6)

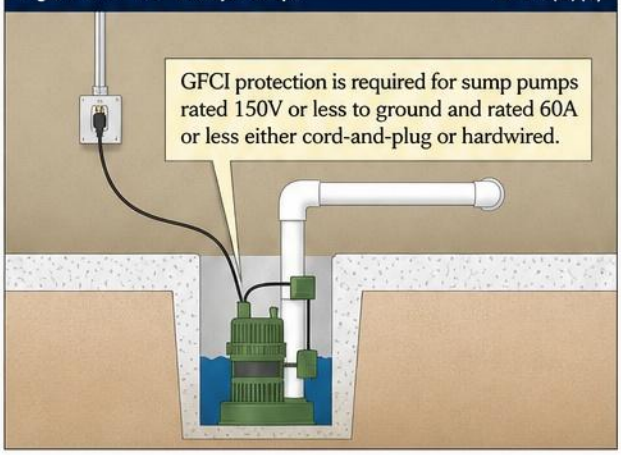


Figure 210–70 Dishwashers 210.8(D)(7)

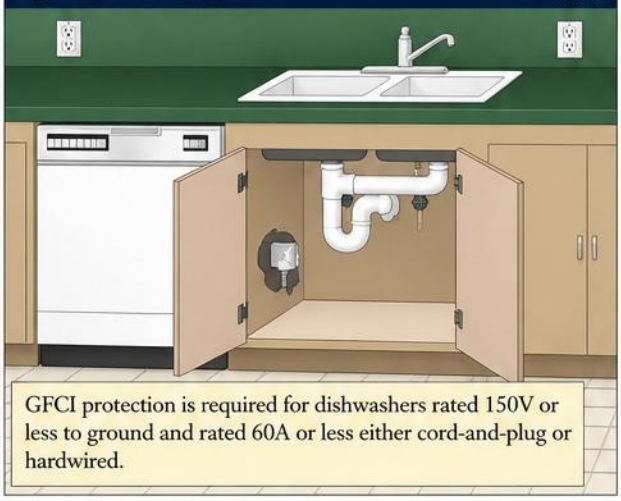
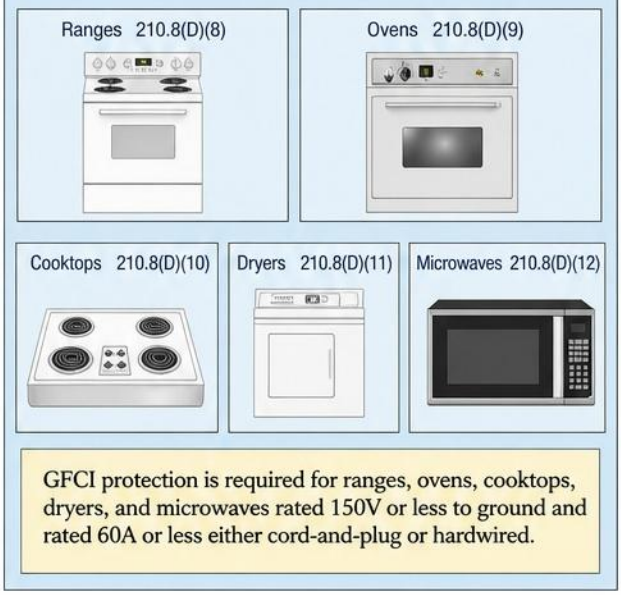


Figure 210–71 Cooking Units and Clothes Dryer 210.8(D)(8) to (12)



Author's Comment:

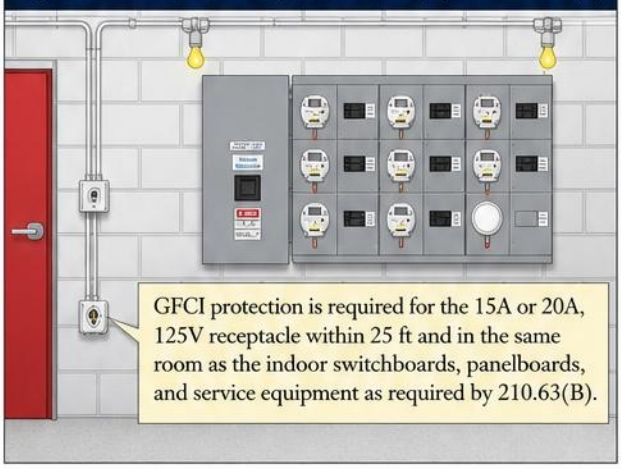
- Electric shock hazards exist whether appliances are hard-wired or cord-and-plug connected. GFCI protection is required for the appliance branch circuit or outlet.

(E) Equipment Requiring Servicing.

Air-Conditioning Equipment. GFCI protection is required for 15A or 20A, 125V receptacles within 25 ft of the air-conditioning equipment as required in 210.63(A).

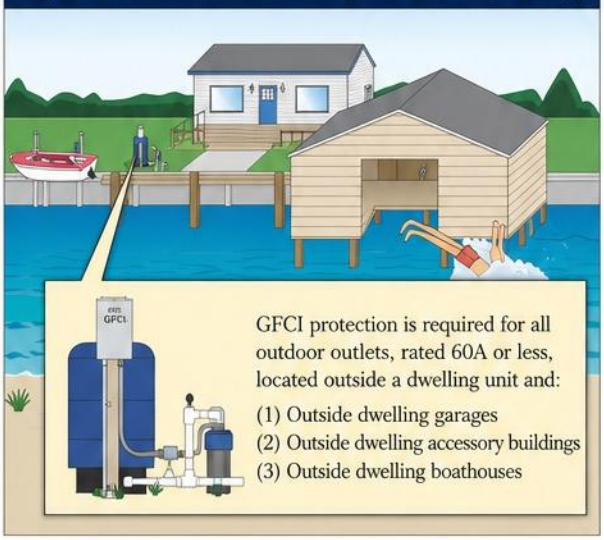
Indoor Equipment. GFCI protection is required for 15A or 20A, 125V receptacles within 25 ft and in the same room as the indoor switchboards, panelboards, and service equipment as required by 210.63(B). ▶ Figure 210–72

Figure 210–72 Service Receptacle Indoor Equipment 210.8(E)



(F) Outdoor Dwelling Unit Outlets. GFCI protection is required for all outdoor outlets, rated 60A or less, located outside a dwelling unit and: **Figure 210–73**

Figure 210–73 Outdoor Dwelling Unit Outlets | 210.8(F)



(1) Outside dwelling garages

(2) Outside dwelling accessory buildings

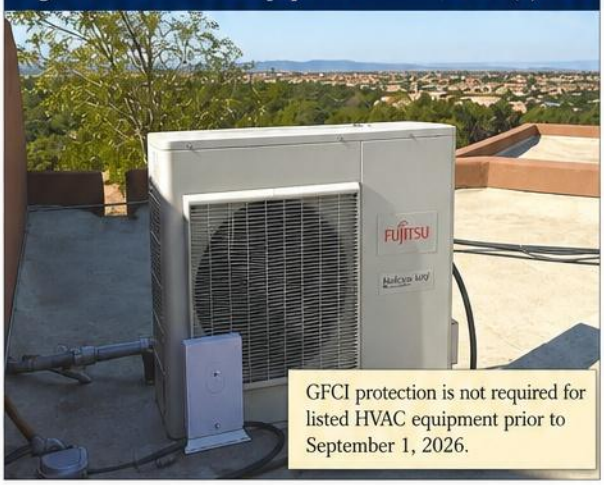
(3) Outside dwelling boathouses

Outlet: A point on the wiring system at which current is taken to supply utilization equipment.

If equipment connected to any of the above outdoor outlets is replaced, the circuit to the outlet must be GFCI protected.

Ex 2: GFCI protection is not required for listed HVAC equipment prior to September 1, 2026. **Figure 210–74**

Figure 210–74 HVAC Equipment | 210.8(F) Ex 2



Author's Comment:

- In accordance with *UL 60335-2-40*, listed HVAC equipment includes air-conditioning and heat pumps used for cooling and heating.

210.11 Branch Circuits Required

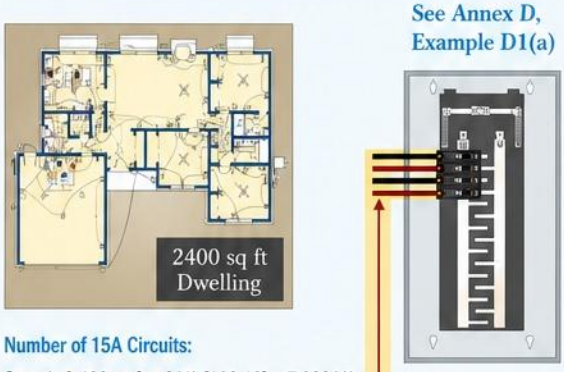
(A) Number of Branch Circuits. The number of branch circuits required is determined by dividing the total calculated load by the ampere rating of the circuit.

▶ Dwelling 15A Circuit [210.11(A)] Example

Question: *How many 15A, 120V circuits are required for the general lighting and general-use receptacles load for a 2,400 sq ft dwelling unit?* **Figure 210–75**

(a) 2 circuits (b) 3 circuits (c) 4 circuits (d) 5 circuits

Figure 210–75 Number of Branch Circuits Required 210.11(A) Dwelling Unit Example 1



Number of 15A Circuits:

Step 1: 2,400 sq ft × 3 VA [120.13] = 7,200 VA

Step 2: 7,200 VA/120V = 60A

Step 3: 60A/15A = **4 Circuits**

Solution:

Step 1: *Determine the total VA load.*

VA = 2,400 sq ft × 3 VA per sq ft [120.13]

VA = 7,200 VA

Step 2: *Determine the amperes.*

I = Volt-Amperes / Volts

I = 7,200 VA / 120V

I = 60A

Step 3: *Determine the number of circuits.*

Number of 15A Circuits = 60A/15A
Number of 15A Circuits = 4

Answer: *(c) 4 circuits*

Author's Comment:

- Although dwelling unit general lighting and general-use receptacle loads are now calculated at 2VA/sq ft (120.41), the number of branch circuits required is based on 3VA/sq ft (120.13).

▶ Dwelling 20A Circuit [210.11(A)] Example

Question: *How many 20A, 120V circuits are required for the general lighting and general-use receptacles load for a 2,400 sq ft dwelling unit?*

(a) 1 circuit *(b) 3 circuits* *(c) 4 circuits* *(d) 5 circuits*

Solution:

Step 1: *Determine the total VA load.*

VA = 2,400 sq ft × 3 VA per sq ft [120.13]
VA = 7,200 VA

Step 2: *Determine the amperes.*

I = Volt-Amperes/Volts
I = 7,200 VA/120V
I = 60A

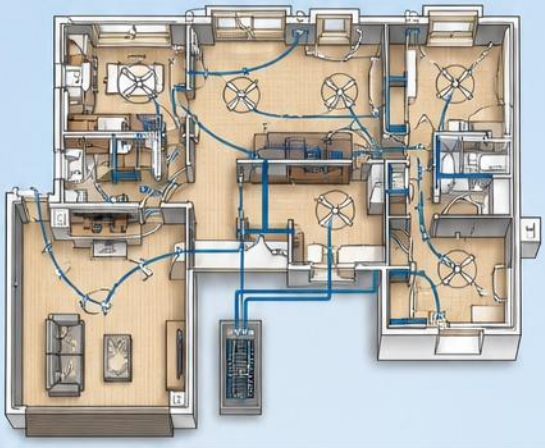
Step 3: *Determine the number of circuits.*

Number of 20A Circuits = 60A/20A
Number of 20A Circuits = 3

Answer: *(b) 3 circuits*

(B) Evenly Proportioned Load Among Branch Circuits. If the load is calculated based on VA per sq ft, the wiring system must serve the calculated load. The load must be evenly proportioned among the branch circuits within the panelboard.

Figure 210–76 **Evenly Proportion the Load Among Branch Circuits** **210.11(B)**



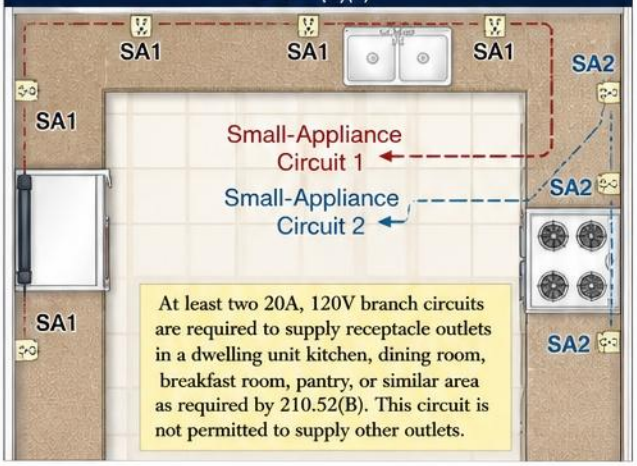
House = 2,148 square feet
2,148 sq ft × 3 VA = 6,444 VA/120V = 53.70A/15A = 3.58
= 3.58 = Minimum of four 15A general lighting and general-use receptacle circuits

The calculated load is based on VA per sq ft and must be evenly apportioned among the branch circuits within the panelboard.

(C) Dwelling Unit, Circuits Required.

(1) Small-Appliance Branch Circuits. At least two 20A, 120V branch circuits are required to supply receptacle outlets in a dwelling unit kitchen, dining room, breakfast room, pantry, or similar area as required by 210.52(B). This circuit is not permitted to supply lighting outlets or any other receptacle outlets. Figure 210–77

Figure 210–77 **Small-Appliance Branch Circuits Dwelling Unit** *210.11(C)(1)*



Author's Comment:

- Two 20A small-appliance branch circuits can be supplied by one 3-wire multiwire circuit or two separate 120V circuits [210.4(A)].

(2) Laundry Area Branch Circuit. One 20A, 120V branch circuit is required to feed the receptacle outlets for a dwelling unit laundry area as required by 210.52(F). This circuit is not permitted to supply lighting outlets or any other receptacle outlets.

Figure 210–78 Laundry Area Branch Circuit 210.11(C)(2)

At least one 20A, 120V branch circuit is required to feed the receptacle outlets for a dwelling unit laundry area as required by 210.52(F). This circuit is not permitted to supply other outlets.

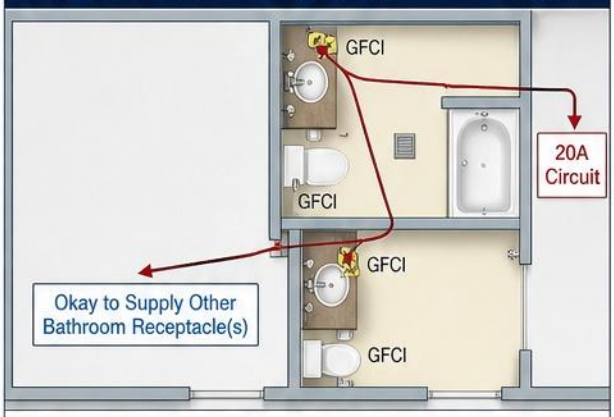
Author's Comment:

- The laundry receptacle circuit is permitted to feed the clothes washer and gas dryer receptacle outlet if the washer does not exceed 80 percent of the branch-circuit ampere rating [210.23(B)(1)].
- A 20A, 120V laundry branch circuit is required even if the laundry appliance is a 30A, 240V combination washer/dryer. ▸Figure 210–79

Figure 210–79 Laundry Area Branch Circuit Comment 210.11(C)(2)

(3) Bathroom Branch Circuit. One 20A, 120V branch circuit is required to feed the dwelling unit bathroom sink receptacle outlets as required by 210.52(D). This circuit is not permitted to supply lighting outlets or any other receptacle outlets.

Figure 210–80 Bathroom Branch Circuit 210.11(C)(3)



At least one 20A, 120V branch circuit is required to feed the dwelling unit bathroom sink receptacle outlets required by 210.52(D).

Figure 210–81 Bathroom Branch Circuit 210.11(C)(3)

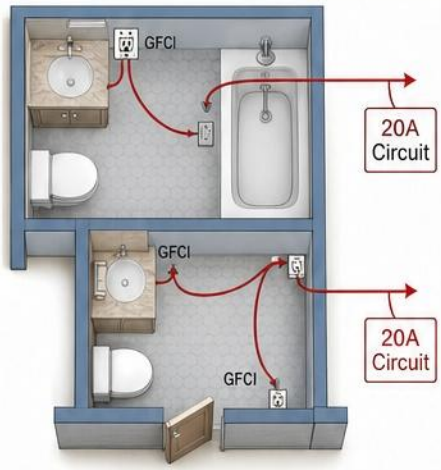
The 20A, 120V bathroom circuit is not permitted to supply lighting, fans, heaters, or other receptacle outlets used for any other purpose.

Author's Comment:

- The 20A, 120V bathroom circuit is only permitted to feed the required bathroom sink receptacle outlets [210.52(D)] in one or more bathrooms.

Ex: *A single 20A, 120V branch circuit can supply all the outlets in a single bathroom in accordance with 210.23(B)(1) and (B)(2).* ▸Figure 210–82

Figure 210-82 Bathroom Branch Circuit 210.11(C)(3) Ex

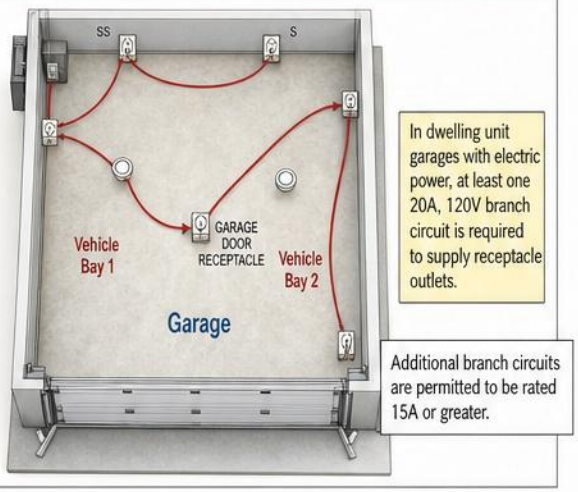


A single 20A, 120V branch circuit can supply all the outlets in a single bathroom area.

(4) Garage Branch Circuits. In dwelling unit garages with electric power, one 20A, 120V branch circuit is required to supply receptacle outlets. This circuit is permitted to supply other garage receptacle outlets, but not outlets in other areas of the dwelling unit.

Branch circuits are permitted in addition to the required 20A, 120V garage vehicle bay branch circuit.

Figure 210-83 Garage Branch Circuit Dwelling Unit 210.11(C)(4)



Ex 1: Outdoor receptacle outlets can be supplied by the 20A, 120V garage branch circuit. (Figure 210-84)

Ex 2: The 20A, 120V garage branch circuit is permitted to supply other outlets in addition to receptacle outlets in a single-vehicle bay garage. (Figure 210-85)

Figure 210-84 Garage Branch Circuit Dwelling Unit 210.11(C)(4) Ex 1

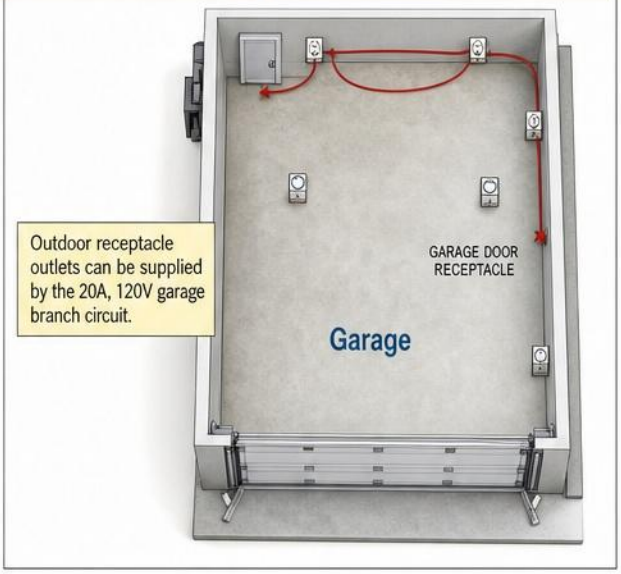
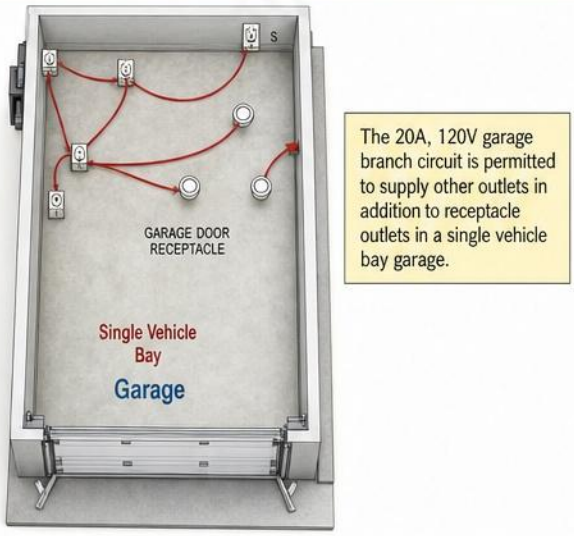


Figure 210-85 Garage Branch Circuit Dwelling Unit, Single Vehicle Bay 210.11(C)(4) Ex 2



210.12 Arc-Fault Circuit-Interrupter Protection

AFCI protection is required in accordance with 210.12(B) through (E), and the *AFCI* device must be located at a readily accessible location.

Arc-Fault Circuit Interrupter (AFCI). A device intended to de-energize the circuit when it detects the current waveform characteristics unique to an arcing fault. (Figure 210-86)

Figure 210–86 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 210–87 AFCI Protection, Dwelling Units 210.12(B)

- Bedrooms
- Closets
- Dens
- Dining Rooms
- Family Rooms
- Hallways
- Kitchens
- Laundry Areas
- Libraries
- Living Rooms
- Parlors
- Rec Rooms
- Sunrooms
- Similar Areas

AFCI protection is required for 15A or 20A, 120V branch circuits listed above.

(B) Dwelling Units. AFCI protection is required for 15A or 20A, 120V branch circuits in the following dwelling unit locations:

(1) Kitchens

(2) Family rooms

(3) Dining rooms

(4) Living rooms

(5) Parlors

(6) Libraries

(7) Dens

(8) Bedrooms

(9) Sunrooms

(10) Recreation rooms

(11) Closets

(12) Hallways

(13) Laundry areas

(14) Similar areas ▶Figure 210–87

Ex 1: *AFCI protection is not required for an individual branch circuit supplying a fire alarm system.*

Author's Comment:

▶ According to the *NFPA Handbook*, smoke alarms not powered and controlled by a fire alarm control panel are not considered to be part of the fire alarm system. As a result, the dwelling unit circuit supplying smoke alarms must have AFCI protection. ▶Figure 210–88

Figure 210–88 AFCI Protection, Dwelling Units Smoke Alarms 210.12(B) Comment

According to the *NFPA Handbook*, smoke alarms not powered and controlled by a fire alarm control panel are not considered to be part of the fire alarm system. Therefore, the circuit supplying smoke alarms must have AFCI protection in dwelling units.

(C) Dormitories. AFCI protection is required for 15A or 20A, 120V branch circuits in the following dormitory unit locations:

(1) Bedrooms

(2) Living rooms

(3) Hallways

(4) Closets

(5) Bathrooms

(6) Similar rooms ▸Figure 210–89

Figure 210–89 Similar Rooms in a Dormitory 210.12(C)

AFCI protection is required for 15A or 20A, 120V branch circuits in dormitory bedrooms, living rooms, hallways, closets, bathrooms, or similar rooms.

Dormitory. A space in which sleeping accommodations are provided for more than 16 persons not of the same family, under joint occupancy and single management, but without individual cooking facilities. ▸Figure 210–90

Figure 210–90 Dormitory (*Article 100 Definition*)

A space in which sleeping accommodations are provided for more than 16 persons not of the same family, under joint occupancy and single management, but without individual cooking facilities.

(D) Other Occupancies. AFCI protection is required for 15A or 20A, 120V branch circuits in the following locations:

(1) Guest rooms and guest suites of hotels and motels ▸Figure 210–91

Figure 210–91 Hotel Guest Room and Guest Suite 210.12(D)(1)

AFCI protection is required for 15A and 20A, 120V branch circuits in guest rooms and guest suites of hotels and motels.

Guest Room. An accommodation space combining living, sleeping, sanitary, and storage. ▸Figure 210–92

Figure 210–92 Guest Room (*Article 100 Definition*)

An accommodation space combining living, sleeping, sanitary, and storage.

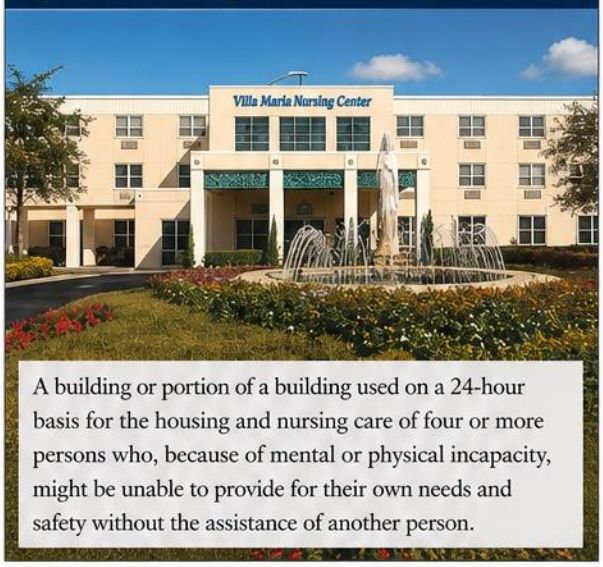
Guest Suite. An accommodation space with two or more rooms that provides living, sleeping, sanitary, and storage. ▸Figure 210–93

(2) Nursing homes and limited care facilities areas used exclusively as patient sleeping rooms ▸Figure 210–94

Figure 210-93 Guest Suite *Article 100 Definition*

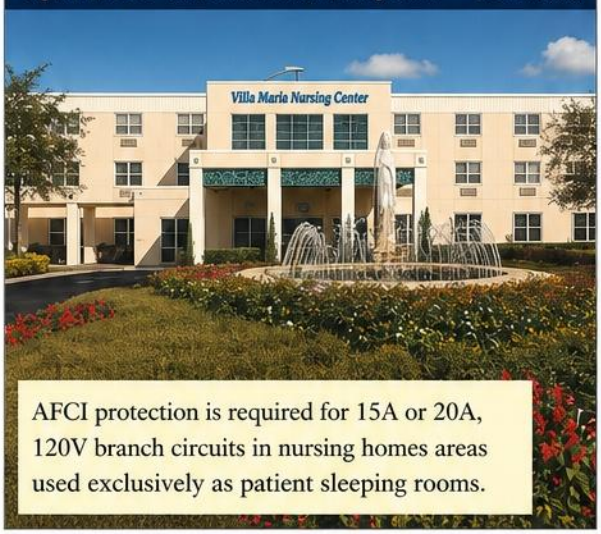
An accommodation space with two or more rooms that provides living, sleeping, sanitary, and storage.

Figure 210-95 Nursing Home *Article 100 Definition*



A building or portion of a building used on a 24-hour basis for the housing and nursing care of four 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.

Figure 210-94 AFCI Protection, Nursing Home *210.12(D)(2)*



AFCI protection is required for 15A or 20A, 120V branch circuits in nursing homes areas used exclusively as patient sleeping rooms.

Figure 210-96 Limited Care Facility *Article 100 Definition*

A building or an area used for the housing, on a 24-hour basis, of four or more persons who are incapable of self-preservation.

Nursing Home. A building or portion of a building used on a 24-hour basis for the housing and nursing care of four 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. (Figure 210-95)

Limited Care Facility. A building or an area of a building used for the 24-hour housing of four or more persons who are incapable of self-preservation because of their condition. These conditions include age, physical limitations due to accident or illness, or limitations such as intellectual disability, developmental disability, mental illness, or chemical dependency. (Figure 210-96)

(3) Areas designed for use exclusively as sleeping quarters in fire stations, police stations, ambulance stations, rescue stations, ranger stations, and similar locations (Figure 210-97)

(E) Branch-Circuit Wiring Extensions or Replacements. If the wiring is extended or replaced in any of the areas specified in 210.12(B), (C), or (D) for 15A or 20A, 120V branch circuits must be provided with AFCI protection using:

(1) AFCI circuit breaker

(2) AFCI receptacle or AFCI-protected switch at the first outlet of the existing branch circuit (Figure 210-98)

Figure 210–97 Other Occupancies, Sleeping Quarters 210.12(D)(3)

AFCI protection is required for 15A and 20A, 120V branch circuits in sleeping quarter areas in fire stations, police stations, ambulance stations, rescue stations, ranger stations, and similar locations.

Figure 210–98 Wiring Extensions or Replacements 210.12(E)

If the wiring is extended or replaced in any of the areas specified in 210.12(B), (C), or (D) for 15A or 20A, 120V branch circuits must be provided with AFCI protection using:

(1) AFCI circuit breaker

(2) AFCI receptacle or AFCI protected switch at the first outlet of the existing branch circuit

Ex: AFCI protection is not required for extension wiring that is less than 6 ft in length—if no outlets are added. This measurement does not include the conductors inside an enclosure, cabinet, or junction box.

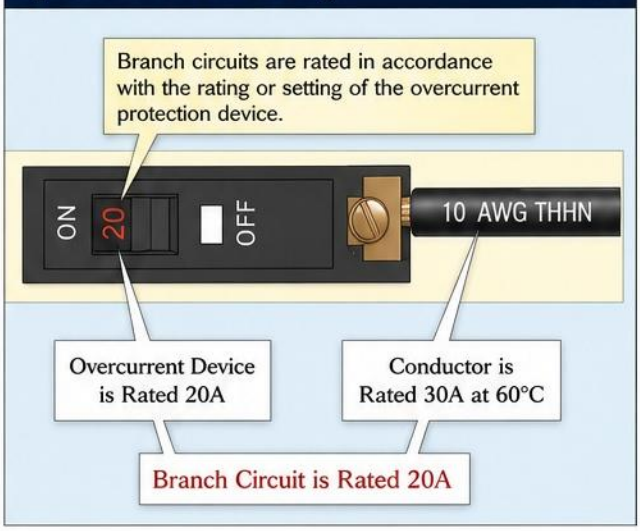
Part II. Branch-Circuit Ratings

210.18 Branch Circuit Rating

Branch circuits are rated in accordance with the rating or setting of the overcurrent protection device. Where conductors of higher ampacity are used for any reason, the ampere rating or setting of the overcurrent protection device determines the circuit rating. ▸Figure 210–99

Ex 2: Branch circuits rated 10A must not supply receptacle outlets.

Figure 210–99 Branch-Circuit Ratings 210.18



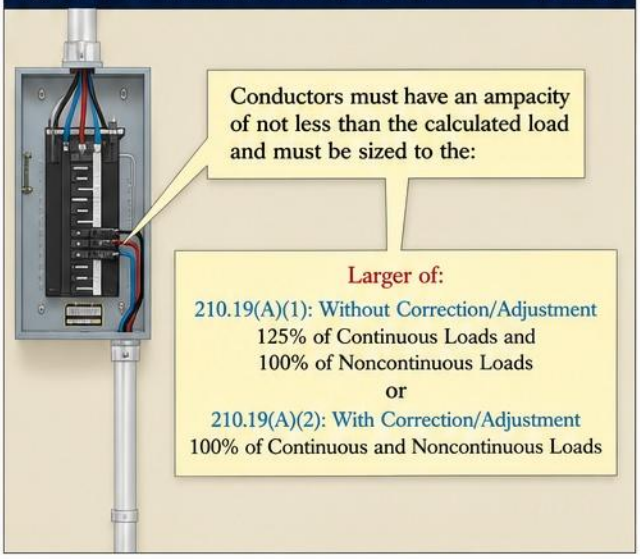
210.19 Conductor Sizing

Branch circuit conductors must have an ampacity in accordance with 210.19(A) through (D).

Note: Conductors for branch circuits sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power and the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent provide reasonable efficiency of operation.

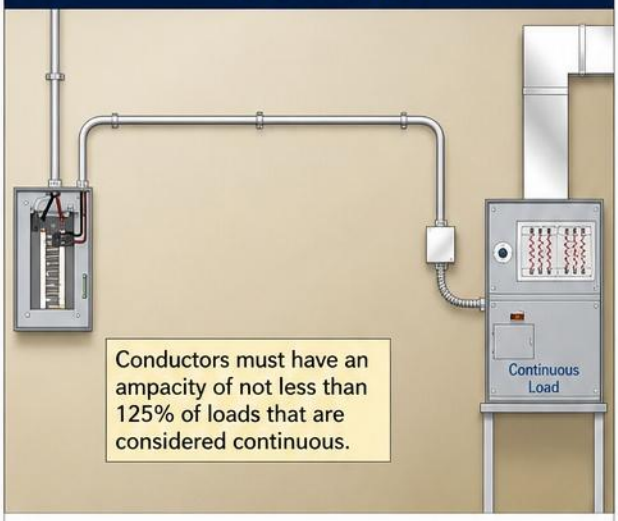
(A) General. Branch-circuit conductors must have an ampacity no less than the calculated load and must be sized to the larger of either 210.19(A)(1) or (2). ▸Figure 210–100

Figure 210–100 Branch-Circuit Conductor Ampacity 210.19(A)



(1) Continuous and Noncontinuous Loads. Branch circuit conductors must be sized with an ampacity of not less than 125 percent of all *continuous loads*, plus 100 percent of all noncontinuous loads. Figure 210–101

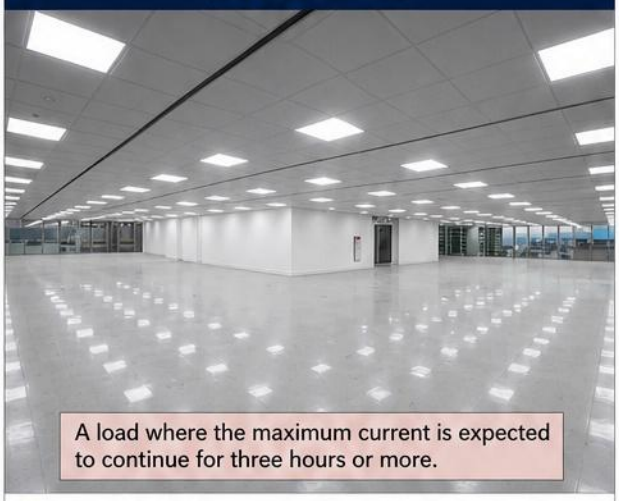
Figure 210–101 Branch-Circuit Conductor Ampacity for Continuous Loads 210.19(A)(1)



Branch-circuit conductors serving continuous loads must be sized for an ampacity of at least 125 percent of those loads.

Continuous Load. A load at which the maximum current is expected to continue for three hours or more. Figure 210–102

Figure 210–102 Continuous Load (Article 100 Definition) 210.19



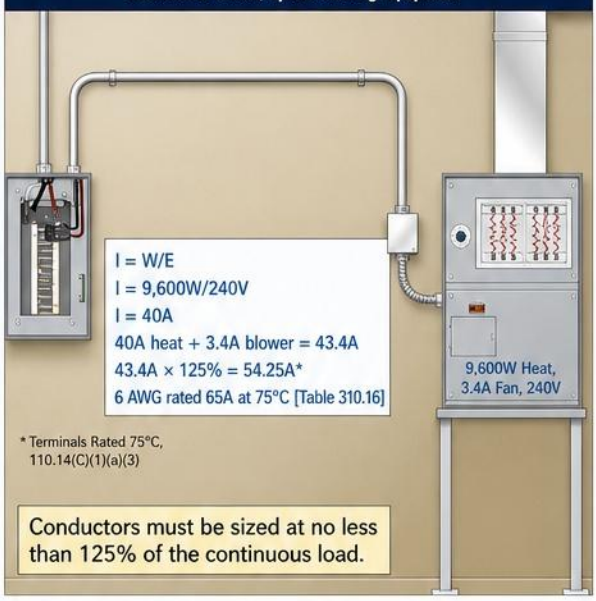
Examples include lighting systems in offices, retail spaces, and other installations expected to operate for extended periods.

Branch Circuit Conductor Sizing [210.19(A)(1)] Example 1

Question: *What size conductor is required for a circuit supplying a 44A continuous load where the equipment is rated for 75°C conductors?*

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 3 AWG

Figure 210–103 Branch-Circuit Conductor Sizing for Continuous Loads, Space-Heating Equipment 210.19(A)(1)



The branch-circuit conductors for this heating equipment must be sized for at least 125 percent of the continuous load.

Solution:

Step 1: *The conductor must have an ampacity not less than 125% of the nameplate rating of the equipment.*

Conductor Ampacity = 44A × 125%

Conductor Ampacity = 55A

Step 2: *Size the conductor in accordance with 110.14(C)(1)(a)(3) and Table 310.16.*

6 AWG rated 65A at 75°C [Table 310.16]

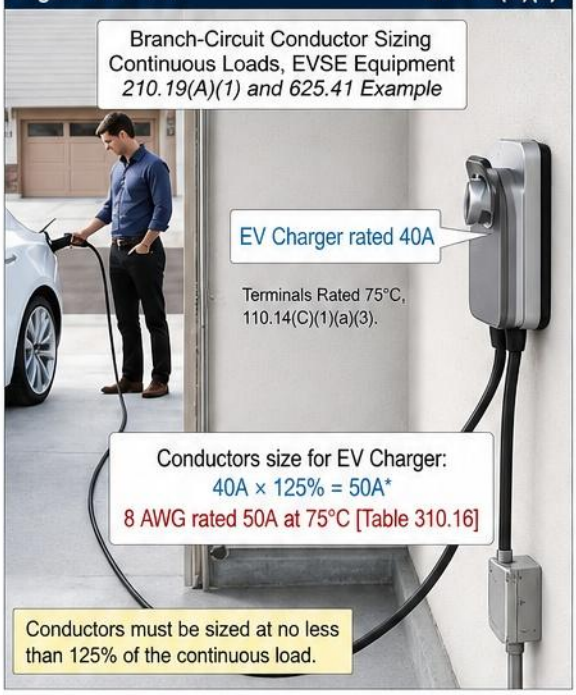
Answer: *(b) 6 AWG*

▶ Branch Circuit Conductor Sizing [210.19(A)(1)] Example 2

Question: What size conductor is required for an EV charger rated 40A continuous where the equipment is rated for 75°C conductors?

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 3 AWG

Figure 210–104 **210.19(A)(1)**



Solution:

Note: *The circuit for EV charging is considered a continuous load [625.41].*

Step 1: The conductor must have an ampacity not less than 125% of the nameplate rating of the EV equipment.

Conductor Ampacity = 40A × 125%
Conductor Ampacity = 50A

Step 2: Size the conductor in accordance with 110.14(C)(1)(a)(3) and Table 310.16.

8 AWG rated 50A at 75°C [Table 310.16]

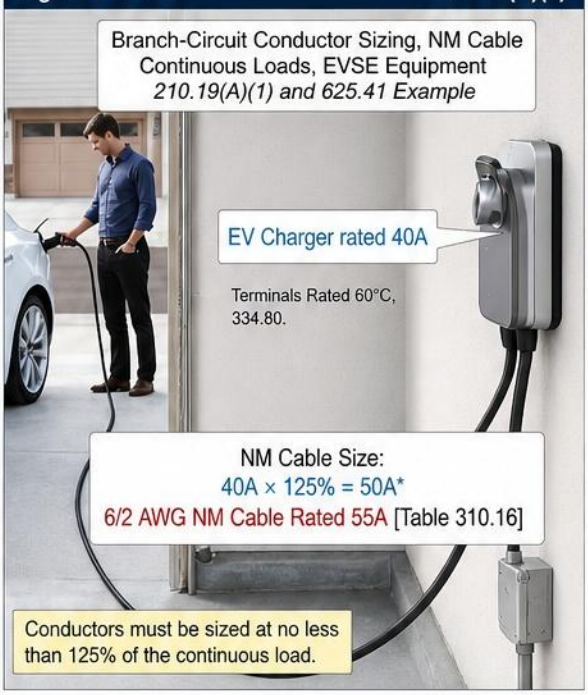
Answer: (a) 8 AWG

▶ Branch Circuit Conductor Sizing [210.19(A)(1)] Example 3

Question: What size conductor is required for an EV charger rated 48A continuous where the equipment is rated for 75°C conductors?

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 3 AWG

Figure 210–105 **210.19(A)(1)**



Solution:

Note: *The circuit for EV charging is considered a continuous load [625.41].*

Step 1: The conductor must have an ampacity not less than 125% of the nameplate rating of the EV equipment.

Conductor Ampacity = 48A × 125%
Conductor Ampacity = 60A

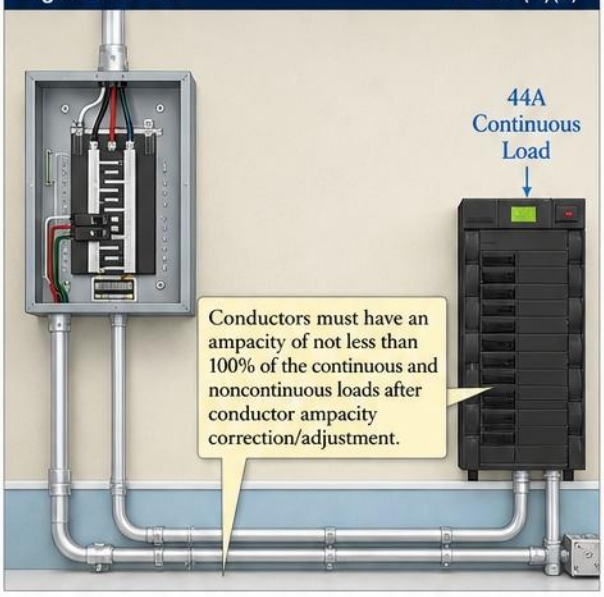
Step 2: Size the conductor in accordance with 110.14(C)(1)(a)(3) and Table 310.16.

6 AWG rated 60A at 75°C [Table 310.16]

Answer: (b) 6 AWG

(2) Ampacity Correction and/or Adjustment Factor. Branch circuit conductors must have an ampacity of no less than 100 percent of the continuous and noncontinuous loads after conductor ampacity correction and/or adjustment in accordance with Table 310.15(B)(1)(1) and Table 310.15(C)(1). ▶Figure 210–106

Figure 210–106 210.19(A)(2)



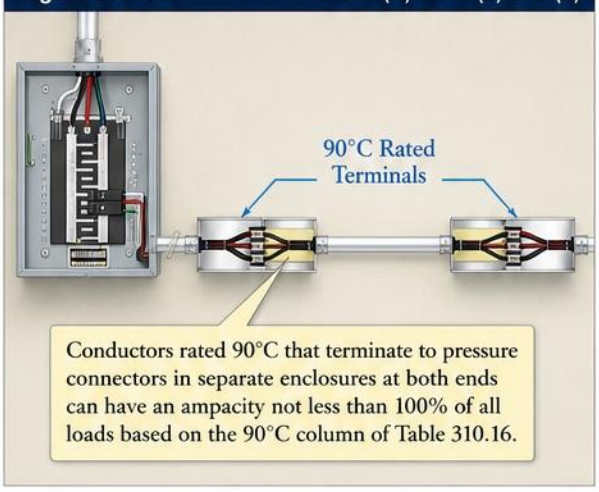
Conductors sized to handle 100% of the adjusted load.

Author's Comment:

The temperature ampacity correction of 310.15(B)(1)(1) and ampacity adjustment factors of 310.15(C)(1) are applied to the ampacities listed in Table 310.16. This is based on the conductor insulation temperature rating, which is typically THWN-2, 90°C [310.15(A)].

Ex to (1) and (2): Conductors rated 90°C that terminate to pressure connectors in separate enclosures or wireways at both ends in accordance with 110.14(C)(2) can have an ampacity not less than the sum of the continuous and noncontinuous load (100 percent of all loads). This is based on the 90°C column of Table 310.16. Figure 210–107

Figure 210–107 210.19(A) Ex to (1) and (2)



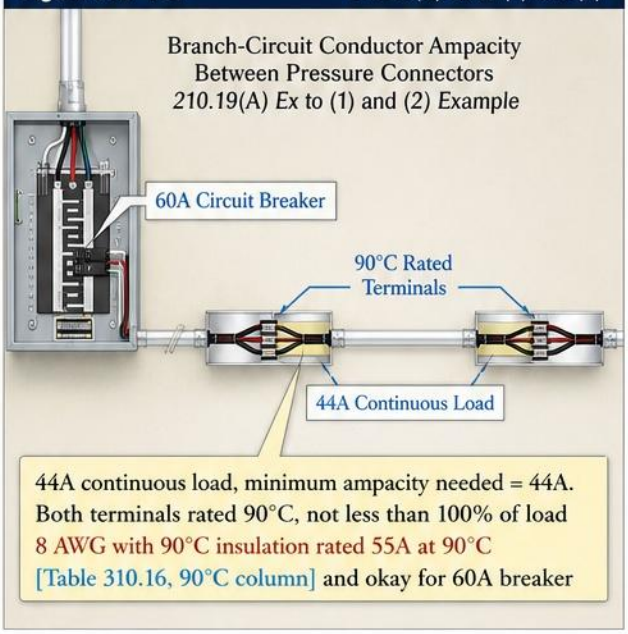
Full-load ampacity allowed when both ends use 90°C pressure connectors.

► Branch Circuit 90°C Conductor Size [210.19(A) Ex to (1) and (2)] Example

Question: *What size branch-circuit conductors rated 90°C are required between terminals rated 90°C for a circuit supplying a 44A continuous load where the conductors are protected by a 60A breaker?* Figure 210–108

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

Figure 210–108 210.19(A) Ex to (1) and (2)



Using 90°C conductors between 90°C pressure connectors.

Solution:

Size the conductors in accordance with 110.14(C)(2) and Table 310.16.

When terminals at each end of a conductor have different terminal temperature ratings, use the lower temperature rating when sizing conductors from Table 310.16.

The terminals are both rated 90°C, so the conductors are selected in accordance with the 90°C column of Table 310.16.

Based on the 44A load at 100 percent, 8 AWG is rated 55A at 90°C. It is permitted to be protected by a 60A overcurrent protective device [240.4(B)].

Answer: *(b) 8 AWG*

(B) Branch Circuits with More than One Receptacle. Branch circuit conductors supplying more than one receptacle for cord-and-plug-connected portable loads must have an ampacity no less than the rating of the branch circuit.

AUTHOR'S COMMENT:

- This rule prohibits the common practice of using a 14 AWG pigtail from 12 AWG to supply a 15A receptacle on a 20A circuit.

(D) Other Loads. Branch-circuit conductors that supply loads other than those specified in 210.14 and other than cooking appliances as covered in 210.19(C) must have an ampacity sufficient for the loads served and cannot be smaller than 14 AWG.

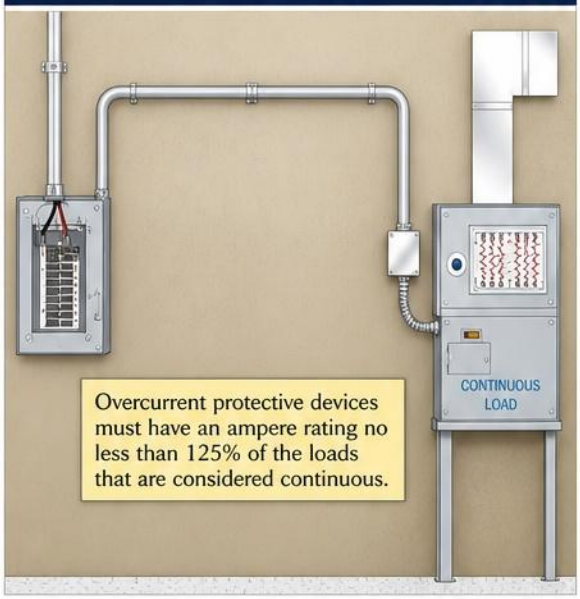
210.20 OVERCURRENT PROTECTION

Branch-circuit conductors must be protected by overcurrent protective devices with a rating or setting provided in 240.6(A) that complies with the following:

(A) Continuous and Noncontinuous Loads. Overcurrent protective devices must have an ampere rating no less than 125 percent of the continuous loads, plus 100 percent of the noncontinuous loads.

▶ Figure 210–109

Figure 210–109 Overcurrent Protection—Continuous Loads 210.20(A)



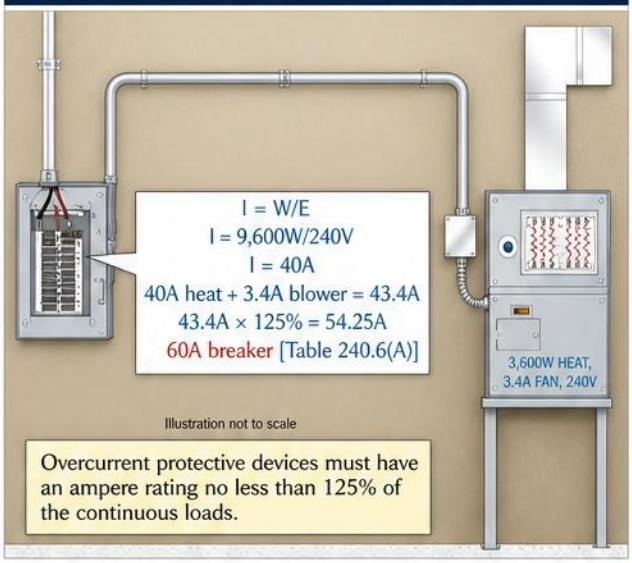
The overcurrent device must be sized at least 125% of the continuous load.

▶ Branch Circuit OCPD Sizing [210.20(A)] Example

Question: *What size circuit breaker is required for a branch circuit that has a 44A continuous load?* ▶ Figure 210–110

(a) 20A *(b) 30A* *(c) 50A* *(d) 60A*

Figure 210–110 Branch-Circuit Conductor Sizing—Continuous Loads, Space-Heating Equipment 210.20(A) and 424.5 Example



Size the overcurrent device using 125% of the continuous load.

Solution:

Protection Rating = 44A × 125%

Protection Rating = 55A

60A circuit breaker [Table 240.6(A)]

Answer: *(d) 60A*

210.21 RECEPTACLE RATING

(B) Receptacle Rating and Load Capacity.

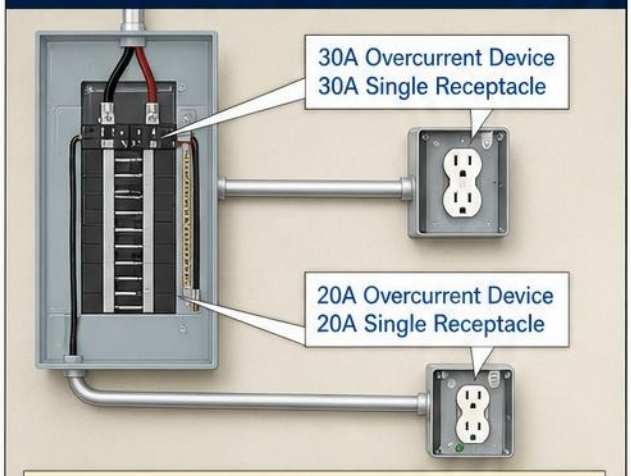
(1) Single Receptacle. A single receptacle on an individual branch circuit must have an ampere rating not less than the rating of the branch circuit. ▶ Figure 210–111

Note: A single receptacle has only one contact device on its yoke. A duplex receptacle is not a single receptacle because it has two receptacles on the yoke of a receptacle.

Receptacle. A contact device installed at an outlet for the connection of an attachment plug. ▶ Figure 210–112

A single receptacle contains one contact device on the same yoke. A multiple receptacle has more than one contact device on the same yoke. ▶ Figure 100–113

Figure 210–111 Single Receptacle Rating on Branch Circuits **210.21(B)(1)**

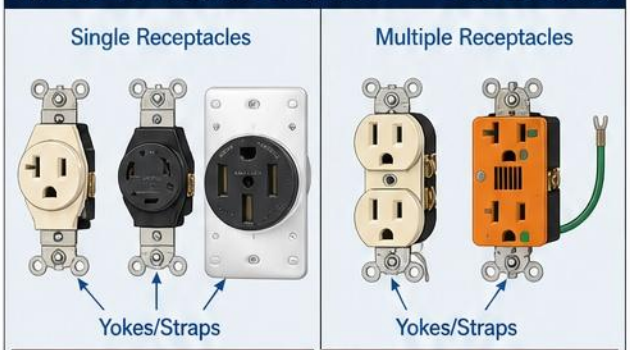


A single receptacle on an individual branch circuit must have an ampere rating that is not less than the rating of the branch-circuit overcurrent protective device.

Figure 210–112 Receptacle Types *Article 100 Definition*

A contact device for the connection of an attachment plug.

Figure 210–113 Receptacle Configurations *Article 100 Definition*



A single receptacle contains one contact device on the same a yoke.

A multiple receptacle has more than one contact device on the same yoke.

Branch Circuit, Individual. A branch circuit that supplies only one utilization equipment. ▸ Figure 210–114

Figure 210–114 Individual Branch Circuit *Article 100 Definition*

(2) Total Cord-and-Plug-Connected Load. Receptacles connected to a branch circuit supplying two or more receptacles are not permitted to supply a total cord-and-plug-connected load in excess of the maximum specified in Table 210.21(B)(2).

Table 210.21(B)(2) Maximum Receptacle Load (Two or More Receptacles)

Circuit Rating	Receptacle Rating	Maximum Load
15A or 20A	15A	12A
20A	20A	16A
30A	30A	24A

(3) Multiple Receptacles. Where two or more receptacles are connected to a branch circuit, their ampere ratings must be in accordance with Table 210.21(B)(3).

Author's Comment:

- 15A or 20A receptacles are permitted on a 20A multioutlet circuit. ▸ Figure 210–115

Figure 210–115 | Branch Circuits, Multiple Receptacles **210.23**

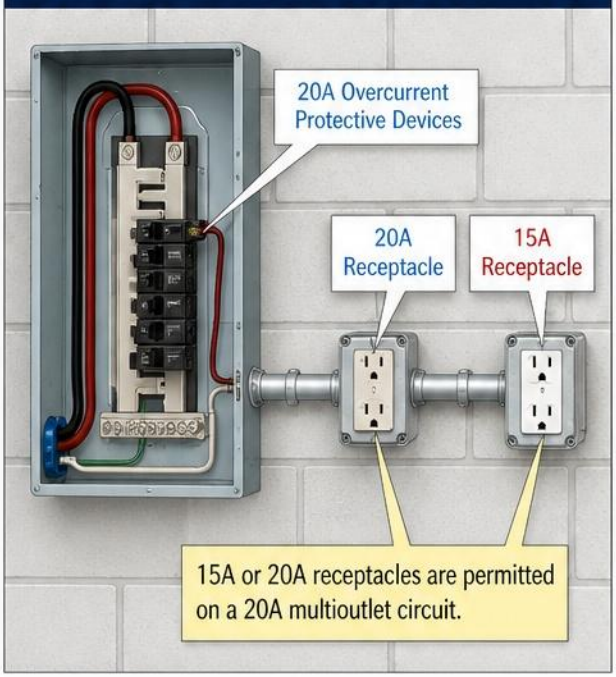


Table 210.21(B)(3) Receptacle Ratings (Two or More Receptacles)

Circuit Rating	Receptacle Rating
15A	15A
20A	15A or 20A
30A	30A
40A	50A
50A	50A

210.22 Permissible Loads, Individual Branch Circuits

An individual branch circuit must have an ampere rating sufficient for the load in accordance with manufacturers instructions.

Individual Branch Circuit Example

Question: *What size individual branch circuit is required for a hood/microwave rated 14.5A?* ▸ Figure 210–116

(a) 10A (b) 15A (c) 20A (d) 25A

Figure 210–116 | Individual Branch Circuits Permissible Load **210.22**

ELECTRICAL REQUIREMENTS

Product rating is 120 volts AC, 60 Hertz, 14.5 amps and 1.7 kilowatts. This product must be connected to a supply circuit of the proper voltage and frequency. Wire size must conform to the requirements of the National Electrical Code or the prevailing local code for this kilowatt rating. The power supply cord and plug should be brought to a separate 15- to 20-ampere branch circuit single grounded outlet. The outlet box should be located in the cabinet above the microwave oven. The outlet box and supply circuit should be installed by a qualified electrician and conform to the National Electrical Code or the prevailing local code.

An individual branch circuit must have an ampere rating sufficient for the load.

Solution:

An individual 15A branch circuit is required for a hood/microwave rated 14.5A, 120V.

Answer: *(b) 15A*

Ex: *A 10A individual branch circuit cannot supply receptacle outlets.*

210.23 Multiple-Outlet Branch Circuits

(A) 10-Ampere Branch Circuits. 10-ampere branch circuits are limited to supply either of the following:

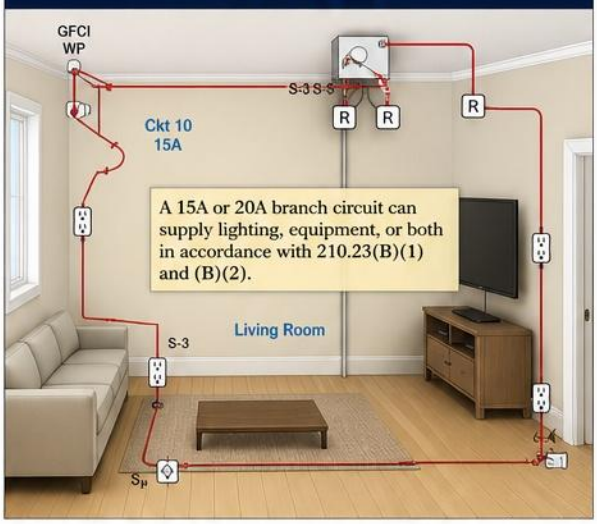
(1) Lighting outlets

(2) Dwelling unit exhaust fans on bathroom and laundry room lighting circuits

(B) 15A or 20A Branch Circuits. A 15A or 20A branch circuit can supply lighting, equipment, or both as follows: ▸ Figure 210–117

(1) **Cord-and-Plug-Connected Equipment.** Cord-and-plug-connected equipment not fastened in place with other outleets is not permitted to exceed 80 percent of the branch-circuit rating.

Figure 210–117 210.23(B)
Multioutlet 15A and 20A Branch Circuits
Permissible Loads



A 15A or 20A branch circuit may serve lighting, equipment, or both in accordance with 210.23(B)(1) and (B)(2).

(2) Equipment Fastened in Place. Equipment that is secured in place may be connected to the same circuit as luminaires and cord-and-plug-connected equipment that is not fastened in place, but the equipment that is secured in place must not account for more than 50 percent of the branch-circuit rating.

Figure 210–118 210.23(B)(2)
Multioutlet 15A and 20A Branch Circuits
Equipment Fastened in Place

Equipment secured in place can share a circuit with lighting and cord-and-plug-connected equipment that is not secured in place, provided the secured-in-place equipment does not exceed 50% of the branch-circuit rating.

Part III. Required Outlets

210.50 Receptacle Outlets

(C) Appliance Receptacle Outlets. Receptacle outlets in dwelling units for specific appliances such as washing machines, dryers, ranges, garage door openers, or refrigerators must be within 6 ft of the intended location of the appliance.

Figure 210–119 210.50(C)
Dwelling Unit Receptacle Outlet
Specific Appliance, Within 6 Ft

Receptacle outlets for specific appliances in dwelling units must be located within 6 ft of where the appliance is intended to be used.

210.52 Dwelling Unit Receptacle Outlet Requirements

The receptacle outlets required by 210.52 are in addition to any receptacle outlets located as follows:

(1) Receptacles that are part of a luminaire or appliance

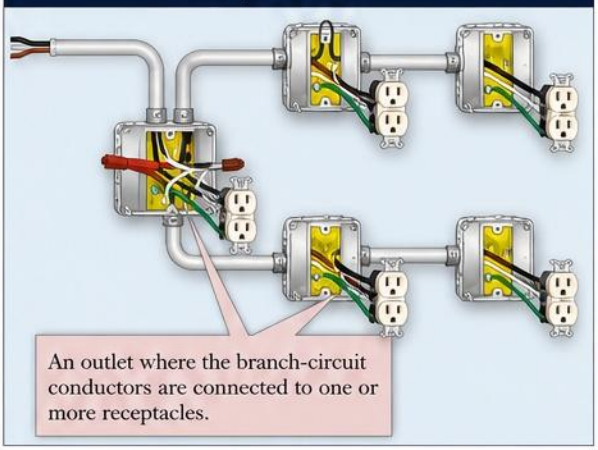
(2) Receptacles controlled by a wall switch or listed wall-mounted control device in accordance with 210.70(A)(1) Ex 1

(3) Receptacle outlets located within cabinets or cupboards

(4) Receptacle outlets located more than 5½ ft above the floor

Receptacle Outlet. An outlet where the branch-circuit conductors are connected to one or more receptacles.

Figure 210–120 Article 100 Definition
Receptacle Outlet

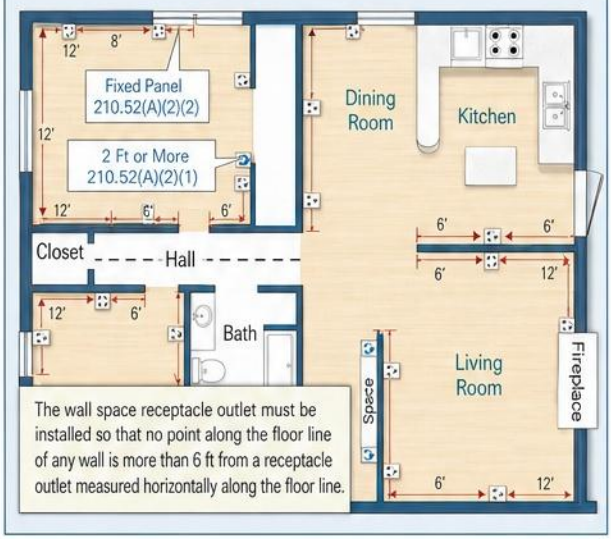


(A) GENERAL REQUIREMENTS FOR RECEPTACLE OUTLETS

A receptacle outlet must be installed along the walls for every kitchen, family room, dining room, living room, sunroom, parlor, library, den, bedroom, recreation room, and similar areas as follows:

(1) Wall Space Receptacle Outlet Spacing. The wall space receptacle outlet must be installed so that no point along the floor line of any wall is more than 6 ft from a receptacle outlet measured horizontally along the floor line. Figure 210–121

Figure 210–121 Wall Space Receptacle Outlet Spacing Requirements 210.52(A)(1)



Author's Comment: ▶ The purpose of this rule is to ensure there are enough general-purpose receptacles conveniently located to reduce the chance that an extension cord will be used.

(2) Wall Space Definition. The wall space for receptacle outlet placement includes the following:

(1) A wall space is any wall 2 ft or more in width that is unbroken along the floor line by doorways, fireplaces, stationary appliances, and fixed cabinets Figure 210–122 and Figure 210–123

(2) A wall space includes the space occupied by fixed panels ▶Figure 210–124

(3) A wall space includes the space occupied by fixed room dividers such as freestanding bar-type counters or railings ▶Figure 210–125

(3) Floor Receptacles. Floor receptacle outlets within 18 in. of the wall can be counted as the required wall space receptacle outlet. ▶Figure 210–126

Figure 210–122 Wall Space Definition 210.52(A)(2)(1)

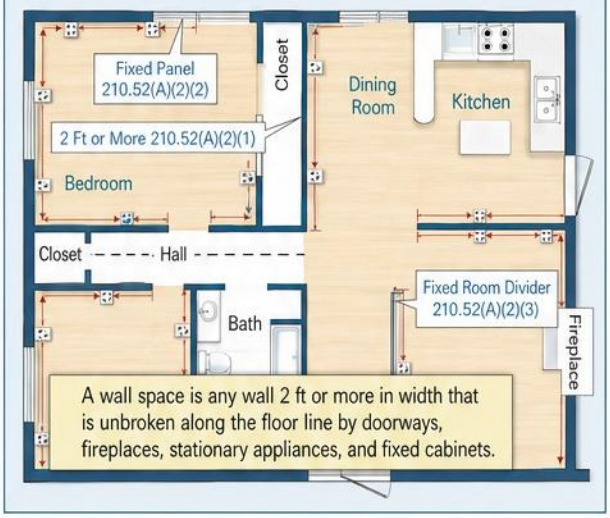


Figure 210–123 Wall Space, Fixed Cabinets 210.52(A)(2)(1)

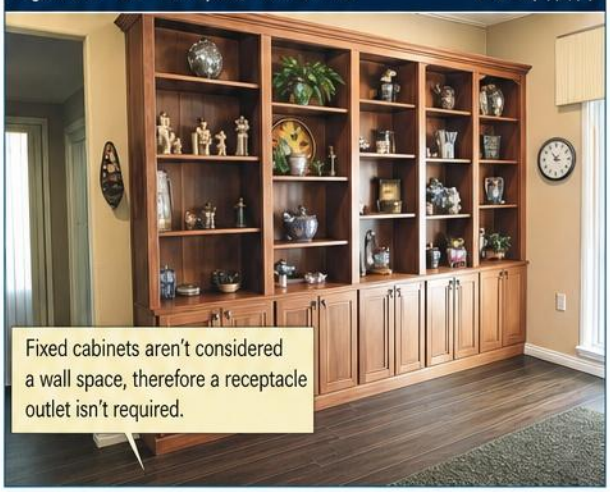
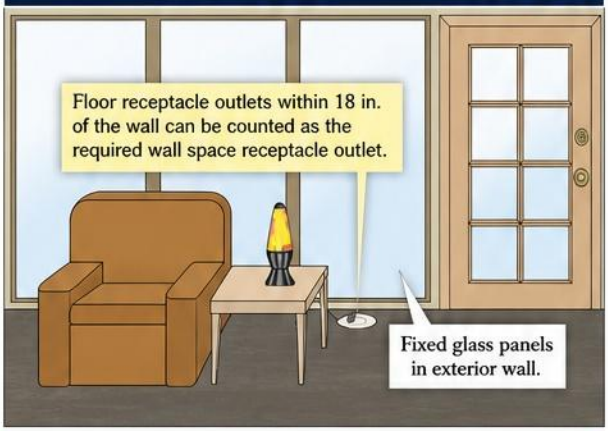


Figure 210–124 Wall Space, Fixed Panels 210.52(A)(2)(2)

Figure 210–125 Dwellings—Unit Receptacle Outlet Wall Space, Bar-Type Counters 210.52(A)(2)(3)

A wall space includes the space occupied by fixed room dividers such as freestanding bar-type counters or railings.

Figure 210–126 Dwellings—Unit Receptacle Outlets Floor Receptacles 210.52(A)(3)



AUTHOR'S COMMENT

Because fixed panels or room dividers are considered a wall space [210.52(A)(2)], a floor receptacle within 18 in. can be used for the required receptacles.

(4) **Countertop Receptacle Outlets.** Receptacle outlets for countertop surfaces required by 210.52(C) cannot be used to meet the wall space receptacle outlet requirements outlined in 210.52(A).

(5) **Prohibited Receptacle Outlet Locations.** Wall space receptacle outlets required by 210.52(A)(2)(3) installed below countertops are not permitted to be located within 24 in. of the countertop. ▸ Figure 210–127

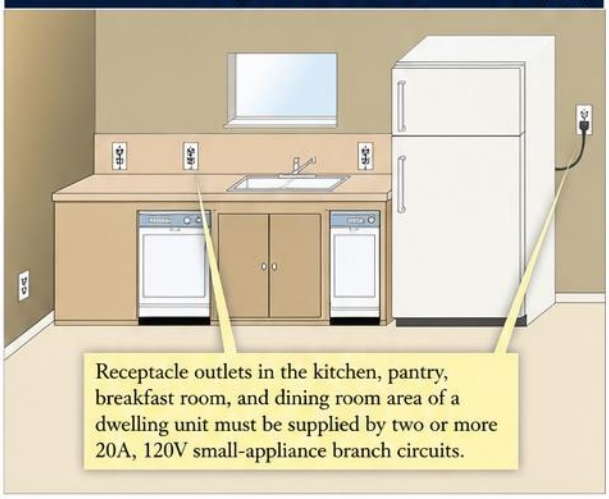
Figure 210–127 Dwellings—Unit Wall Space Receptacle Outlet Prohibited Location 210.52(A)(5)

Wall space receptacle outlets required by 210.52(A)(2)(3) below countertops are not permitted to be located within 24 in. of the countertop.

(B) Small-Appliance Circuit Receptacle Outlets.

(1) **Receptacle Outlets.** In the kitchen, pantry, breakfast room, and dining room area of a dwelling unit, wall and floor receptacle outlets covered by 210.52(A), countertop outlets covered by 210.52(C), and receptacle outlets for refrigerators must be supplied by two or more 20A, 120V small-appliance branch circuits [210.11(C)(1)]. ▸ Figure 210–128

Figure 210–128 Dwellings—Unit Receptacle Outlets Small-Appliance Branch Circuits 210.52(B)(1)



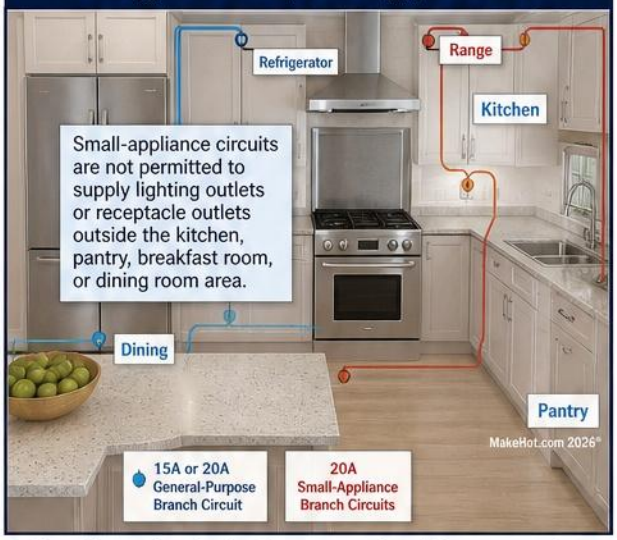
AUTHOR'S COMMENT

No restriction is placed on the number of receptacle outlets connected to a small-appliance branch circuit.

Ex 2: A single branch circuit installed in a dwelling unit kitchen, pantry, breakfast area, or dining room area may serve a receptacle outlet for a specific appliance such as a dishwasher, disposal, trash compactor, or refrigerator.

(2) Not to Supply Other Outlets. The 20A, 120V small-appliance circuits required by 210.11(C)(1) are not allowed to supply any other outlets.

Figure 210–129 **210.52(B)(2)**
Dwelling Unit Receptacle Outlets
Small-Appliance Circuits, Not to Supply Other Outlets



Only outlets within the kitchen, pantry, breakfast area, or dining room area may be supplied by the 20A, 120V small-appliance branch circuits required by 210.11(C)(1).

Ex 2: A receptacle outlet for a gas-fired range, oven, or counter-mounted cooking unit is permitted on the 20A, 120V small-appliance circuit.

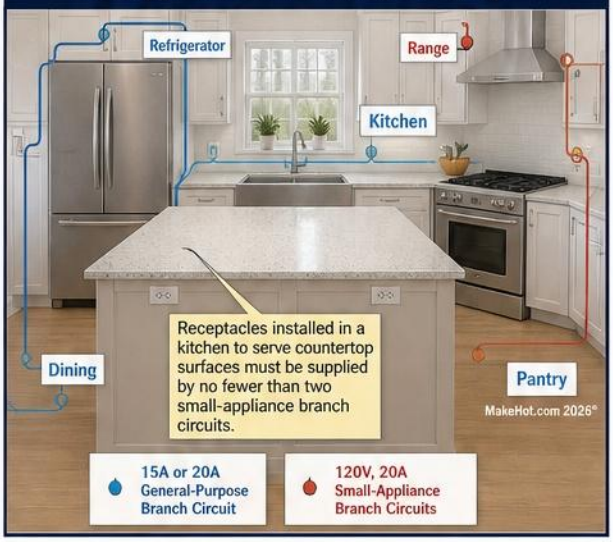
Figure 210–130 **210.52(B)(2) Ex 2**
Dwelling Unit Receptacle Outlets
Small-Appliance Circuits, Not to Supply Other Outlets

Author's Comment:

- The outlet for a hard-wired range hood is not permitted to be supplied by the small-appliance branch circuits.
- A receptacle for a range hood or over-the-range microwave (listed as a range hood that is flexible cord-and-plug-connected) must be supplied by an individual branch circuit [422.16(B)(4)(3)].

(3) Kitchen Countertop Receptacles. Receptacles in kitchen countertop surfaces must be supplied by not fewer than two small-appliance branch circuits. Either or both can supply receptacle outlets in the same kitchen, pantry, breakfast room, or dining room area as specified in 210.52(B)(1).

Figure 210–131 **210.52(B)(3)**
Dwelling Unit Receptacle Outlets
Small-Appliance Circuits, Kitchen Countertop



(C) Countertop Receptacle Outlets. In dwelling unit kitchens, pantries, breakfast rooms, and dining rooms, receptacle outlets for countertops 12 in. or wider must be in accordance with 210.52(C)(1) through (C)(3). They are not permitted to be used to meet the wall space receptacle outlets required by 210.52(A).

Countertop. A surface intended for food or beverage preparation/serving, personal lavation (sink), or laundering (sink) that presents a routine risk of spillage of large quantities of water.

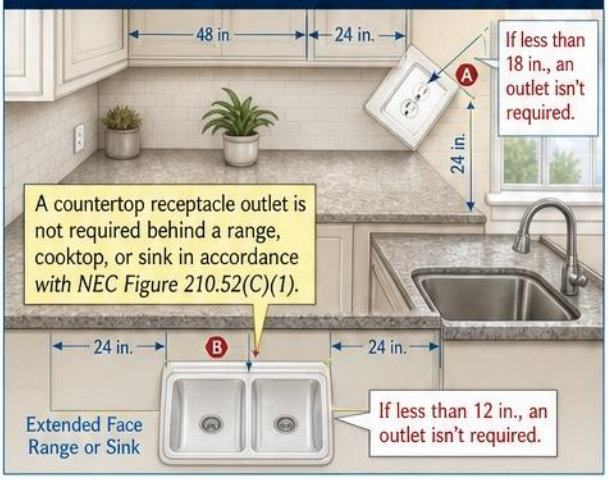
(1) Countertop Wall Spaces. A receptacle outlet must be located to ensure that no point along the countertop wall space is more than 2 ft from a receptacle outlet measured horizontally. It must be located above or in the countertop in accordance with 210.52(C)(3).

Figure 210–132 Dwelling Unit Receptacle Outlets Kitchen Countertop Wall Space 210.52(C)(1)

Example 1: A countertop receptacle outlet is not required behind a range, cooktop, or sink in accordance with Figure 210.52(C)(1) in the NEC.

See Figure 210–133.

Figure 210–133 Dwelling Unit Receptacle Outlets Countertop Wall Space 210.52(C)(1) Ex 1



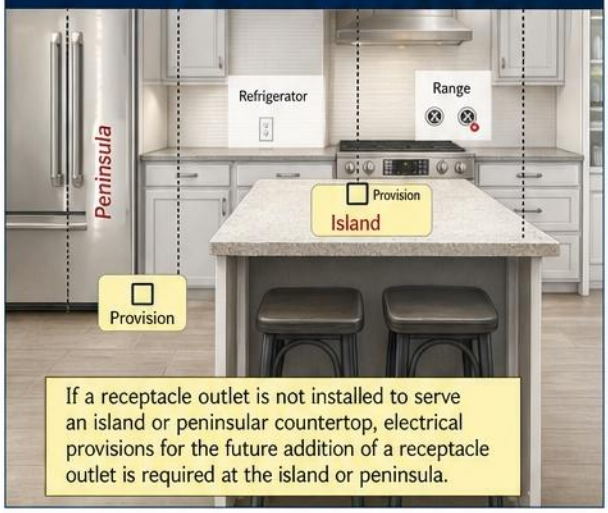
Author's Comment:

- If the countertop space behind a range or sink is larger than the dimensions noted in NEC Figure 210.52(C)(1), a receptacle must be in that space. For all practical purposes, if there is enough space for an appliance, it is assumed that one will be placed there.

(2) Island and Peninsular Countertops. If a receptacle outlet is not installed to serve an island or peninsular countertop, electrical provisions for the future addition of a receptacle outlet are required at the island or peninsula as determined by the AHJ.

See Figure 210–134.

Figure 210–134 Dwelling Unit Receptacle Outlets Kitchen Island and Peninsula, Future Provisions 210.52(C)(2)



Author's Comment:

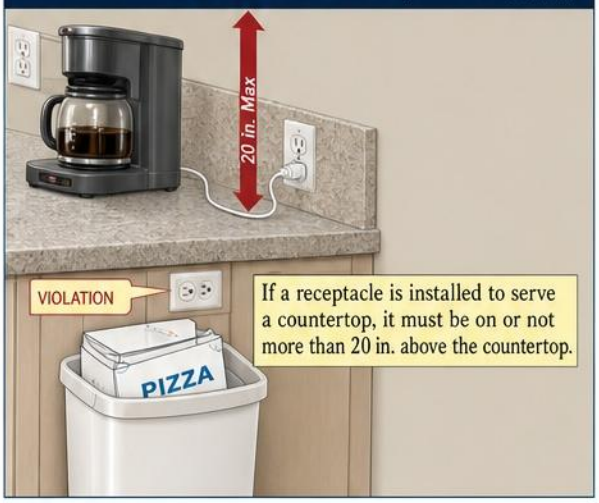
- A receptacle outlet is not required for island or peninsular countertops, but if installed they must be located above or within the countertop in accordance with 210.52(C)(3).

(3) Countertop Receptacle Location. The required kitchen countertop receptacle outlets must be as follows:

(1) On or Above Kitchen Countertops. The receptacle outlets can be on or not more than 20 in. above the countertop.

See Figure 210–135.

Figure 210–135 Dwelling Unit Receptacle Outlets On or Above Kitchen Countertops 210.52(C)(3)(1)



(2) In Kitchen Countertops. Receptacle outlets on the countertop surface must be a receptacle outlet assembly listed for use on a countertop.

See Figure 210–136 and See Figure 210–137.

Figure 210–136 Dwellings—Receptacle Outlets Assembly Listed for Kitchen Countertops 210.52(C)(3)(2)

When installed in an island or a peninsular countertop, the receptacle outlet must be an assembly that is listed for use in a countertop.

Figure 210–137 Dwellings—Receptacle Outlets Assembly Listed for Kitchen Countertops 210.52(C)(3)(2)

When installed in an island or a peninsular countertop, the receptacle outlet must be an assembly that is listed for use in a countertop.

Author's Comment:

- Under *UL Guide RTRT*, countertop pop-up receptacle assemblies are evaluated by a one-half gallon (64 oz.) spill test. They are expected to withstand a routine risk of spillage of large quantities of water.
- Under *UL Guide RTRT*, hard-wired receptacle assemblies are only listed for use in kitchen and bathroom countertops that are physically attached to the building structure.
- Under *UL Guide IYNC*, cord-and-plug-connected receptacle assemblies are listed for installation only in portable (kitchen, bathroom, roll-around type islands) or stationary furniture countertops.

Receptacle outlets that are not easily accessible to appliances attached in place do not count toward the required number of countertop receptacle outlets.

(4) Prohibited Receptacle Outlet Locations. Receptacle outlets are not permitted within 24 in. of the countertop.

▸ Figure 210–138

Figure 210–138 Dwellings—Countertop Receptacle Outlet Prohibited Location 210.52(C)(4)

Receptacle outlets are not permitted within 24 in. of the countertop.

Example: *Receptacle outlets installed in a drawer are permitted below countertops.*

(D) Bathroom Sink Receptacle Outlets. Receptacle outlets must be installed in accordance with the following:

(1) Receptacle Outlet Requirement. At least one 15A or 20A, 125V receptacle outlet must be located within 3 ft of each bathroom sink.

(2) Receptacle Outlet Location. The receptacle outlet must be on a wall or partition that is adjacent to the sink countertop surface or on the side or face of the sink cabinet. The receptacle outlet cannot be more than 12 in. below the top of the sink basin or the sink countertop.

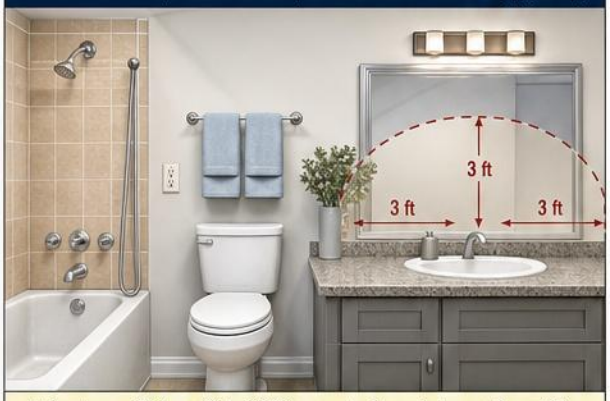
▸ Figure 210–139 and ▸ Figure 210–140

Author's Comment:

- One bathroom receptacle outlet can serve two sinks if it is within 3 ft of each sink.

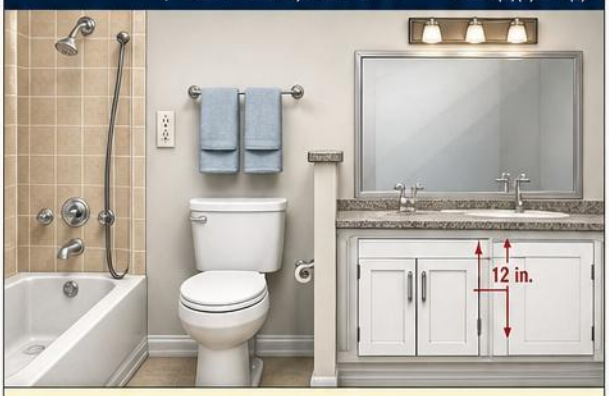
(3) Countertops. Receptacle outlet assemblies listed for use in countertops are permitted to be installed in the bathroom sink countertop.

Figure 210–139 | **Dwelling Unit Receptacle Outlets Bathroom Sink, Within 3 Feet** *210.52(D)(1) and (2)*



At least one 15A or 20A, 125V receptacle outlet must be within 3 ft of each bathroom sink located on a wall or partition adjacent to the sink counter surface or on the side or face of the sink cabinet.

Figure 210–140 | **Dwelling Unit Receptacle Outlets Bathroom Sink, Within 12 in.** *210.52(D)(1) and (2)*



The receptacle outlet cannot be more than 12 in. below the top of the sink or sink countertop.

Figure 210–141 | **One- and Two-Family Dwellings Outdoor Receptacle Outlets** *210.52(E)(1)*

One outdoor receptacle outlet must be at the front and back of each dwelling unit, readily accessible from grade, and no more than 6½ ft above grade.

Figure 210–142 | **Multifamily Dwellings Outdoor Receptacle Outlet** *210.52(E)(2)*

Each dwelling unit of a multifamily dwelling with grade-level entry must have at least one outdoor receptacle outlet, readily accessible from grade, and no more than 6½ ft above grade.

(E) Outdoor Receptacle Outlets. Outdoor receptacle outlets must comply with the following:

(1) One- and Two-Family Dwellings. One outdoor receptacle outlet must be at the front and back of each dwelling unit with two receptacles in total. They must be readily accessible from grade and no more than 6½ ft above grade. **Figure 210–141**

(2) Multifamily Dwelling. Each dwelling unit of a multifamily dwelling with grade-level entry must have at least one outdoor receptacle outlet. They must be readily accessible from grade and no more than 6½ ft above grade. **Figure 210–142**

(3) Balconies, Decks, and Porches. At least one receptacle outlet must be not more than 6½ ft above any balcony, deck, or porch surface located within 4 in. of the dwelling unit. **Figure 210–143**

(F) Laundry Equipment Receptacle Outlet(s). Each dwelling unit must have one receptacle outlet in the area where laundry equipment is intended to be installed. **Figure 210–144**

Ex 1: A laundry receptacle outlet is not required in a dwelling unit located in a multifamily dwelling building with laundry facilities available to all occupants.

(G) Garage, Basement, and Accessory Building Receptacle Outlets. For one-and two-family or multifamily dwellings, at least one receptacle outlet must be installed in accordance with 210.52(G)(1) through (3).

Figure 210–143 Balconies, Decks, and Porches Outdoor Receptacle Outlet 210.52(E)(3)

Figure 210–145 One-, Two-, and Multifamily Dwellings Garage Receptacle Outlets With Electric Power 210.52(G)(1)

Figure 210–144 Dwelling Unit Receptacle Outlets Laundry Area 210.52(F)

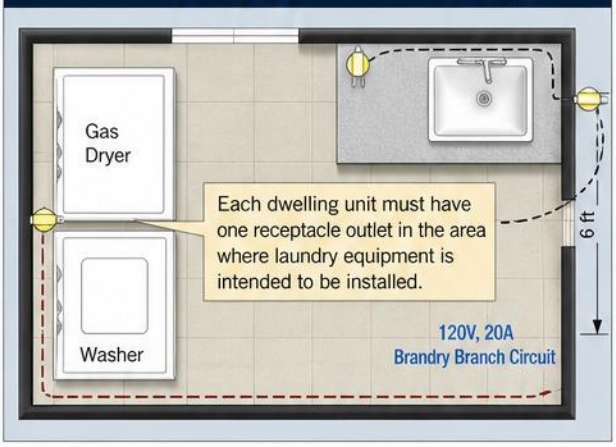
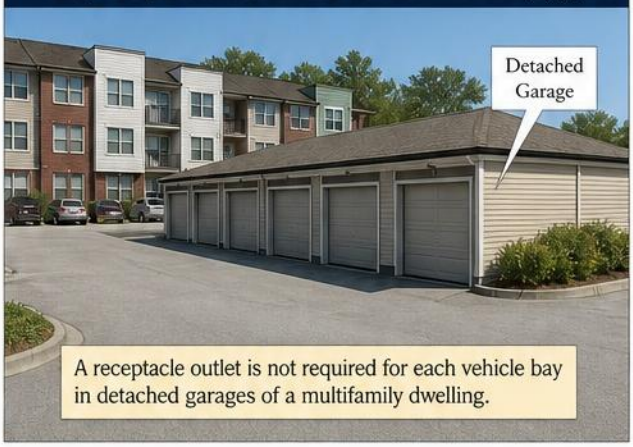


Figure 210–146 Multifamily Dwellings Garage Receptacle Outlets With Electric Power 210.52(G)(1) Ex



(1) Garages. A receptacle outlet is required in each vehicle bay of a garage with electric power located no higher than 5½ ft above the floor. (210.52(G)(1))

Example: A receptacle outlet is not required for the detached garage of an individual dwelling unit in a multifamily dwelling. (210.52(G)(1) Ex)

(2) Accessory Building Receptacle Outlets. A receptacle outlet is required in each accessory building with electric power. (210.52(G)(2))

(3) Basements. Each unfinished portion of a basement must have a receptacle outlet. (210.52(G)(3))

Figure 210–147 One-, Two-, and Multifamily Dwellings Accessory Building Receptacle Outlet 210.52(G)(2)

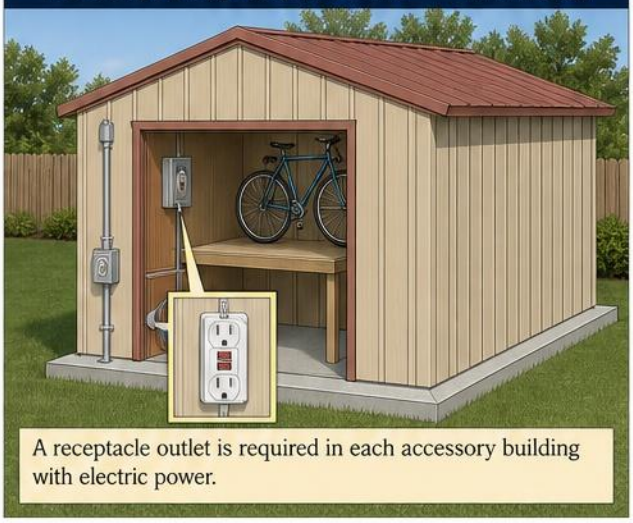


Figure 210–148 One-, Two-, and Multifamily Dwellings Basement Receptacle Outlet *210.52(G)(3)*

Each unfinished portion of a basement must have a receptacle outlet.

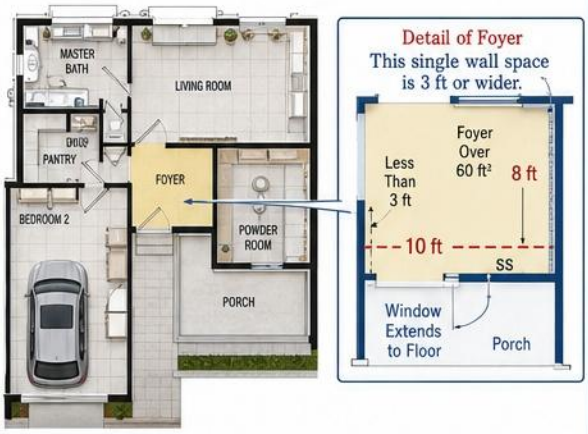
(H) Hallway Receptacle Outlet. At least one receptacle outlet must be installed in each hallway of 10 ft or more in length (measured along the centerline of the hallway without passing through a doorway). Figure 210–149

Figure 210–149 Dwelling Unit Receptacle Outlet Hallway *210.52(H)*

At least one receptacle outlet must be installed in each hallway 10 ft or more in length, measured along the centerline of the hallway without passing through a doorway.

(I) Foyer Receptacle Outlets. Foyers having an area greater than 60 sq ft must have a receptacle outlet installed on any wall space that is 3 ft or more in width, and unbroken by doorways, windows next to doors that extend to the floor, and similar openings. Figure 210–150

Figure 210–150 Dwelling Unit Receptacle Outlet Foyer *210.52(I)*



Foyers having an area greater than 60 sq ft must have a receptacle outlet installed on any wall space that is 3 ft or more in width and unbroken by doorways, windows next to doors that extend to the floor, and similar openings.

210.62 Show-Window Receptacles

At least one 15A or 20A, 125V receptacle outlet must be installed within 18 in. of the top of each *show window*, and no point along the top of the window can be further than 6 ft from a receptacle outlet. Figure 210–151

Figure 210–151 Show Window Receptacle Outlet *210.62*

At least one 125V, single-phase, 15A or 20A rated receptacle outlet must be installed within 18 in. of the top of each show window and no point along the top of the window can be farther than 6 ft from a receptacle outlet.

Show Window. Windows above doors which are used or *designed for the display of goods or advertising material.*

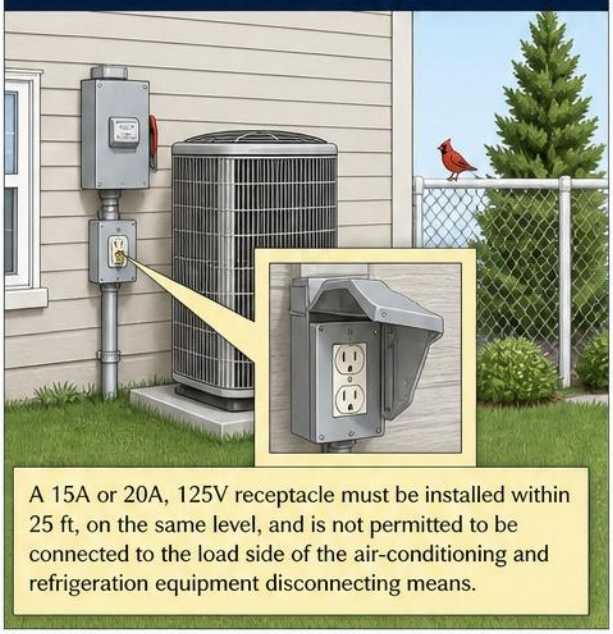
210.63 Equipment Requiring Servicing

A 15A or 20A, 125V receptacle outlet must be within 25 ft of the equipment as specified in 210.63(A) and (B).

Note: For GFCI requirements see 210.8(E).

(A) Air-Conditioning and Refrigeration Equipment. A 15A or 20A, 125V receptacle outlet must be installed within 25 ft and on the same level as the air-conditioning and refrigeration equipment. A 15A or 20A, 125V receptacle outlet is not permitted to be connected to the load side of the equipment's disconnecting means.

Figure 210–152 Air-Conditioning Equipment Service Receptacle Outlet 210.63(A)

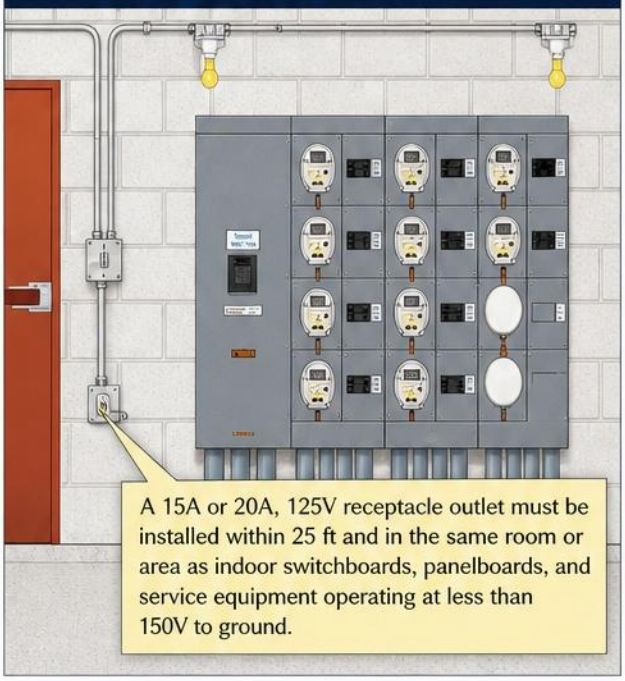


Ex: A receptacle outlet is not required in one- and two-family dwellings for servicing evaporative coolers.

Figure 210–153 Evaporative Coolers One- and Two-Family Dwellings 210.63(A) Ex

(B) Indoor Electrical Equipment. In other than dwelling units, a 15A or 20A, 125V receptacle outlet must be installed within 25 ft and in the same room (or area) as indoor switchboards, panelboards, and service equipment operating at less than 150V to ground (120/240V or 208Y/120V).

Figure 210–154 Indoor Equipment, Other Than Dwelling Units Service Receptacle Outlet 210.63(B)



210.65 Meeting Rooms

(A) General. Meeting rooms having an area of 215 sq ft and larger, but not larger than 1000 sq ft, must have 15A or 20A, 125V receptacle outlets installed in accordance with 210.65(B).

Figure 210–155 Meeting Room Receptacle 210.65(A)

The size of a room or space that can be served by a movable partition depends on whether the partitions can be moved so that the results in the smallest size meeting room.

Note 1: Spaces designed or intended for meetings are typically arranged for seated occupants during conferences, deliberations, or similar activities where portable electronic devices (such as computers, projectors, or similar equipment) are likely to be in use.

Figure 210–156 210.65(A) Note 1

Spaces designed or intended for meetings are typically arranged for seated occupants during conferences, deliberations, or similar activities where portable electronic devices (such as computers, projectors, or similar equipment) are likely to be in use.

Note 2: Examples of rooms that are not meeting spaces include auditoriums, school classrooms, and coffee shops.

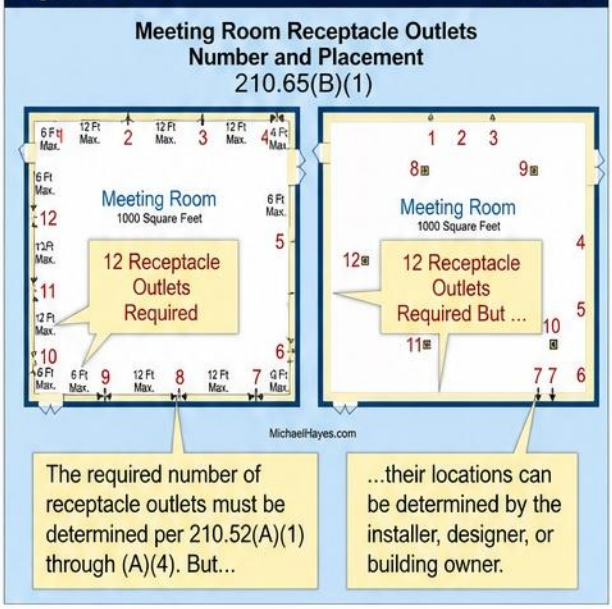
Figure 210–157 210.65(A) Note 2

Examples of rooms that are not meeting spaces include auditoriums, school classrooms, and coffee shops.

(B) Meeting Room Outlet Requirements. The total number of wall receptacle outlets, floor receptacle outlets, floor outlets, and receptacle outlets in fixed furniture must not exceed the following:

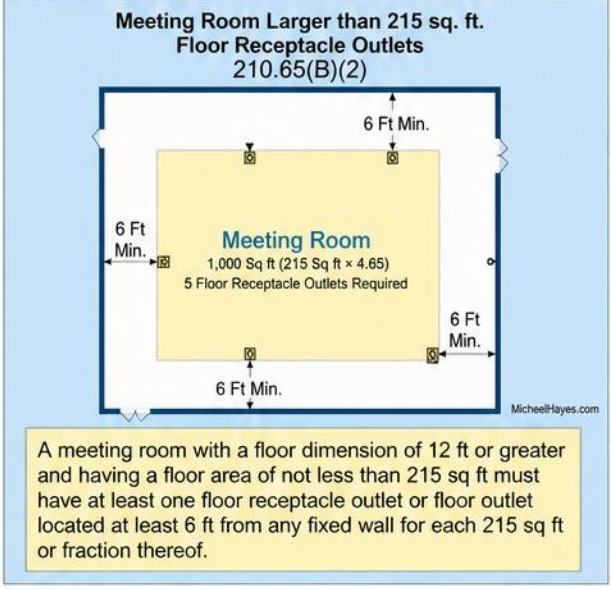
(1) Receptacle Outlets in Fixed Walls. The required number of wall receptacle outlets must be determined in accordance with 210.52(A)(1) through (A)(4). The placement of the receptacle outlets is determined by the installer, designer, or building owner.

Figure 210–158 210.65(B)(1)



(2) Floor Receptacle Outlets. A meeting room with a floor dimension of 12 ft or greater, but not less than 215 sq ft, must have at least one floor receptacle outlet or floor outlet located at least 6 ft from any fixed wall; for each 215 sq ft or fraction thereof.

Figure 210–159 210.65(B)(2)



Note 1: For requirements on floor boxes used for receptacles in the floor, see 314.27(C).

AUTHOR'S COMMENT

In commercial buildings, there are no wall space receptacle outlet requirements. However, in meeting rooms there is a need to provide receptacles to facilitate the attendees using computers and other electronic devices. The purpose of this rule is to ensure there are enough receptacles conveniently located to reduce the use of extension cords.

210.70 LIGHTING OUTLET REQUIREMENTS

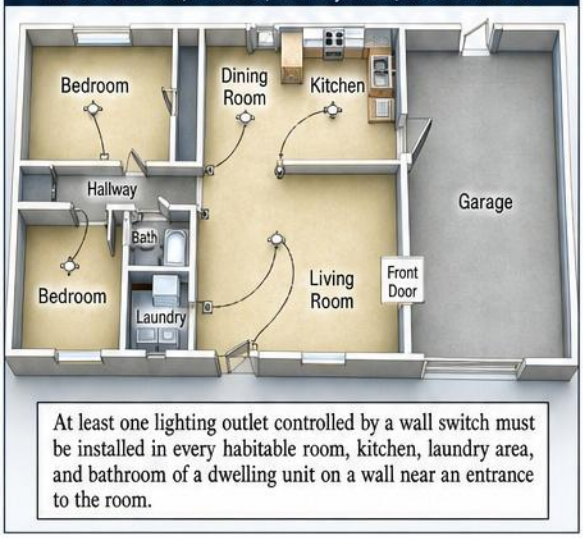
Lighting outlets must be installed in accordance with 210.70(A), (B), and (C).

(A) Dwelling Unit Lighting Outlets. Lighting outlets must be installed in:

(1) Habitable Rooms, Kitchens, Laundry Areas, and Bathrooms. At least one lighting outlet controlled by a wall switch must be installed in every habitable room, kitchen, laundry area, and bathroom. The wall switch must be on a wall near an entrance to the room.

Figure 210–160 210.70(A)(1)

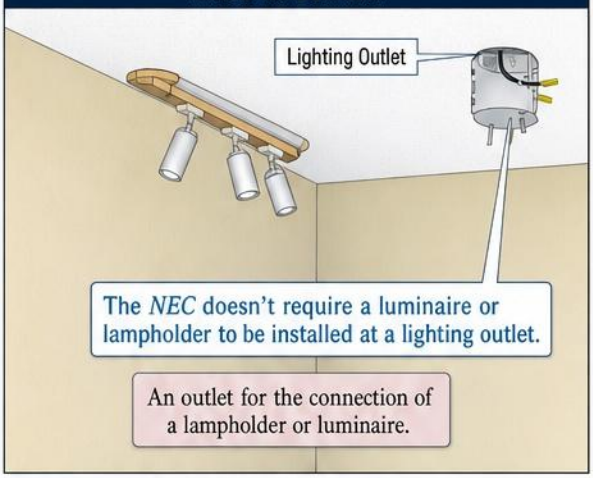
Dwelling Unit Lighting Outlets
Habitable Rooms, Kitchens, Laundry Areas, and Bathrooms



Lighting Outlet. An outlet for connecting a lampholder or luminaire.

Figure 210–161 210.70(A)

Lighting Outlet
Article 100 Definition

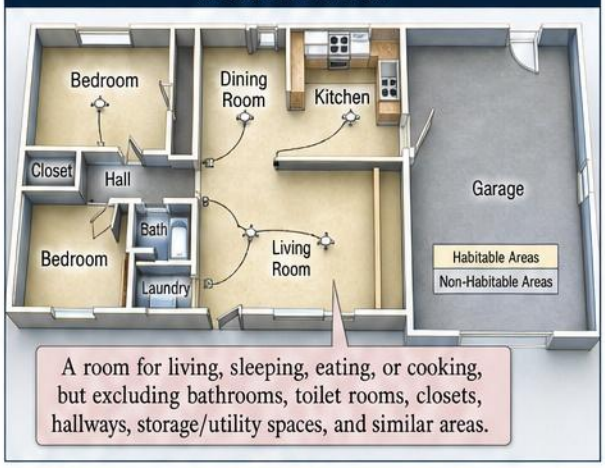


A lighting outlet is the point provided for connecting a lampholder or luminaire. No luminaire is required by the *NEC*.

Habitable Room. A room for living, sleeping, eating, or cooking, but excluding bathrooms, toilet rooms, closets, hallways, storage/utility spaces, and similar areas.

Figure 210–162 210.70(A)(1)

Habitable Room
Article 100 Definition



Habitable rooms are intended for human activity such as living, sleeping, eating, or cooking.

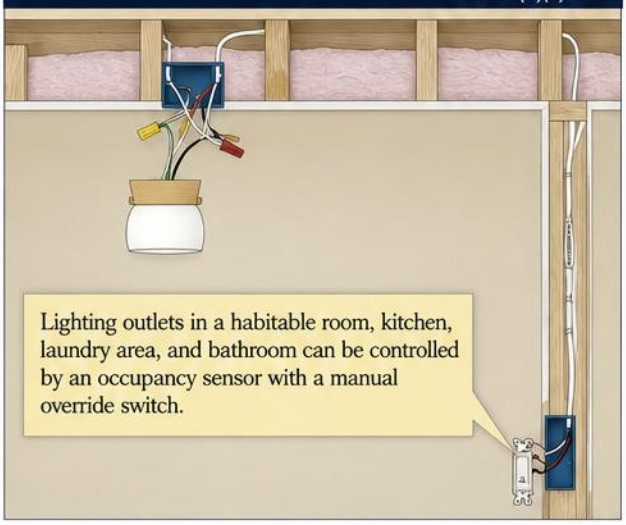
Ex 1: Other than kitchens, laundry areas, and bathrooms, a receptacle controlled by a wall switch can be used instead of a lighting outlet. 210.70(A)(1) • Figure 210–163

Ex 2: Lighting outlets in a habitable room, kitchen, laundry area, and bathroom can be controlled by an occupancy sensor with a manual override switch. 210.70(A)(1) • Figure 210–164

Figure 210–163 Dwelling Unit Lighting Outlets *210.70(A)(1) Ex 1*

In other than kitchens, laundry areas, and bathrooms, a receptacle controlled by a wall switch can be used instead of a lighting outlet.

Figure 210–164 Dwelling Unit Lighting Outlets *210.70(A)(1) Ex 2*



Lighting outlets in a habitable room, kitchen, laundry area, and bathroom can be controlled by an occupancy sensor with a manual override switch.

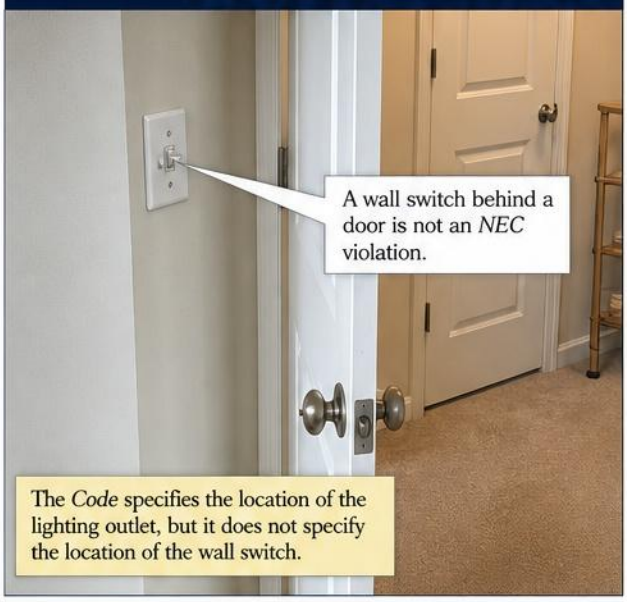
Author's Comment:

- The *Code* specifies the location of the lighting outlet, but not the wall switch. This provides a lot of flexibility when deciding how to switch the laundry area lighting outlet. **Figure 210–165**

Ex 3: The laundry area lighting outlet and its switch can be located outside the closet that houses the laundry equipment.

(2) Additional Locations. A lighting outlet must be installed in the following locations:

Figure 210–165 Dwelling Unit Lighting Outlets: Wall Switch Location *210.70(A)(1) Comment*



A wall switch behind a door is not an *NEC* violation.

The *Code* specifies the location of the lighting outlet, but it does not specify the location of the wall switch.

(1) Hallways, Stairways, Garages, and Accessory Buildings. At least one lighting outlet controlled by a wall switch must be installed in hallways, stairways, garages, and accessory buildings with electric power. **Figure 210–166**

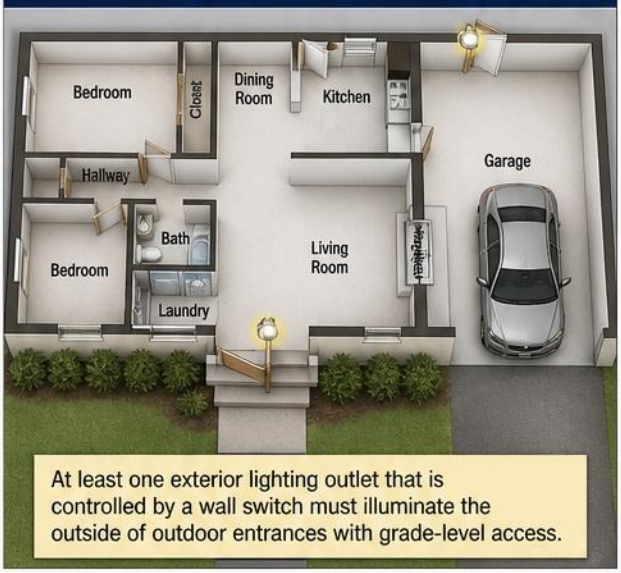
Figure 210–166 Dwelling Unit Lighting Outlets Hallways, Stairways, Garages, and Accessory Buildings *210.70(A)(2)(1)*

At least one lighting outlet controlled by a wall switch must be installed in hallways, stairways, garages, and accessory buildings with electric power.

(2) Exterior Entrance. At least one exterior lighting outlet controlled by a wall switch must be installed for attached or detached garages with electric power to provide illumination on the exterior side of outdoor entrances with grade-level access. A garage vehicle door is not considered an outdoor entrance or exit. **Figure 210–167**

Ex to 2: For an outdoor grade-level stairway access to a basement, the lighting outlet that provides illumination on the stairway steps is permitted to be in the basement interior within 5 ft horizontally of the bottommost stairway riser. This lighting outlet is permitted to be controlled by a wall switch or switch on the luminaire.

Figure 210–167 Dwelling Unit Lighting Outlets—Exterior Entrance 210.70(A)(2)(2)



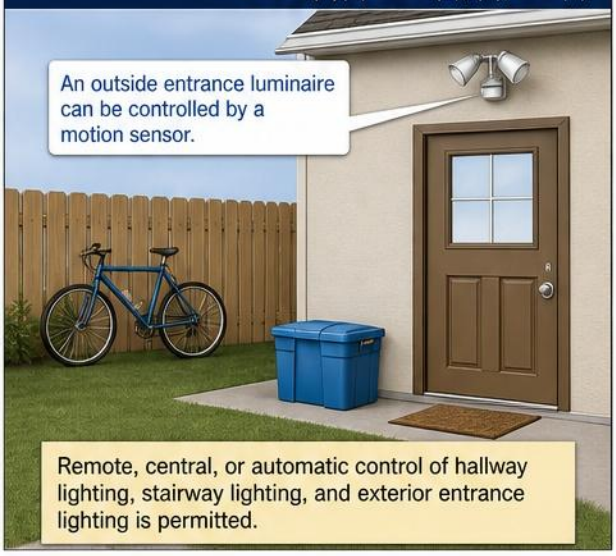
(3) Stairways. When lighting outlet(s) are installed in interior stairways with six risers or more between floor levels, they must be controlled by a wall switch positioned at each floor and at the landing level that includes the stairway entry. **Figure 210–168**

Figure 210–168 Dwelling Unit Lighting Outlet—Interior Stairway 210.70(A)(2)(3)

Ex to (1), (2), and (3): Remote, central, or automatic control of hallway, stairway, and exterior entrance lighting is permitted. **Figure 210–169**

(4) Dimmer Control. Stairway lighting outlets cannot be controlled by a dimmer—unless the dimming provides a maximum brightness at each control location.

Figure 210–169 Dwelling Unit Lighting Outlets—Hallways, Stairways, and Exterior Entrances 210.70(A)(2) Ex to (1), (2), and (3)



(C) Storage and Equipment Spaces. At least one lighting outlet that has a switch or is controlled by a wall switch must be installed in attics, underfloor spaces, utility rooms, and basements. These spaces are intended for storage or for equipment that requires servicing and must comply with the following: **Figure 210–170**

Figure 210–170 Storage and Equipment Space Lighting Outlets 210.70(C)

(1) The switch must be located at each entry that allows access to the attic, underfloor space, utility room, or basement.

(2) The lighting outlet for equipment that requires service must be positioned at or near the equipment.

(3) The lighting outlet cannot be controlled by automatic means unless a manual bypass is provided.

Article 600 – Electric Signs and Outline Lighting

Article 600 covers the installation requirements for electric signs and outline lighting systems.

An electric sign is defined as a structure that has lights and is used outdoors or indoors to identify, attract attention, or advertise. It may be designed to illuminate a surface, surrounding area, or both.

Each electric sign must be marked with the maximum circuit voltage and current, either on a single label or multiple labels that provide the same information. The marking must be placed on the sign where it is readily visible after installation.

Electric signs and outline lighting systems must be installed in accordance with the manufacturer's instructions and be Listed or Classified.

Door openings in electric signs must be closed with doors or covers that are securely fastened. These openings must be as small as possible and located away from areas where unauthorized individuals might gain access.

Raceways and other wiring methods must be routed so they are not exposed to physical damage.

Open wiring on signs or outline lighting systems is permitted only as allowed in 600.10(A)(1) or (2).

A bond must be provided between metal parts that are likely to become energized and all metal parts of the sign structure.

If an electric sign or outline lighting system is installed within 8 ft (2.4 m) of a pool, spa, or fountain, it must be installed in accordance with 680.22(B).

For locations where corrosive vapors, gases, or liquids are present, the parts of an electric sign or outline lighting system must be made of materials that are resistant to the specific substance or enclosed in a protective enclosure. Equipment compartments, junction boxes, and fittings must be sealed to prevent the entry of the specific substance.

600.3 Identification

Each electric sign must include a marking that indicates the maximum circuit voltage and current. This information can be provided on a single label or on multiple labels, as long as the same details are conveyed.

The marking must be located on the sign in a position where it can be easily seen after the sign is installed.

600.4 Installation

Electric signs and outline lighting equipment must be installed in accordance with the manufacturer's instructions and must be Listed or Classified.

Door openings in electric signs must be covered with securely fastened doors or covers. These openings must be as small as practicable and positioned away from areas accessible to unauthorized persons.

Raceways and other wiring methods must be arranged and installed to prevent physical damage.

Open wiring on electric signs or outline lighting systems is allowed only under the conditions specified in 600.10(A)(1) or (2).

Figure 600.3 Electric Sign Identification 600.3

Each electric sign must be marked to show its maximum circuit voltage and current. The marking must be placed on the sign where it is readily visible after installation.

ARTICLE

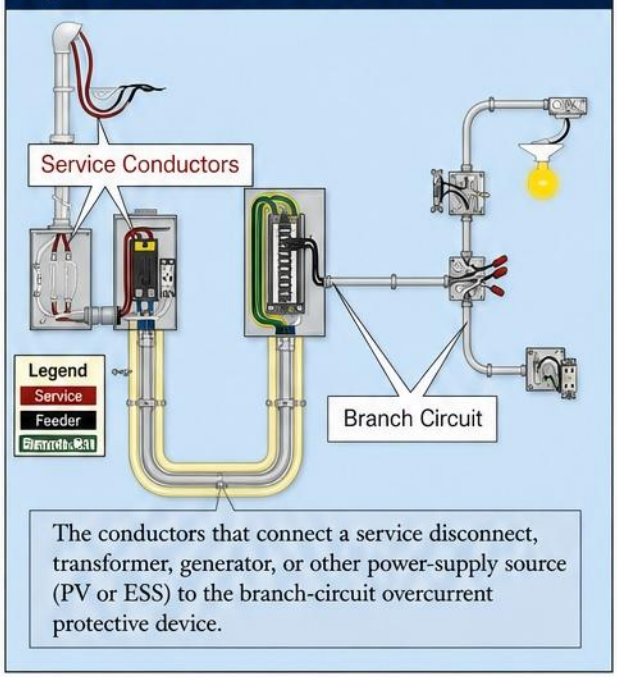
215 Feeders

Introduction to Article 215—Feeders

Article 215 sets forth the rules for feeder conductors that run between a service disconnect, transformer, generator, photovoltaic (PV) system output circuit (or another power-supply source), and their overcurrent protective devices. Feeders have requirements that are different from those for branch circuits and services, so correctly identifying feeders is essential. To apply these rules properly, it is important to understand what a "feeder" is, where it begins, and where it terminates.

Feeder. The conductors that connect a service disconnect, transformer, generator, or other power-supply source (PV or ESS) to the branch-circuit overcurrent protective device. Figure 215–1

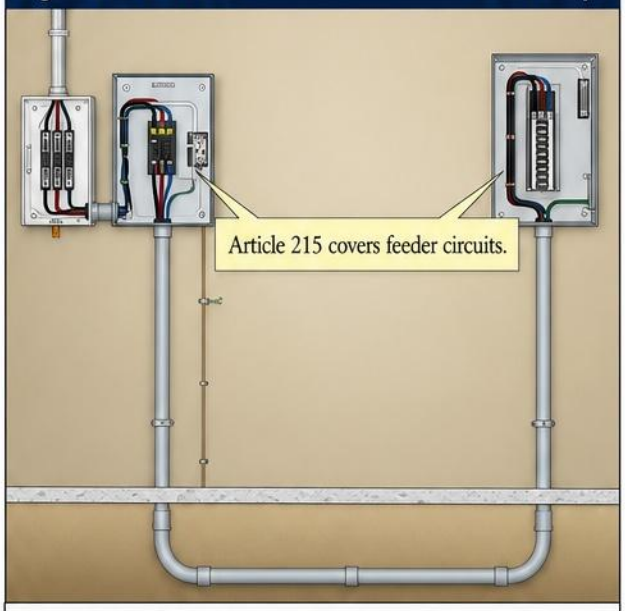
Figure 215–1 Feeder Article 100 Definition



215.1 Scope

This article addresses the installation, conductor sizing, and overcurrent protection requirements for feeder circuits. Figure 215–2

Figure 215–2 Feeder **215.1 Scope**



This article addresses feeder circuit installations, including conductor sizing and overcurrent protection requirements.

Author's Comment:

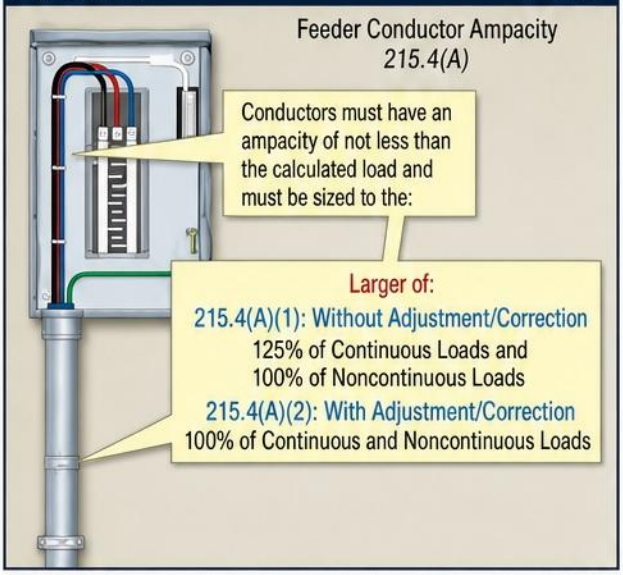
Article 215 contains the general requirements for feeders. Specific feeder equipment requirements are contained in specific articles:

- Motors [430.24]
- Air-conditioning [440.33]
- Elevators [620.13]
- Electric vehicles [625.42]

215.4 Conductor Sizing

(A) General. Feeder conductors must have an ampacity no less than the calculated load and must be sized to the larger of either 215.4(A)(1) or (2). ▸ Figure 215–3

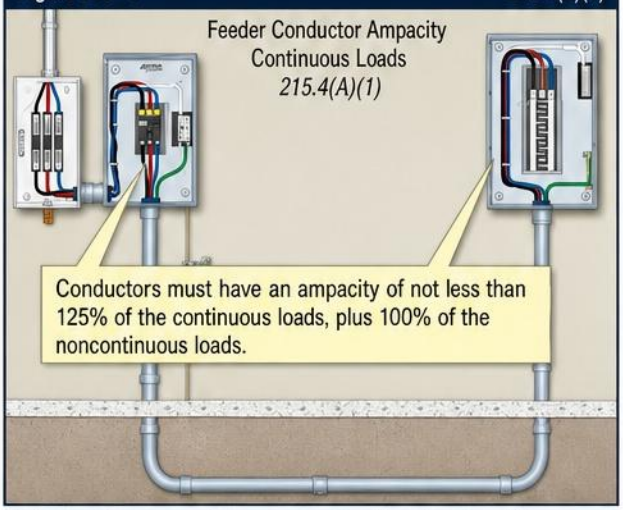
Figure 215–3 215.4(A)



Feeder conductors must have an ampacity of not less than the calculated load and must be sized to the larger of either 215.4(A)(1) or (2).

(1) Continuous and Noncontinuous Loads. Feeder conductors must have an ampacity no less than 125 percent of the *continuous loads*, plus 100 percent of the noncontinuous loads. ▸ Figure 215–4

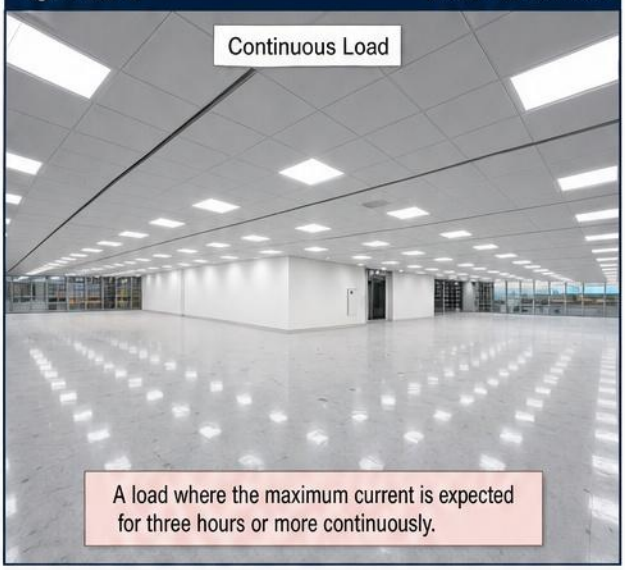
Figure 215–4 215.4(A)(1)



Feeder conductors must have an ampacity of not less than 125 percent of the continuous loads, plus 100 percent of the noncontinuous loads.

Continuous Load. A load where the maximum current is expected for three hours or more continuously. ▸ Figure 215–5

Figure 215–5 Article 100 Definition



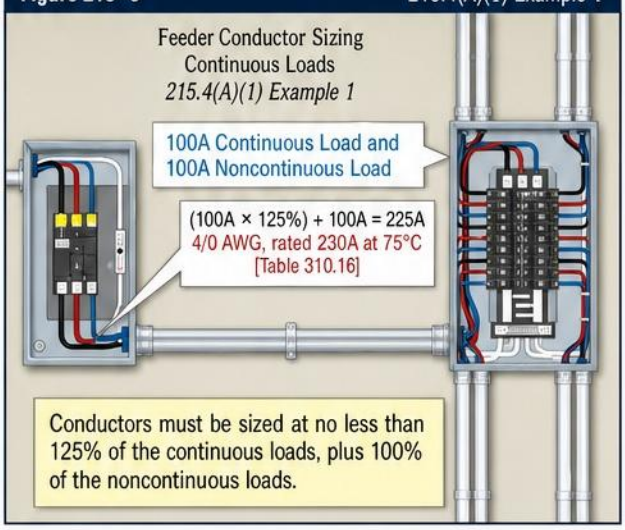
A continuous load is one where the maximum current is expected for three hours or more continuously.

▶ Feeder Conductor Sizing [215.4(A)(1)] Example 1

Question: *What size conductors are required for a 100A continuous load and 100A noncontinuous load where the circuit overcurrent protection device is 225A?* ▸ Figure 215–6

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

Figure 215–6 215.4(A)(1) Example 1



Solution:

Step 1: *Determine the minimum conductor ampacity.*

Minimum Conductor Ampacity = (100A × 125%) + 100A
Minimum Conductor Ampacity = 125A + 100A
Minimum Conductor Ampacity = 225A

Step 2: *Determine the conductor size.*

4/0 AWG, rated 230A at 75°C [Table 310.16]

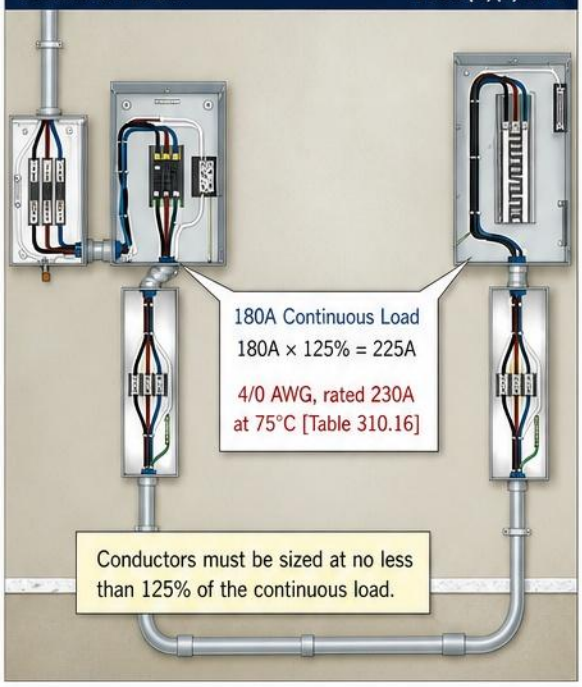
Answer: *(d) 4/0 AWG*

▶ Feeder Conductor Sizing [215.4(A)(1)] Example 2

Question: *What size conductors are required for a 180A continuous load where the circuit overcurrent protection device is 225A?*

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

Figure 215-7 – Feeder Conductor Sizing Continuous Loads 215.4(A)(1) Ex 2



Solution:

Step 1: *Determine the minimum conductor ampacity.*

Minimum Conductor Ampacity = 180A × 125%

Minimum Conductor Ampacity = 225A

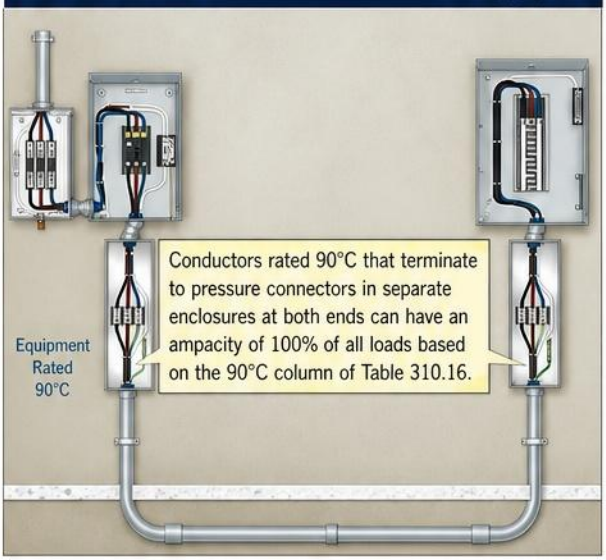
Step 2: *Determine the conductor size.*

4/0 AWG, rated 230A at 75°C [Table 310.16]

Answer: *(d) 4/0 AWG*

Ex 2: Conductors rated 90°C that terminate to pressure connectors in separate enclosures or wireways at both ends in accordance with 110.14(C)(2) can have an ampacity not less than the continuous and noncontinuous loads based on the 90°C column of Table 310.16. Figure 215-8.

Figure 215-8 – Feeder Conductor Ampacity Between Pressure Connectors 215.4(A)(1) Ex 2



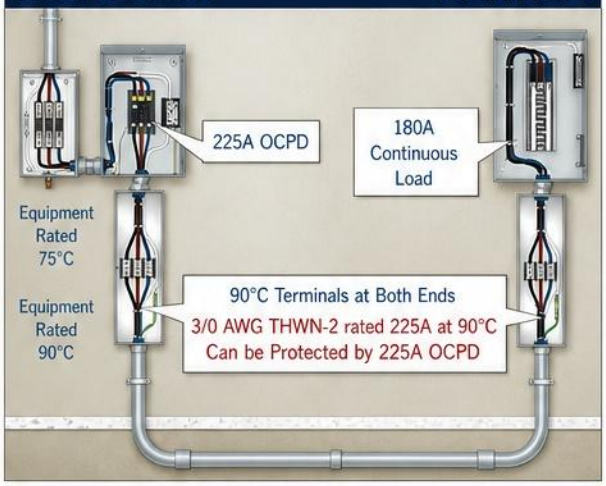
Explanatory caption: *See Ex 2 and 110.14(C)(2).*

▶ Feeder 90°C Conductor Size [215.4 Ex 2] Example

Question: *What size AWG, THWN-2 feeder conductors rated 90°C are required between power distribution blocks rated 90°C for a circuit supplying a 180A continuous load where the circuit overcurrent protection is 225A?*

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

Figure 215-9 – Feeder Conductor Sizing Between Pressure Connectors 215.4(A)(1) Ex 2



Explanatory caption: *See Ex 2 and 110.14(C)(2).*

Solution:

Step 1: *Determine the minimum conductor ampacity at 90°C.*

When terminals of separately installed connectors at each end of a conductor are rated at 90°C, the feeder conductor between the 90°C rated connectors can be sized to not less than 100 percent of the 180A continuous load based on the 90°C column of Table 310.16 *[215.4(A)(1) Ex 2].*

Minimum Conductor Ampacity = 180A

Step 2: *Determine the conductor size.*

Feeder conductors must be sized to carry the 180A continuous at 90°C and be protected by an overcurrent protection device having a rating no less than 125% of the 180A continuous load = 225A in accordance with 240.4 [215.5].

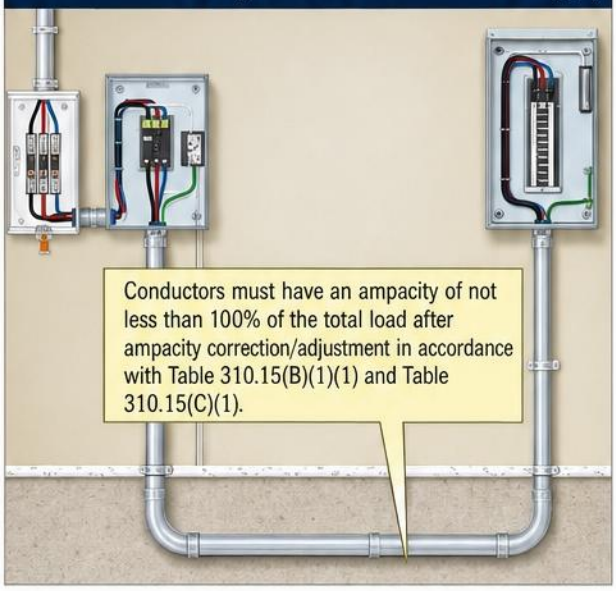
Consideration 1: *2/0 AWG THWN-2, rated 195A at 90°C is suitable to carry the 180A continuous load at 100%, but it's not permitted to be protected by a 225A circuit breaker [240.4].*

Consideration 2: *3/0 AWG THWN-2 is rated 225A at 90°C is suitable to carry the 180A continuous load at 100% and is permitted to be protected by a 225A circuit breaker [240.4(B)].*

Answer: *(c) 3/0 AWG*

(2) Ampacity Correction and/or Adjustment Factor. Conductors must have an ampacity of no less than 100 percent of the continuous and noncontinuous loads after conductor ampacity correction and/or adjustment in accordance with Table 310.15(B)(1)(1) and Table 310.15(C)(1). ▶ Figure 215–10

Figure 215–10 Conductor Ampacity Correction and Adjustment Factors 215.4(A)(2)



Conductors are adjusted for temperature, number of current-carrying conductors, and other applicable factors per 310.15.

Author's Comment:

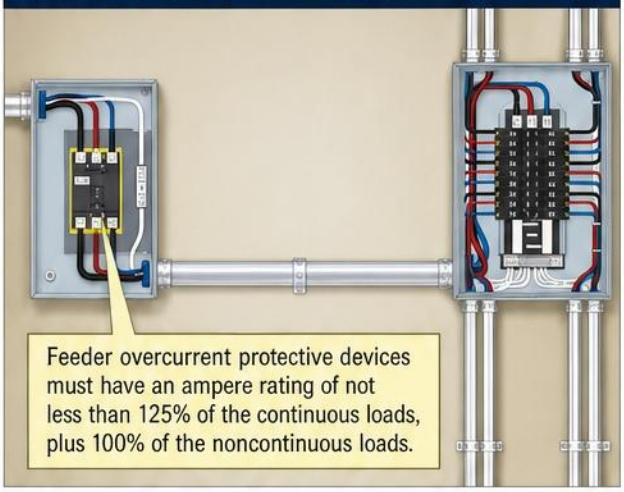
- The temperature ampacity correction [310.15(B)(1)(1)] and ampacity adjustment factors [310.15(C)(1)] are applied to the ampacities listed in Table 310.16. This is based on the conductor insulation temperature rating, which is typically THWN-2, 90°C [310.15(A)].

215.5 Overcurrent Protection Sizing

Feeder overcurrent protective devices must have an ampere rating no less than 125 percent of the continuous loads, plus 100 percent of the noncontinuous loads.

▶ Figure 215–11

Figure 215–11 Feeder Overcurrent Protection Sizing 215.5



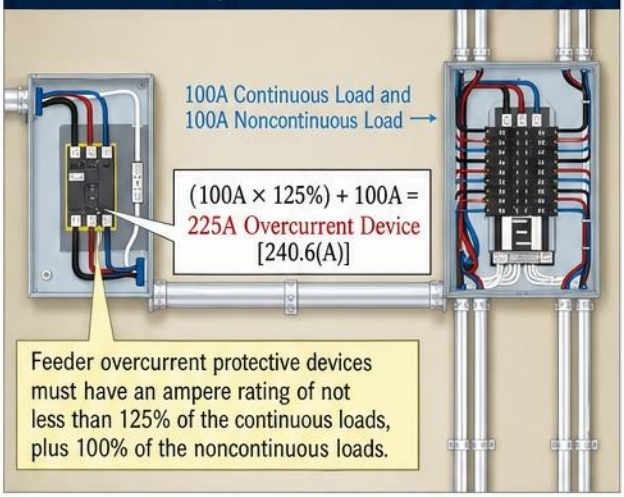
Protection must be sufficient for both continuous and noncontinuous load components.

▶ Feeder OCPD Sizing [215.5] Example

Question: *What size feeder overcurrent protective device is required for a 100A continuous load and a 100A noncontinuous load?* ▶ Figure 215–12

(a) 200A *(b) 225A* *(c) 250A* *(d) 300A*

Figure 215–12 Feeder Overcurrent Protection Sizing Example 215.5 Example



The calculated requirement is rounded up to the next standard overcurrent device rating.

Solution:

Overcurrent Protective Device = (100A continuous Load × 125 percent) + 100A noncontinuous load

Overcurrent Protective Device = (100A × 125%) + 100A

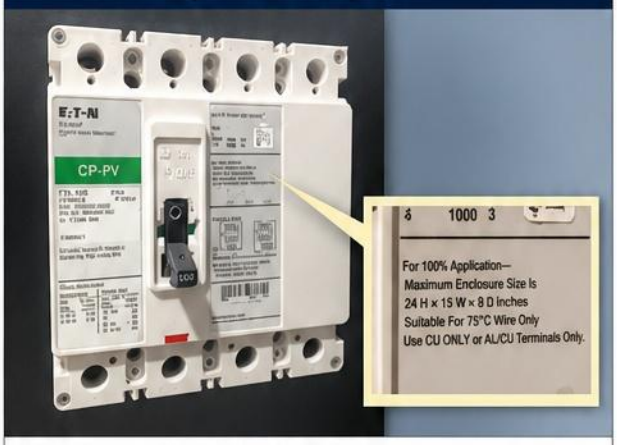
Overcurrent Protective Device = 125A + 100A

Overcurrent Protective Device = 225A [240.6(A)]

Answer: *(b) 225A*

Ex 1: The assembly that includes the feeder overcurrent protective devices listed for operation at 100 percent of its rating, the ampere rating of the overcurrent protective device can be sized at 100 percent of the continuous and noncontinuous loads. ➤ Figure 215–13

Figure 215–13 Feeder Overcurrent Protection Sizing Rated For 100% Operation 215.5 Ex 1



When the assembly includes the feeder overcurrent protective devices listed for operation at 100% of its rating, the ampere rating of the overcurrent protective device can be sized at 100% of the continuous and noncontinuous loads.

215.12 Conductor Identification

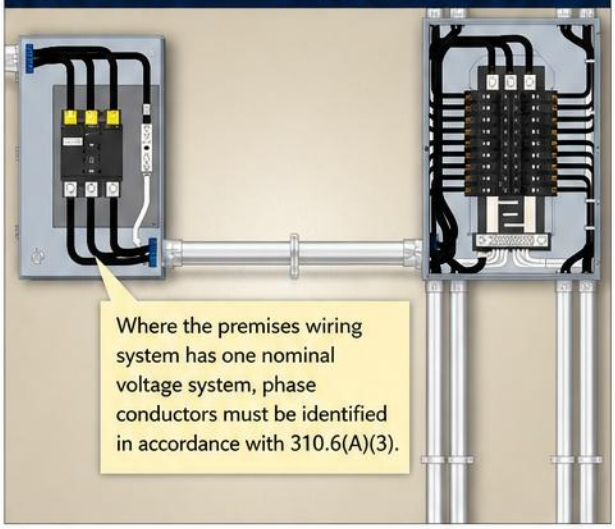
(A) Neutral Conductor. The feeder neutral conductor must be identified in accordance with 200.7.

(B) Equipment Grounding Conductor. The feeder equipment grounding conductor must be identified in accordance with 250.119.

(C) Identification of Phase Conductors. Feeder phase conductors must be identified as follows:

(1) Feeders Supplied from One Nominal Voltage System. Where the premises wiring system has feeders supplied from one nominal voltage system, the feeder phase conductors must be identified in accordance with 310.6(A)(3). ➤ Figure 215–14

Figure 215–14 Feeder Phase Conductor Identification Supplied from One Nominal Voltage System 215.12(C)(1)



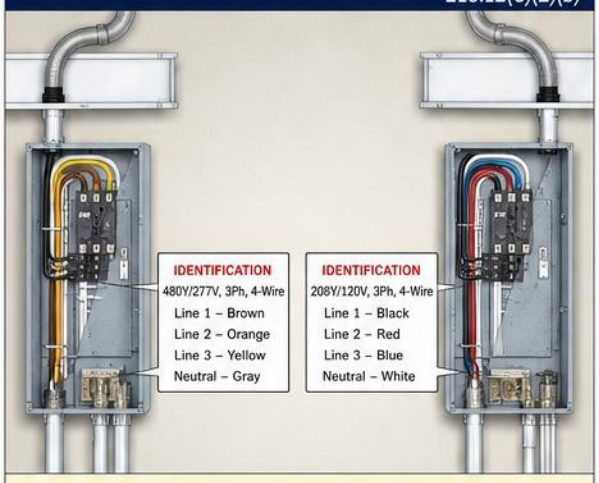
(2) Supplied from More Than One Nominal Voltage System. Where wiring is supplied from more than one nominal voltage system, the feeder phase conductors must be identified by phase and nominal voltage system at termination, connection, and splice points in accordance with 215.12(C)(2)(a) and (b).

(a) Means of Identification. Identification of the feeder phase conductors can be by color coding, marking tape, tagging, or other means approved by the authority having jurisdiction (AHJ). ➤ Figure 215–15

Figure 215–15 Feeder Phase Conductor Identification, Marking Supplied from More Than One Nominal Voltage System 215.12(C)(2)(a)

(b) Posting of Identification. Feeder phase conductor identification must be readily available or posted at the panelboard. The identification is not permitted to be handwritten and must withstand the environment involved. ➤ Figure 215–16

Figure 215–16 Feeder Phase Conductor Identification, Posting Supplied from More Than One Nominal Voltage System *215.12(C)(2)(b)*



Phase conductor identification must be readily available or posted at each panelboard, not to be handwritten, and be sufficiently durable to withstand the environment.

Figure 215–17 Conductor Identification Practices *215.12(C) Comment*

Although the *NEC* does not require a specific color code for phase conductors, electricians often use the following for power and lighting conductor identification:

- 120/240V, single-phase—black, red, and white
- 208Y/120V, three-phase—black, red, blue, and white
- 240V/120V, three-phase (high-leg)—black, orange, blue, and white
- 480Y/277V, three-phase—brown, orange, yellow, and gray; or, brown, purple, yellow, and gray

Author's Comment:

- When a premises has more than one voltage system, the phase conductors must be identified by phase and system. This can be done by permanently posting an identification legend that describes the method used (such as color-coded marking tape or color-coded insulation).
- Whichever color scheme is used, it is important that it remains consistent wherever phase conductors are terminated or accessible throughout the entire premises.
- Although the *NEC* does not require a specific color code for phase conductors, electricians often use the following systems:
  - 120/240V, single-phase—black, red, and white
  - 208Y/120V, three-phase—black, red, blue, and white
  - 240V/120V, three-phase (high-leg)—black, orange, blue, and white
  - 480Y/277V, three-phase—brown, orange, yellow, and gray; or brown, purple, yellow, and gray

215.15 Barriers

Feeder Taps. Barriers must be placed on energized phase terminals of panelboards or switchboards supplied by a feeder tap installed in accordance with 240.21(B). Figure 215–18

Figure 215–18 Feeder Tap Terminal Protective Barrier *215.15*

Barriers must be placed on energized phase terminals of panelboards or switchboards supplied by a feeder tap.

Secondary Conductors. Barriers must be placed on energized phase terminals of panelboards or switchboards supplied by the transformer secondary conductors installed in accordance with 240.21(C). Figure 215–19

Author's Comment:

- During maintenance and servicing, it is highly likely an electrical worker can be exposed to inadvertent contact with energized parts on the line side of a feeder tap or secondary conductor termination into an overcurrent protective device—even if the disconnect is in the open position.

Figure 215–19 Secondary Conductor Terminal Protective Barrier 215.15

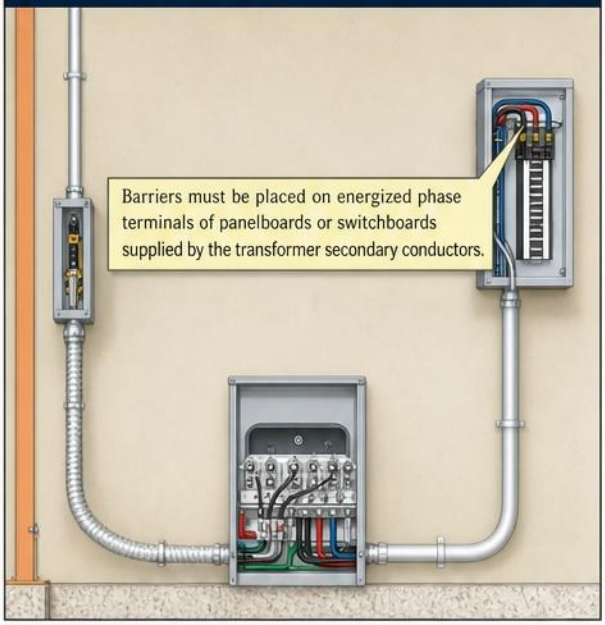
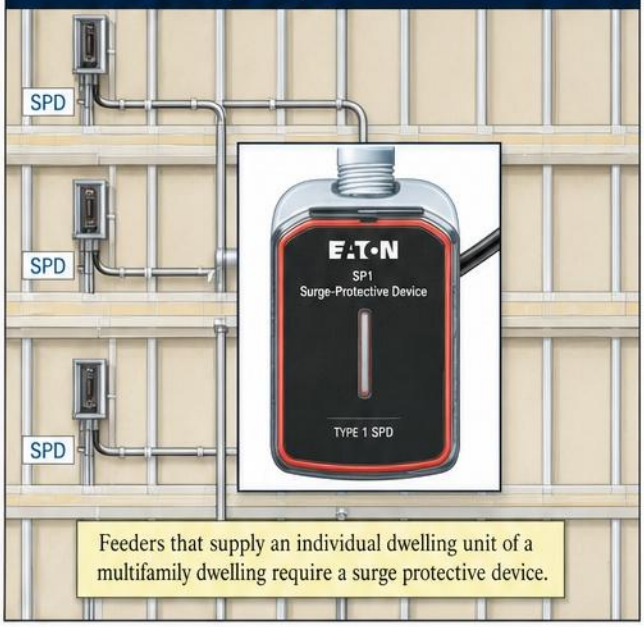


Figure 215–21 Feeders, Surge-Protective Device (SPD) Multifamily Dwelling Units 215.18(A)(1)

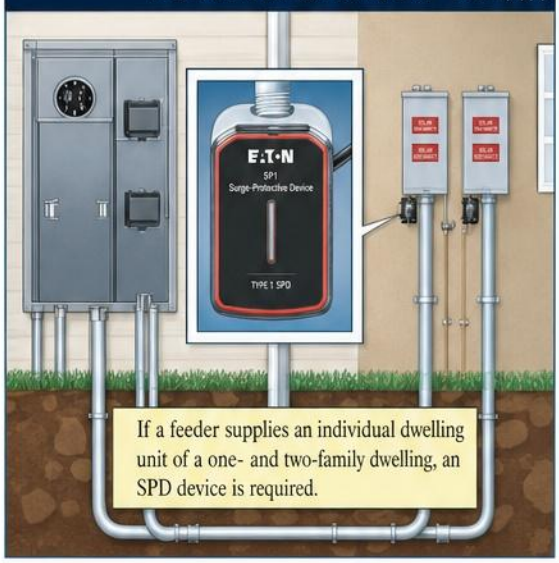


215.18 Surge Protection

(A) Surge-Protective Device (SPD). If a feeder supplies any of the following occupancies, a surge-protective device is required:

(1) Dwelling units ▶Figure 215–20 and ▶Figure 215–21

Figure 215–20 Feeders, Surge-Protective Device (SPD) One- and Two-Family Dwelling Units 215.18(A)(1)



Author's Comment:

This rule requires a surge-protective device to the feeder "supplying" a dwelling unit—not a feeder "in" a dwelling unit.

(2) Dormitories ▶Figure 215–22

Figure 215–22 Feeders, Surge-Protective Device (SPD) Dormitories 215.18(A)(2)

(3) Guest rooms and guest suites of hotels, motels, and dormitories

(4) Areas of nursing homes and limited care facilities used exclusively as patient sleeping rooms

(5) Areas for sleeping quarters in fire stations, police stations, ambulance stations, rescue stations, ranger stations, and similar locations ▶Figure 215–23

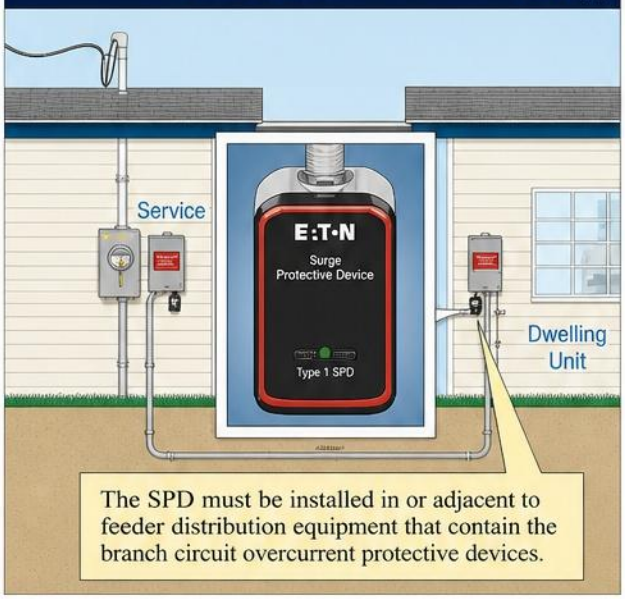
(B) Location. The surge-protective device (SPD) must be installed in or adjacent to feeder distribution equipment that contain the branch circuit overcurrent protective devices. ▶Figure 215–24

Note: Surge protection from surges generated from lightning, electric utility, or utilization equipment is most effective when located closest to the branch circuits.

Figure 215–23 Feeders, Surge-Protective Device (SPD) Emergency Responder Sleeping Area 215.18(A)(5)

A surge-protective device is required for feeders supplying sleeping quarters in fire stations, police stations, ambulance stations, rescue stations, ranger stations, and similar locations.

Figure 215–24 Feeders, Surge-Protective Device (SPD) Placement Location 215.18(B)

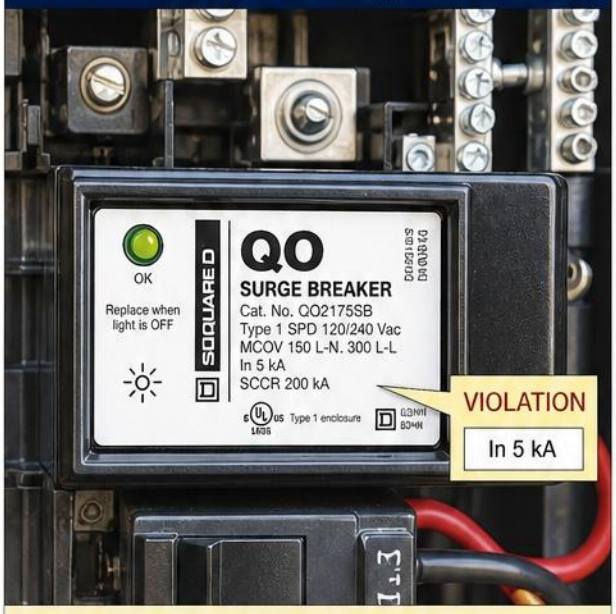


(D) Replacement of Distribution Equipment. Where feeder-supplied distribution equipment is replaced in dwelling units, dormitories, guest rooms and guest suites of hotels and motels, and areas of nursing homes and limited care facilities used exclusively as patient sleeping rooms, an SPD is required for the distribution equipment.

(E) Ratings. SPDs must have a nominal discharge current rating (In) no less than 10 kA.

▶ Figure 215–25

Figure 215–25 Feeders, Surge-Protective Device (SPD) Discharge Current Rating (In) 215.18(E)



SPDs must have a nominal discharge current rating (In) of not less than 10kA.

Author's Comment:

- See Parts I and II of Article 242 for installation requirements that apply to surge protection devices.

ARTICLE 225

Outside Branch Circuits and Feeders

Introduction to Article 225—Outside Branch Circuits and Feeders

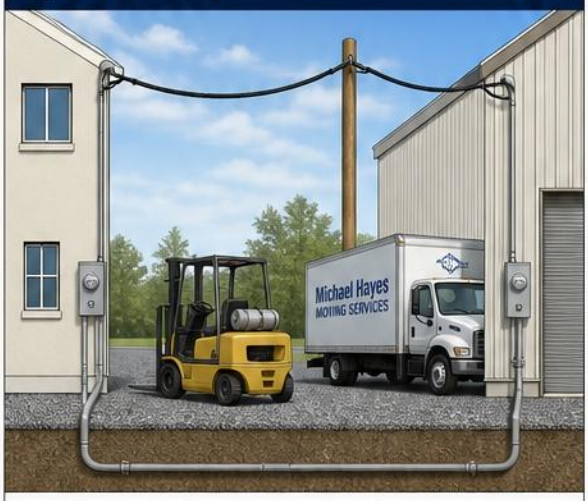
Article 225 sets out the requirements for outside branch circuits and feeders installed on or between buildings, structures, or poles. Conductors installed outdoors have many uses, such as supplying lighting, powering outdoor equipment, or delivering power to separate buildings. Because outdoor installations are exposed to physical damage, weather, and other environmental factors, Article 225 establishes provisions for conductor material and wiring method, support, clearances, disconnecting means, and the number of feeders that can supply a building.

Part I. General

225.1 Scope

Article 225 sets out the requirements for outside branch circuits and feeders installed on or between buildings, structures, or poles.

Figure 225–1 Scope 225.1



Article 225 establishes requirements for outside branch circuits and feeders installed on or between buildings, structures, or poles.

Note 2: See Article 210 and Article 215 for the general requirements for branch circuits and feeders. The requirements in Article 225 are in addition to the requirements in Article 210 and Article 215, as applicable.

225.6 Minimum Conductor Size and Support

(A) Overhead Spans.

Conductor Size. Conductors 10 AWG and larger are permitted for overhead spans up to 50 ft long. For spans over 50 ft, the minimum size conductor is 8 AWG—unless supported by a messenger wire.

Figure 225–2 Overhead Conductor Spans 225.6(A)(1)

Conductors 10 AWG and larger are permitted for overhead spans up to 50 ft long. For spans over 50 ft, the minimum size conductor is 8 AWG unless supported by a messenger wire.

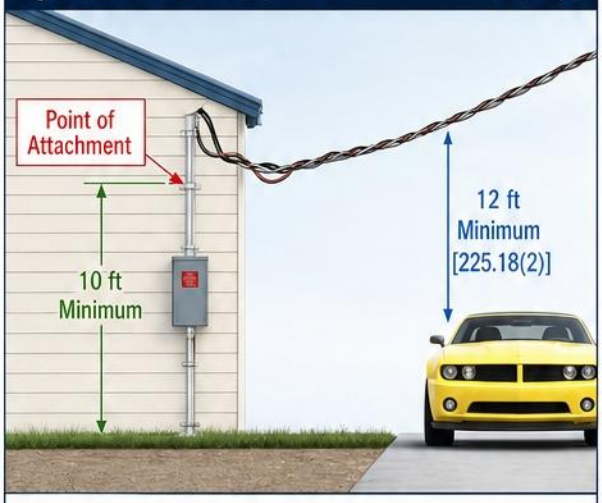
AUTHOR'S COMMENT:

- The size limitation of conductors for overhead spans is based on the need for adequate mechanical strength to support the weight of the conductors. These conductors must withstand wind, ice, and other similar conditions.

225.16 ATTACHMENT TO BUILDINGS

(A) Point of Attachment. The point of attachment for overhead conductors to buildings must be no less than 10 ft above the finished grade [230.26].

Figure 225–3 – Point of Attachment **225.16(A)**



The point of attachment for overhead conductors to buildings must not be less than 10 ft above the finished grade [230.26].

CAUTION: *Conductors might need to have the point of attachment raised so overhead conductors comply with the clearances from building openings and other building areas required by 225.19.*

(B) Means of Attachment. Open conductors must be attached to buildings by fittings identified for use with conductors, or noncombustible/nonabsorbent insulators securely attached to the building [230.27].

225.17 MASTS AS SUPPORTS

Masts for the support of overhead conductors must be as follows:

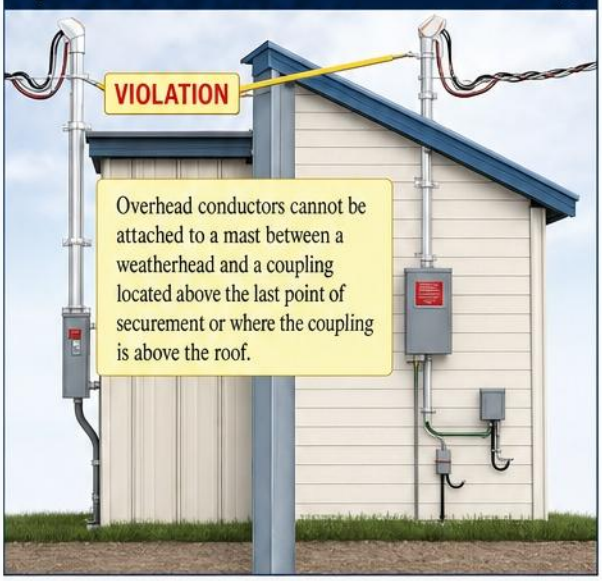
(A) Strength. The mast must have adequate strength, braces, or guy wires to safely withstand the strain caused by the overhead conductors.

Figure 225–4 – Mast Strength **225.17(A)**

The mast must have adequate strength, braces, or guy wires to safely withstand the strain caused by the overhead conductors.

(B) Attachment. Overhead conductors cannot be attached to a mast between a weatherhead and a coupling located above the last point of securement or where the coupling is above the roof.

Figure 225–5 – Attachment of Mast **225.17(B)**

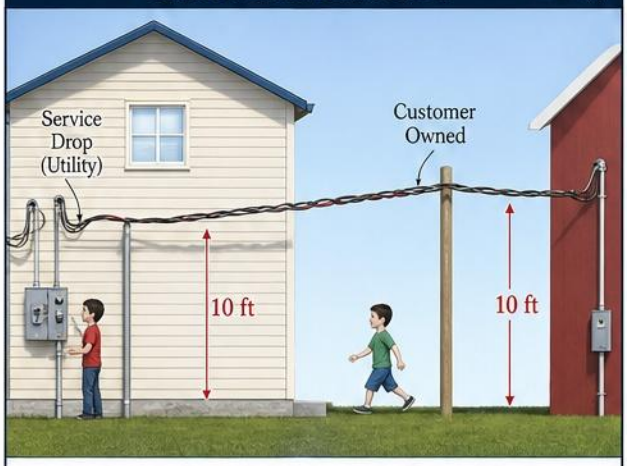


225.18 CLEARANCE FOR OVERHEAD CONDUCTORS

Overhead conductor spans must maintain a vertical clearance no less than:

(1) 10 ft above finished grade, sidewalks, platforms, or projections that permit personal contact for conductors supplied by 208Y/120V or 120/240V circuits [see Figure 225–6].

Figure 225–6 Outside Branch Circuits and Feeders Clearance for Overhead Conductors, 10 Ft 225.18(1)



Overhead conductors must be maintained with a vertical clearance of not less than 10 ft above finished grade, sidewalks, platforms, or projections that allow personnel contact for conductors supplied by 208Y/120V or 120/240V circuits.

(2) 12 ft above residential property, residential driveways, and commercial areas not subject to truck traffic for conductors supplied by 120/208V or 120/240V, 208Y/120V, or 480Y/277V circuits.

Figure 225–7 Outside Branch Circuits and Feeders Clearance for Overhead Conductors, 12 Ft 225.18(2)

Overhead conductors must be maintained with a vertical clearance of not less than 12 ft above residential property, residential driveways, and commercial areas not subject to truck traffic for conductors supplied by 120/208V or 120/240V, 208Y/120V, or 480Y/277V circuits.

(4) 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).

AUTHOR'S COMMENT:

- Overhead conductors above pools, outdoor hot tubs, diving structures, observation stands, towers, or platforms must be installed in accordance with the clearance requirements in 680.9.

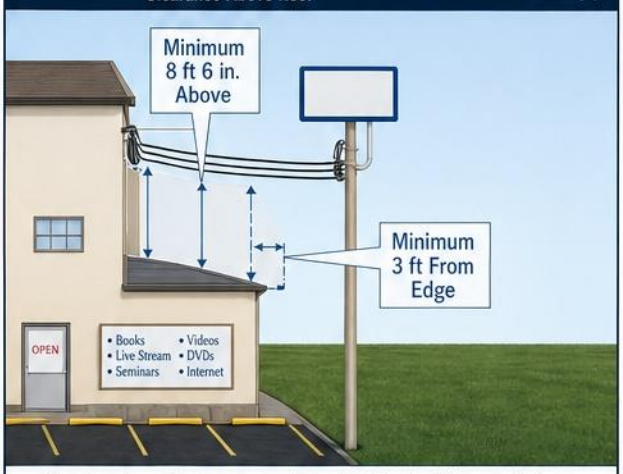
Figure 225–8 Outside Branch Circuits and Feeders Clearance for Overhead Conductors, 18 Ft 225.18(4)

225.19 Clearances from Buildings

Overhead spans of conductors must comply with the following:

(A) Above Roofs. Overhead conductors must maintain a vertical clearance of 8½ ft above the roof surface for not less than 3 ft from the roof edge. Figure 225–9

Figure 225–9 Outside Branch Circuits and Feeders Clearance Above Roof 225.19(A)



Overhead conductors must be maintained with a vertical clearance of 8 ft 6 in. above the surface of a roof for a distance of not less than 3 ft from the edge of the roof.

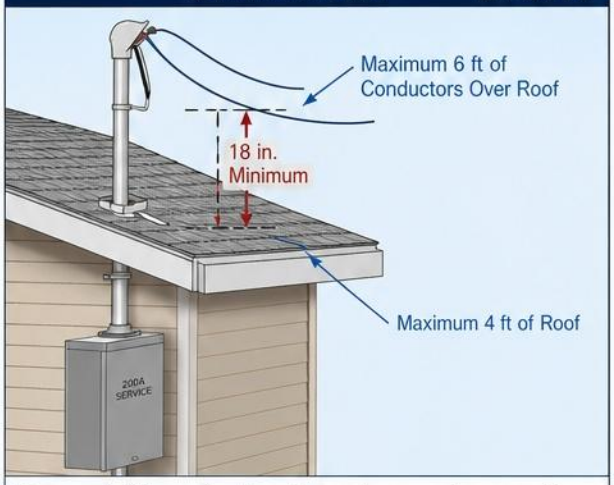
Ex 2: The overhead conductor clearances from the roof can be reduced to 3 ft if the slope of the roof meets or exceeds 4 in. vertical rise for every 12 in. of horizontal run.

Ex 3: Roof overhead conductor clearances can be reduced to 18 in. if both the following conditions are met:

(1) No more than 6 ft of conductors pass over no more than 4 ft of roof overhang for 120/240V or 208Y/120V circuits.

(2) Conductors are terminated at a through-the-roof raceway or approved support.

Figure 225–10 Outside Branch Circuits and Feeders Clearance Above Roof 225.19(A) Ex 3



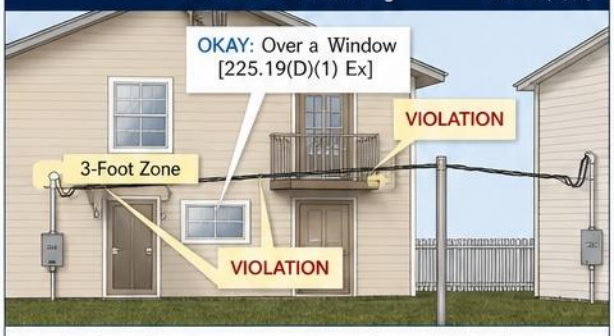
The permissible overhead conductor clearance above a roof may be reduced to 18 in., provided no more than 6 ft of conductors cross over no more than 4 ft of roof overhang, when supplied by 120/240V or 208Y/120V conductors.

(B) From Other Structures. Overhead conductors must maintain a clearance of no less than 3 ft from signs, chimneys, radio/television antennas, tanks, and other nonbuilding structures.

(D) Final Span Clearance.

(1) Clearance from Windows. Overhead conductors must maintain a clearance of no less than 3 ft from windows (that open), doors, porches, balconies, ladders, stairs, fire escapes, or similar locations.

Figure 225–11 Outside Branch Circuits and Feeders Clearance from Building 225.19(D)(1)



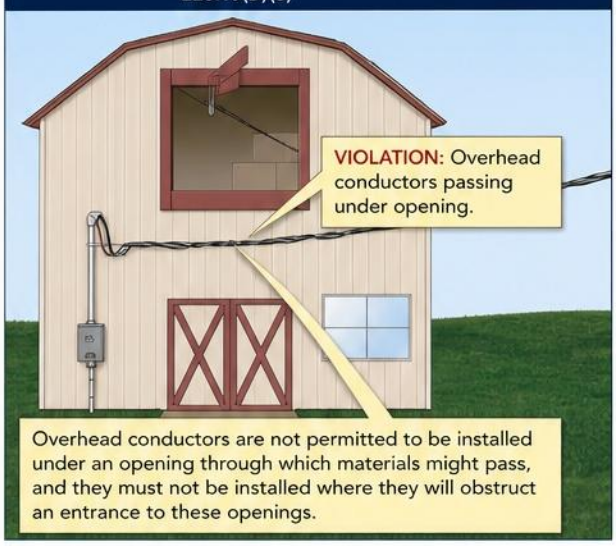
Overhead conductors must maintain a clearance of no less than 3 ft from windows that open, doors, porches, balconies, ladders, stairs, fire escapes, or similar locations.

Ex: Overhead conductors installed above a window are not required to maintain the 3-ft distance from the window.

(2) Vertical Clearance. A vertical clearance of 10 ft for overhead conductors must be maintained for 3 ft (measured horizontally from the platforms, projections, or surfaces) from which they might be reached.

(3) Below Openings. Overhead conductors are not permitted to be installed under an opening through which materials might pass or obstruct an entrance to these openings.

Figure 225–12 Outside Branch Circuits and Feeders Clearance Below Openings 225.19(D)(3)



225.22 Raceways on Exterior Surfaces of Buildings

Raceways on exterior surfaces of buildings or structures must be arranged to drain and be listed or approved for use in wet locations.

Figure 225–13 Outside Branch Circuits and Feeders Raceways on Exterior Surfaces 225.22

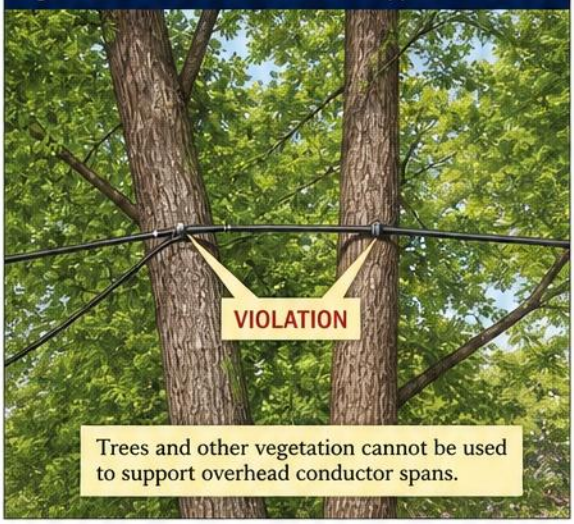
Raceways on exterior surfaces of buildings or structures must be arranged to drain and be listed or approved for use in wet locations.

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

225.26 Trees for Conductor Support

Trees and other vegetation are not permitted to be used for the support of overhead conductor spans. ▶ Figure 225–14

Figure 225–14 Trees for Conductor Support 225.26



The branches of these trees are being used to support the conductors, which is not permitted.

Author's Comment:

- Overhead conductor spans for services [230.10] and temporary wiring [590.4(J)] are not permitted to be supported by vegetation.

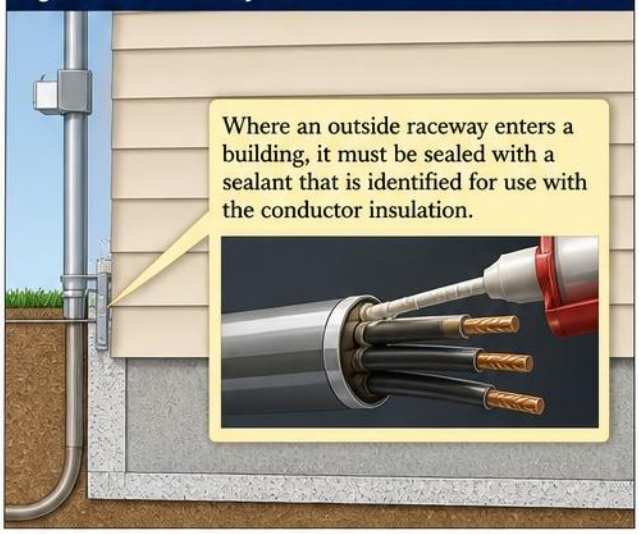
225.27 Raceway Seals

When an outside raceway enters a building, it must be sealed with a sealant that is identified for use with the conductor insulation. ▶ Figure 225–15

Author's Comment:

- According to the *NEC Handbook*, sealant (such as duct seal) is required to be used to seal the ends of service raceways. The intent is to prevent water (usually from condensation due to temperature differences) from entering the equipment through the raceway. The sealant material should be compatible with the conductor insulation, and it should not cause deterioration of the insulation over time.

Figure 225–15 Raceway Seals 225.27



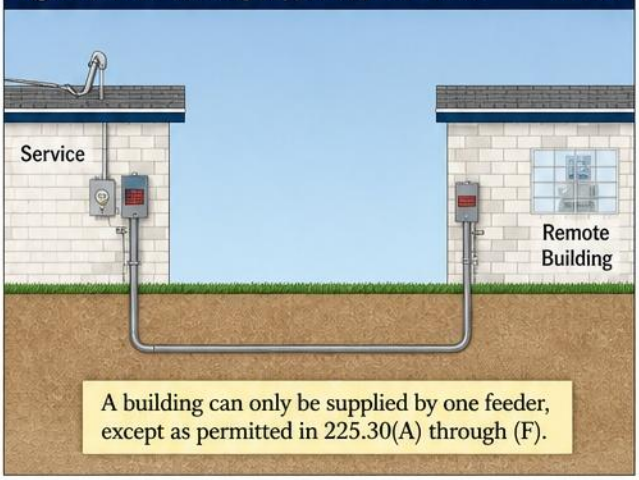
A listed sealant is applied around the raceway and conductors where they enter the building.

Part II. Buildings or Other Structures Supplied by a Feeder

225.30 Number of Supplies

A building can only be supplied by one feeder, except as permitted in 225.30(A) through (F). ▶ Figure 225–16

Figure 225–16 Building Supplied by One Feeder 225.30



(A) Special Conditions. Additional feeders are permitted to supply:

(1) Fire pumps

(2) Emergency systems

(3) Legally required standby systems

(4) Optional standby systems

(5) Parallel power production sources

(6) Systems designed for connection to multiple sources of supply for the purpose of enhanced reliability

(7) Electric vehicle power transfer systems listed, labeled, and identified for more than a single branch circuit or feeder

(8) Docking facilities

(B) More than One Feeder. Up to six feeders originating in the same panelboard or distribution equipment are permitted to a building if the disconnects are grouped together at the separate building. Figure 225–17 and Figure 225–18

Figure 225–17 Building Supplied by More than One Feeder 225.30(B)

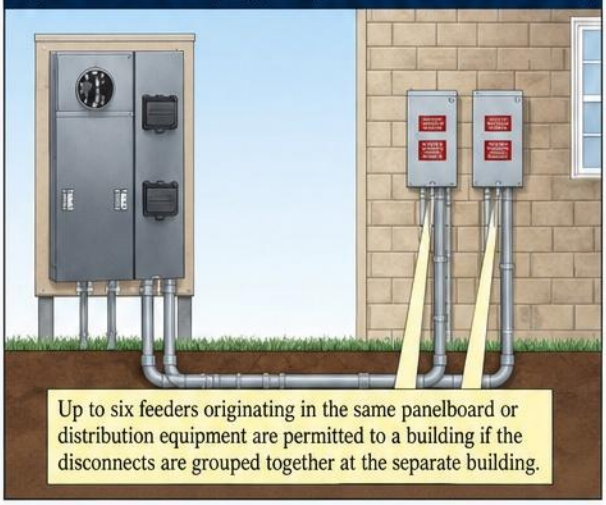
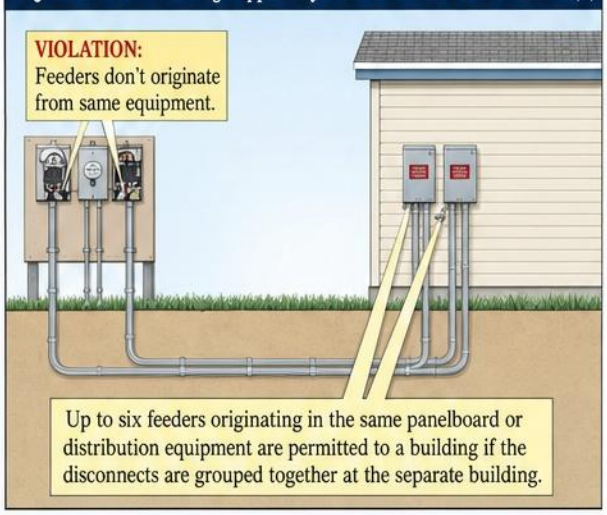


Figure 225–18 Building Supplied by More than One Feeder 225.30(B)



(C) Special Occupancies. By special permission, additional feeders are permitted for:

(1) Multiple-occupancy buildings where there is no available space for supply equipment accessible to all occupants

(2) Buildings so large that two or more supplies are necessary

(D) Capacity Requirements. Additional feeders are permitted for a building where the capacity requirements exceeds 2000A.

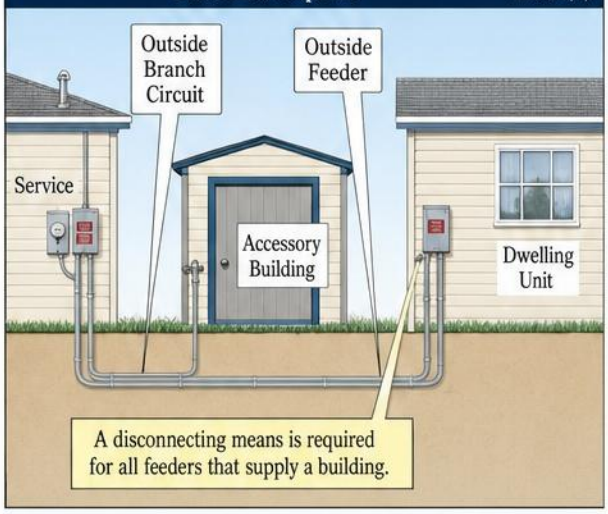
(E) Different Characteristics. Additional feeders are permitted for different voltages, frequencies, or uses (such as controlling outside lighting from multiple locations).

(F) Documented Switching Procedures. Additional feeders are permitted where documented safe switching procedures are established and maintained.

225.31 Disconnecting Means

(A) General. A disconnecting means is required for all feeders that supply a building. Figure 225–19

Figure 225–19 Building Supplied by Feeder Disconnect Required 225.31(A)

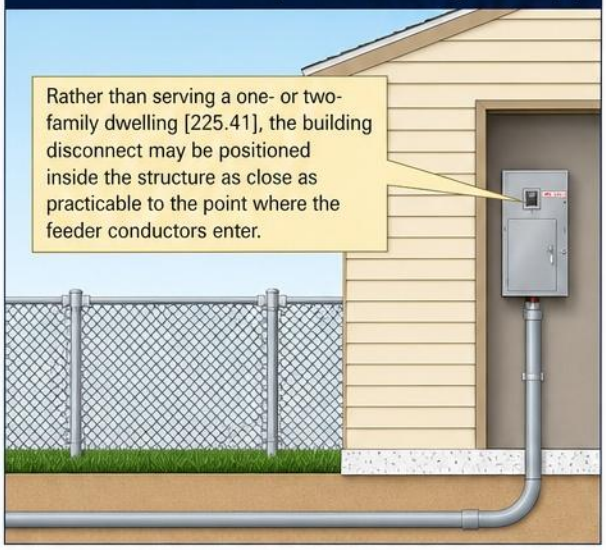


(B) Location.

Inside. In other than one- and two-family dwellings [225.41], the building feeder disconnect can be located inside the building nearest the point of entrance of the feeder conductors. Figure 225–20

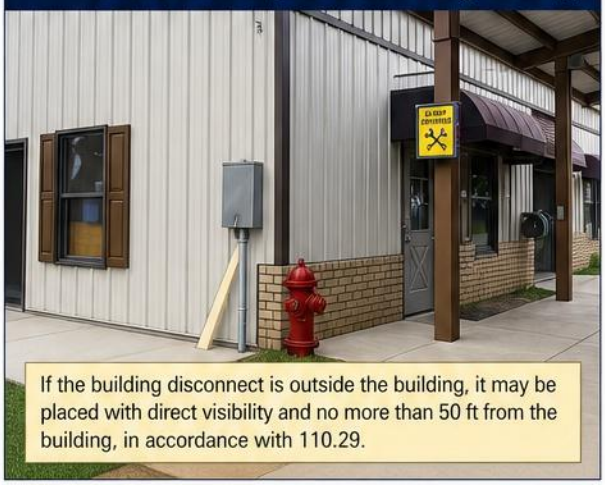
Outside. If the building feeder disconnect is located outside of the building, the disconnecting means can be located on or within sight and not more than 50 ft from the building in accordance with 110.29. Figure 225–21

Figure 225–20 Building Supplied by Feeder Disconnect Location, Inside the Building 225.31(B)



The disconnect is located inside the building, near the feeder conductors' point of entry.

Figure 225–21 Building Supplied by a Feeder Disconnect Location, Outside the Building 225.31(B)

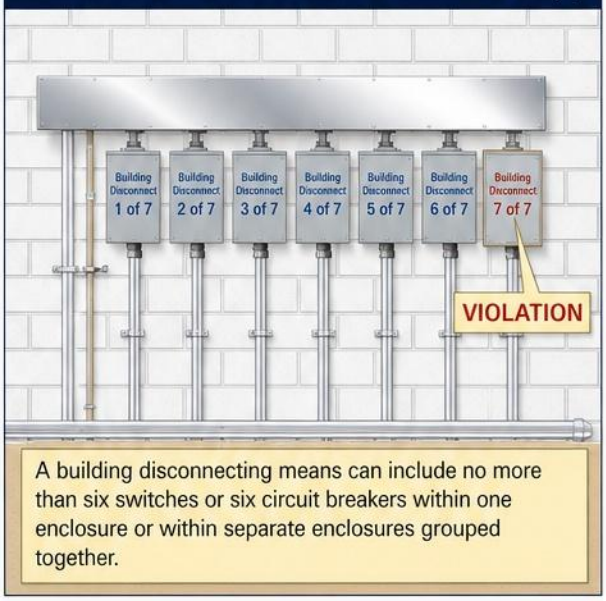


Feeder conductors that are not less than 2 in. of concrete encasement or that are not less than 2 in. of concrete are considered outside a building [230.6].

225.33 Maximum Number of Disconnects

(A) General. A building feeder disconnecting means may consist of no more than six switches/circuit breakers within a single enclosure or within separate enclosures grouped together. 225.33(A)

Figure 225–22 Building Supplied by Feeder Maximum Number of Disconnects 225.33(A)



A building disconnecting means can include no more than six switches or six circuit breakers within one enclosure or within separate enclosures grouped together.

225.34 Grouping of Disconnects

(A) General. Building feeder disconnecting means must be collected in one location and clearly labeled to show the loads they supply. 225.34(A) See Figure 225–23.

Figure 225–23 Building Supplied by Feeder Grouping of Disconnects 225.34(A)

Disconnecting means must be grouped in one location and clearly labeled to indicate the loads they serve.

Author's Comment:

- If a building is fed by more than one feeder, a permanent plaque or directory must be installed at each feeder disconnect location. It should identify every other feeder that supplies the building, along with the area each feeder serves. See 225.37.

(B) Additional Disconnects. To minimize the risk of unintentional interruption of critical power systems, disconnects for fire pumps, emergency systems, legally required standby systems, or optional standby systems must be installed remotely from the standard utility disconnect.

225.37 Identification of Multiple Supplies

If a building is supplied by more than one feeder or service, a durable plaque or directory must be installed at each feeder and service disconnect location. The marking must clearly identify all other feeders or services that supply the building, as well as the area served by each.

Author's Comment:

- This information is essential for first responders. In many facilities, electrical distribution details may be unfamiliar and the disconnect could be the only means to shut off power during an emergency.

225.39 Rating of Disconnecting Means

The ampere rating of feeder disconnecting means specified in 225.31 must not be less than:

(A) One-Circuit Installation. For a single branch circuit, the disconnect must be rated at not less than 15A.

(B) Two-Circuit Installation. For two 2-wire branch circuits, the disconnect must be rated at not less than 30A.

(C) One-Family Dwelling. For a one-family dwelling, the disconnect must be rated at not less than 100A.

(D) Other Installations. For other installations, the disconnect must be rated at not less than 60A.

225.41 Emergency Disconnect

A disconnecting means is required for one- and two-family dwellings that are supplied by a feeder.

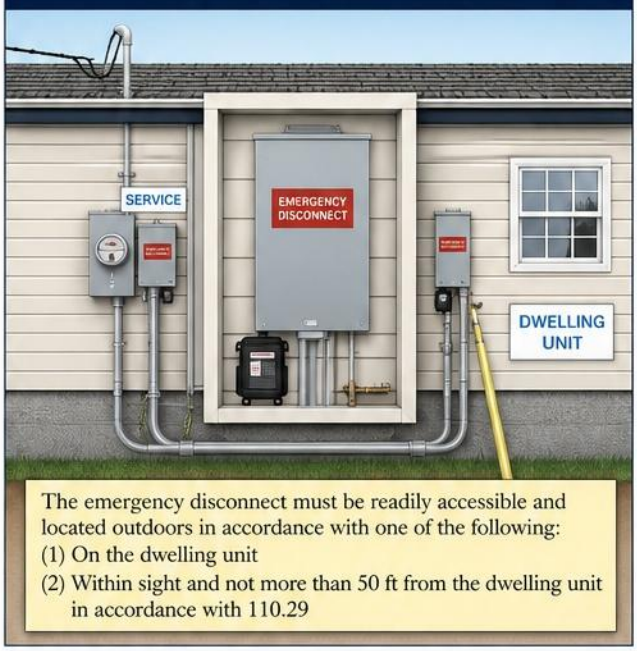
(A) General.

(1) Location. The emergency disconnect must be readily available and located outdoors in accordance with one of the following:

(1) On the dwelling unit

(2) Within sight and not more than 50 ft from the dwelling unit in accordance with 110.29

Figure 225–24 Emergency Disconnect Location One- and Two-Family Dwelling 225.41(A)(1)



The emergency disconnect must be outdoors and either mounted on the dwelling unit or within sight and not more than 50 ft from the unit in accordance with 110.29.

(3) Grouping. If more than one emergency disconnect is provided at a building, they must be grouped outdoors.

Figure 225–25 Emergency Disconnect Grouping One- and Two-Family Dwelling 225.41(A)(3)

(B) Identification of Other Source Disconnects. When disconnects for alternate energy source systems are not located next to the emergency disconnect, a plaque or directory must be used to indicate where those source disconnects are. These markings must be placed adjacent to the emergency disconnect.

Note: For examples of other energy source system disconnecting means, see 445.18, 480.7, 705.20, and 706.15.

(C) MARKING

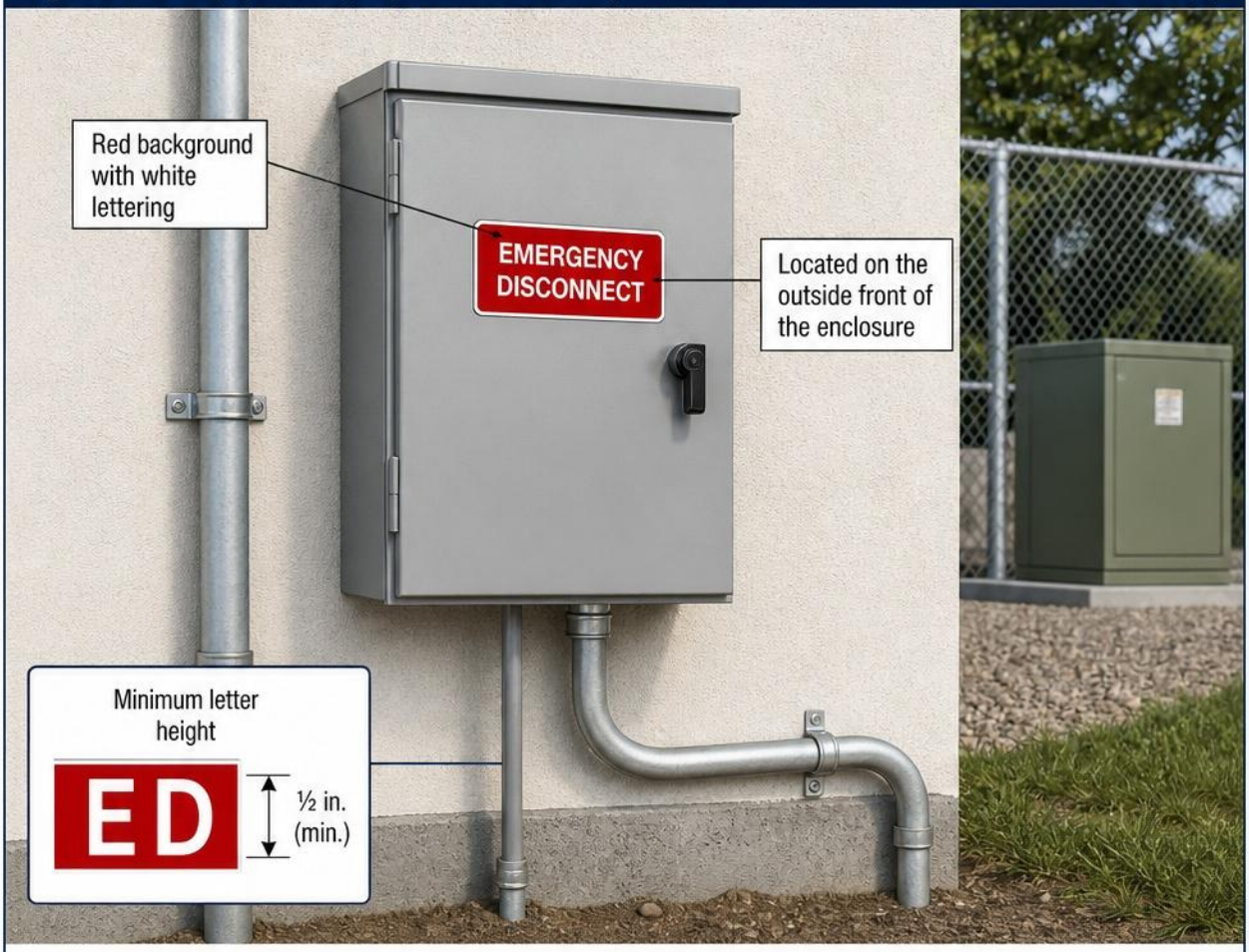
The emergency disconnect enclosure must be marked "EMERGENCY DISCONNECT." The marking must be of sufficient durability to resist the environment, not be handwritten, and be permanently affixed to the equipment in accordance with 110.21(B).

The marking or label must comply with the following:

(1) The marking must be located on the exterior front of the disconnect enclosure and must have a red background with white lettering.

(2) The letters used must be at least ½ in. high.

Figure 225.41(C) Emergency Disconnect Marking 110.21(B)



The emergency disconnect enclosure must be marked "EMERGENCY DISCONNECT" with a permanently affixed label that has a red background, white letters, and letters at least ½ in. high.

Article 110 — General Requirements

Article 110 establishes general requirements for the installation, use, and identification of electrical equipment to ensure safety, proper operation, and compliance with the NEC.

110.1 Scope

This article covers general requirements for electrical installations, including equipment usage, identification, working space, and structural support.

110.2 Approval of Equipment

Electrical equipment must be approved. Approved equipment is marked, labeled, or certified for the intended use and installed in accordance with the listing or labeling.

110.3 Installation and Use

Electrical equipment must be installed and used in accordance with this Code and any instructions included with the equipment. It must be used in a manner consistent with its listing, labeling, or certification.

110.4 Working Space

Sufficient space must be provided and maintained about electrical equipment to permit ready and safe operation and maintenance.

Figure 110.4(A) — Working Space **110.4(A)**

Working space in front of electrical equipment must be clear and unobstructed to allow safe access and operation.

110.5 Access

Electrical equipment must be accessible to qualified persons. Access must not require the removal or destruction of any building part or permanent structural element.

110.6 Arrangement and Protection

Electrical equipment and conductors must be arranged and protected so as not to be exposed to physical damage. Locations subject to damage must be protected by guards, enclosures, or by being located so as to be out of harm's way.

110.7 Mechanical Execution

Electrical installations must be mechanically secure, properly supported, and capable of performing their intended function.

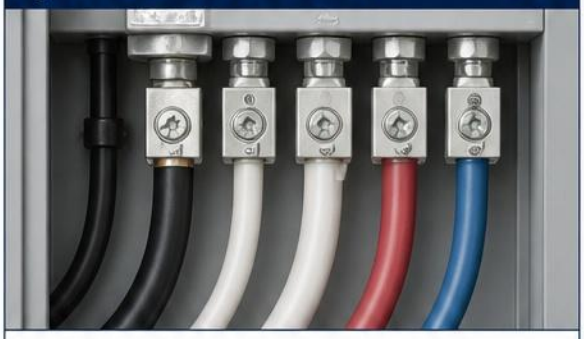
110.8 Identification

Electrical equipment must be durably and legibly marked or labeled to indicate its purpose or use.

110.9 Electrical Connections

Electrical connections must be suitable for the use, installed in accordance with this Code, and securely fastened.

Figure 110.9 — Electrical Connections **110.9**



Electrical connections must be made with components identified for the purpose and securely fastened.

110.10 Electrical Equipment on Rooftops

Electrical equipment installed on rooftops must be suitable for the environment and protected from damage, including that caused by maintenance equipment.

110.11 Hazardous (Classified) Locations

Electrical equipment installed in hazardous (classified) locations must be suitable for the location and installed in accordance with the requirements of Article 500.

Figure 110.34 — Service Disconnecting Means **110.34**

The service disconnecting means must be located at the point of entrance of the service conductors.

ARTICLE

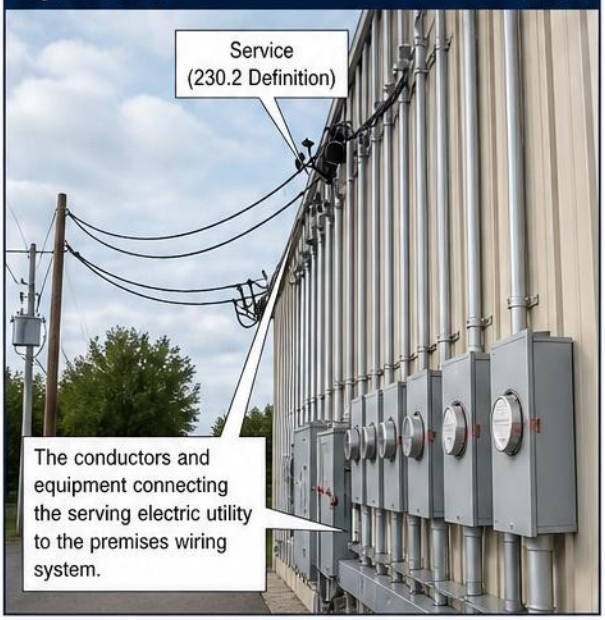
230 Services

Introduction to Article 230–Services

Article 230 sets forth the requirements for *services*, *service conductors*, and *service equipment*. The location where the utility supply conductors attach to customer premises wiring is called the *service point*. To correctly apply these rules, it is important to know what constitutes a "service," where it begins, and where it terminates. Because the conductors on the line side of service equipment have limited overcurrent protection, these rules frequently require that the conductors be provided with more physical protection than is required for feeders or branch circuits.

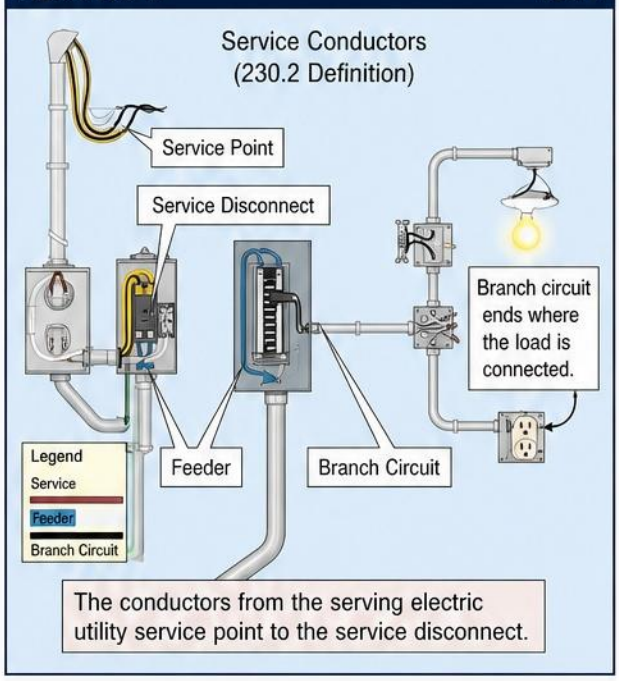
Service. The conductors and equipment connecting the serving electric utility to the premises wiring system.
▶ Figure 230–1

Figure 230–1 **230.2**



Service Conductors. The conductors from the serving electric utility service point to the service disconnect.
▶ Figure 230–2

Figure 230–2 **230.2**



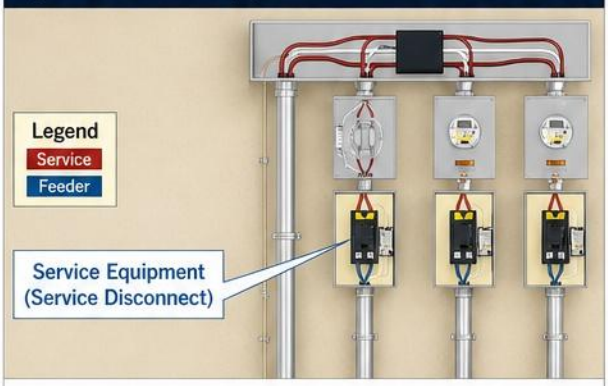
Service Equipment. Equipment consisting of circuit breakers or fused switches intended to disconnect the power from the serving electric utility.
▶ Figure 230–3 and ▶ Figure 230–4

Service Point. The point where the serving electric utility conductors connect to customer-owned premises wiring.
▶ Figure 230–5 and ▶ Figure 230–6

Figure 230-3 Service Equipment — Article 100 Definition

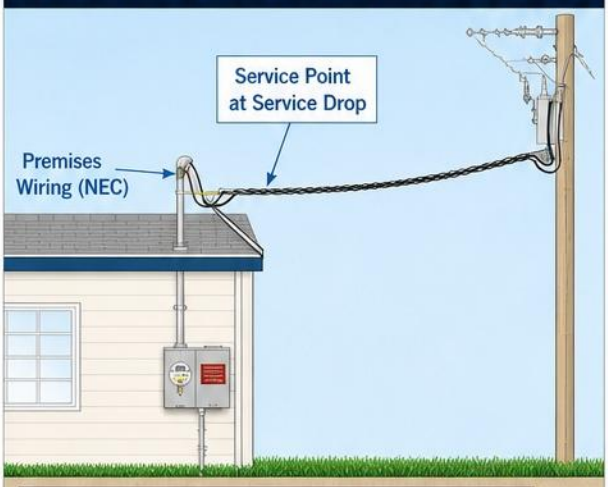
Equipment that includes circuit breakers or fused switches used to disconnect the electrical supply from the utility.

Figure 230-4 Service Equipment — Article 100 Definition



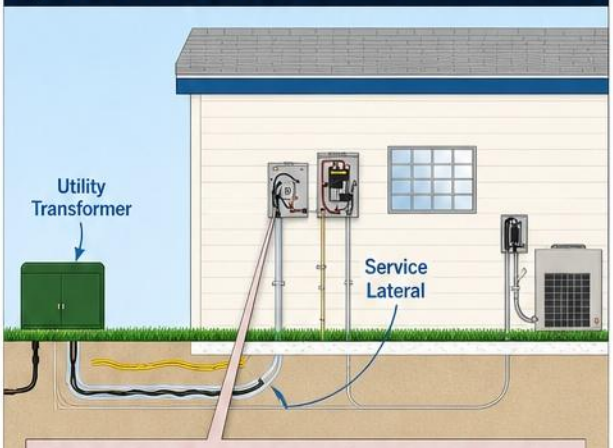
Equipment that includes circuit breakers or fused switches used to disconnect the electrical supply from the utility.

Figure 230-5 Service Point at Service Drop — Article 100 Definition



The location where conductors from the electric utility connect to the wiring of customer-owned premises.

Figure 230-6 Service Point at Meter Enclosure — Article 100 Definition



The location where conductors from the electric utility connect to the wiring of customer-owned premises.

Part I. General

230.1 Scope

This article sets out the requirements for service conductors and service equipment. Figure 230-7

Figure 230-7 Services — 230.1 Scope

230.2 Listing Requirements

(A) Listed. The following equipment must be listed:

(1) Meter sockets not supplied by an electric utility

(2) Meter-mounted transfer switches

(3) Power distribution blocks

(4) Pressure connectors

(5) Devices for splices and taps

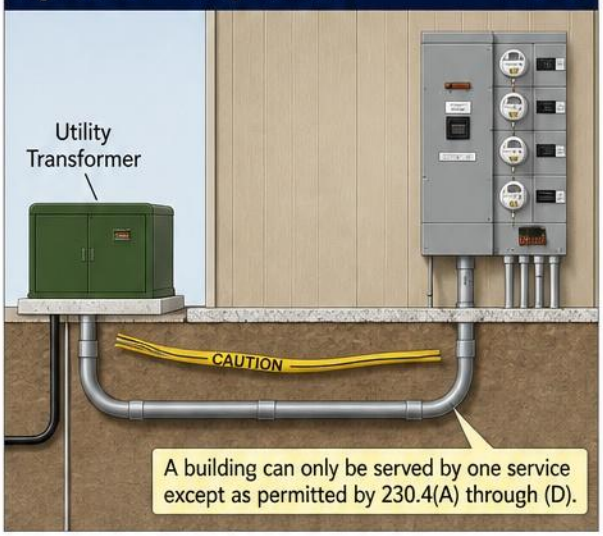
(6) Permanently mounted absence of voltage testers

(B) Listed or Field Evaluated. Service equipment must be listed or field evaluated.

230.4 Number of Services

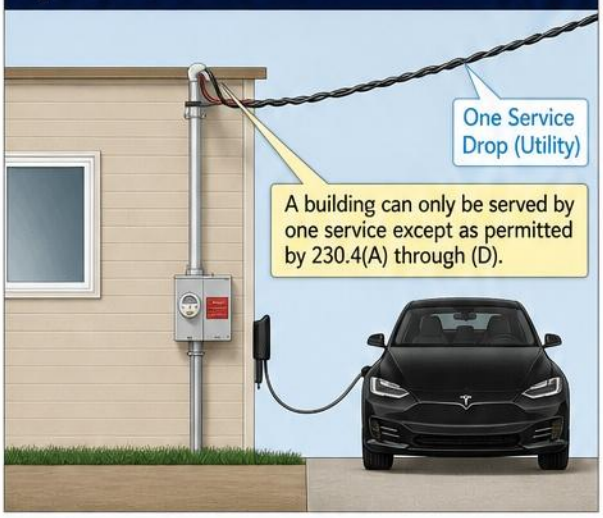
A building can only be served by one service except as permitted by 230.4(A) through (D). ▶Figure 230–8 and ▶Figure 230–9.

Figure 230–8 Underground Service NEC 230.4



Example of an underground service installation.

Figure 230–9 Overhead Service NEC 230.4



Example of an overhead service installation.

(A) Special Conditions. Additional services are permitted for the following:

(1) Fire pumps

(2) Emergency systems

(3) Legally required standby systems

(4) Optional standby systems

(5) Interconnected electric power production sources

(6) Systems designed for connection to multiple sources of supply to enhance reliability

(B) Special Occupancies. Additional services are permitted for the following where *special permission* has been given:

> ***Special Permission.*** Written consent of the authority having jurisdiction (AHJ).

(1) Multiple-occupancy buildings where there is no available space for supply equipment accessible to all occupants

(2) Buildings so large that two or more services are necessary

(C) Capacity Requirements. Additional services are permitted for the following:

(1) Buildings with capacity requirements that exceed 2000A

(2) If the load requirements of a single-phase installation exceeds the serving electric utility's power capacity

(3) By special permission

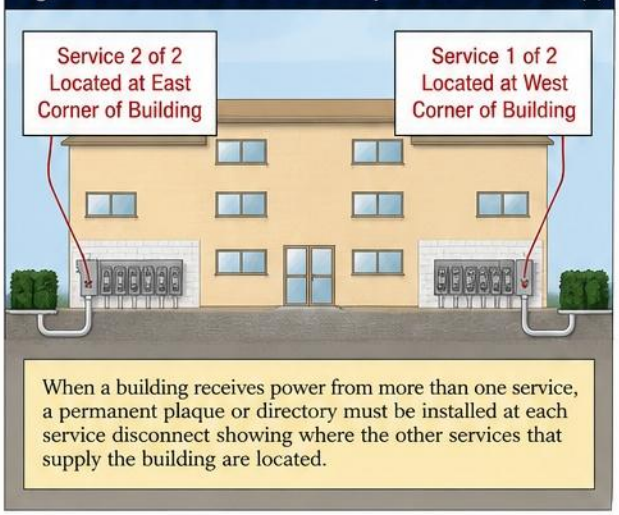
(D) Different Characteristics. Additional services are permitted bır different voltages, frequencies, phases, or for different uses (such as varying electricity rate schedules).

Author's Comment:

- An example of different service characteristics is a building supplied by a 3-wire, 120/240V, single-phase service, and the same building also supplied by a 3-phase, 4-wire, 480Y/277V service.

(E) Identification of Multiple Services. If a building is supplied by more than one service, a permanent plaque or directory must be installed at each service disconnect indicating the location of other services supplying that building. ▶Figure 230–10.

Figure 230–10 Identification of Multiple Services 230.4(E)



Author's Comment:

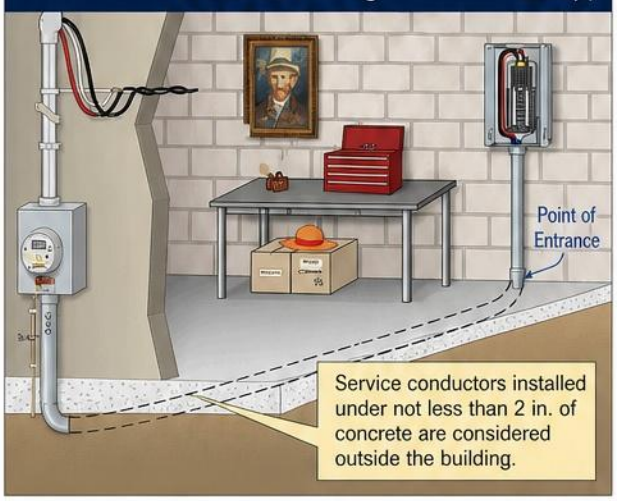
- This information is critically important to first responders who may be unfamiliar with the facility's electrical distribution system and need to shut off power to the building in an emergency.

230.6 Conductors Considered Outside a Building

Service conductors installed under the following conditions are considered outside the building:

(1) Under not less than 2 in. of concrete (See Figure 230–11)

Figure 230–11 Service Conductors Considered Outside the Building 230.6(1)



Service conductors installed beneath at least 2 in. of concrete are classified as being outside the building.

(2) In a raceway encased in not less than 2 in. of concrete or brick

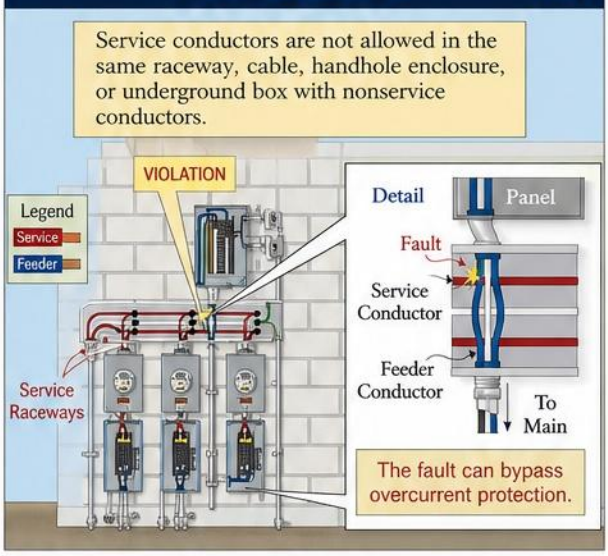
(3) In transformer vaults that meet the requirements of Article 450

(4) In dirt floor buildings with the raceway installed not less than 18 in. below the finished surface

230.7 Service Conductors Separate from Other Conductors

Service conductors are not allowed in the same raceway, cable, handhole enclosure, or underground box with nonservice conductors. (See Figure 230–12)

Figure 230–12 Service Conductors Separate from Other Conductors 230.7



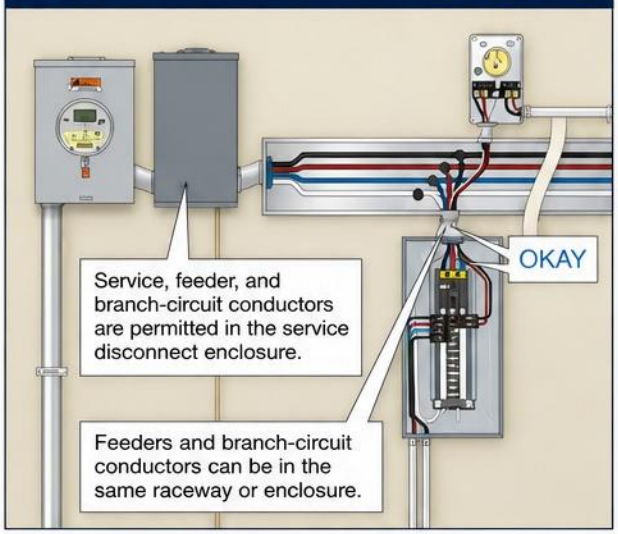
Placing service conductors and other than service conductors in the same raceway or enclosure—or creating a short between them—can allow a fault to bypass the overcurrent protective device for the other conductors.

WARNING: If service conductors and other than service conductors are in the same raceway and a short circuit occurs between the service and other conductors, the overcurrent protection for the other conductors will be bypassed.

Author's Comment:

- Service and other than service conductors are not permitted in a wireway because a wireway is a raceway in accordance with the definition contained in Article 100.
- Service, feeder, and branch-circuit conductors are permitted in the service disconnect enclosure.
- Feeders and branch-circuit conductors can be in the same raceway or enclosure. (See Figure 230–13)

Figure 230–13 230.7 Comment



Service conductors are permitted in the service disconnect enclosure, and feeder and branch-circuit conductors may occupy the same raceway or enclosure.

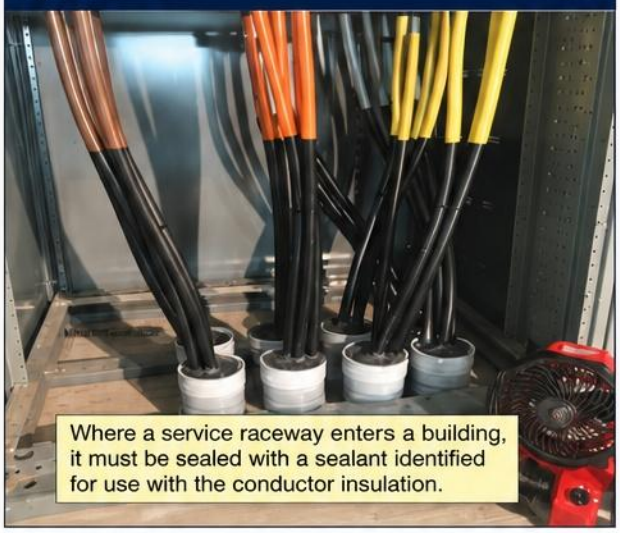
230.8 Raceway Seals

When a service raceway penetrates a building, it must be sealed with a sealant that is identified for use with the conductor insulation, whether the conductor insulation is cable, bare conductor, shield, or another component. See Figure 230–14 and Figure 230–15.

Figure 230–14 230.8

Seal the penetration of the service raceway through the building structure using a sealant that is identified for use with the conductor insulation.

Figure 230–15 230.8



When a service raceway penetrates a building, the opening must be sealed using a sealant that is identified for use with the conductor insulation, whether the conductor insulation is cable, bare conductor, shield, or another component.

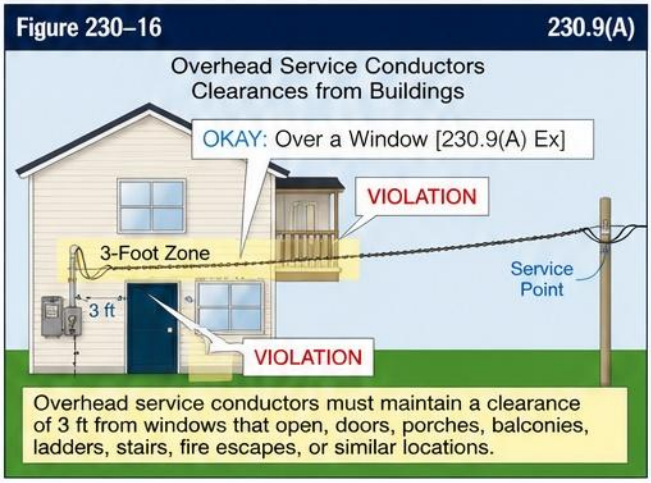
Author's Comment:

According to the *NEC Handbook*, sealant (such as duct seal) is required to be used to seal the ends of service raceways. The intent is to prevent water (usually from condensation due to temperature differences) from entering the equipment through the raceway. The sealant material should be compatible with the conductor insulation and should not cause deterioration of the insulation over time.

230.9 Clearances on Buildings

(A) Clearance. Overhead service conductors must maintain a clearance of 3 ft from windows that open, doors, porches, balconies, ladders, stairs, fire escapes, or similar locations. See Figure 230–16.

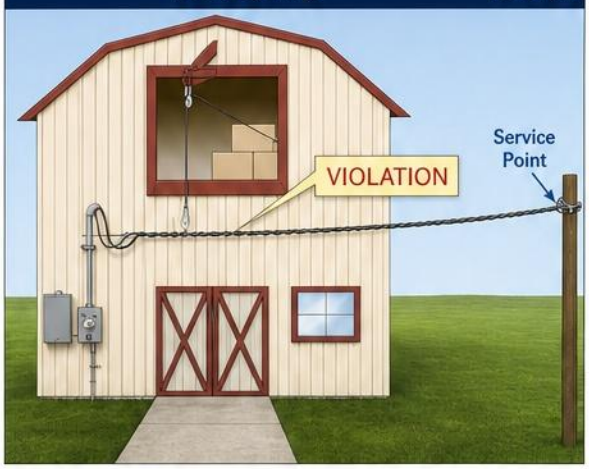
Figure 230–16 230.9(A)



(B) Vertical Clearance. Service conductors installed overhead within 3 ft (measured horizontally) of platforms, projections, or surfaces that might be used for personal contact must maintain a vertical clearance of not less than 10 ft above those platforms, projections, or surfaces, in accordance with 230.24(B).

(C) Below Openings. Overhead service conductors are not permitted to be installed across an opening through which building materials could pass or where such materials could obstruct access to the building opening. **Figure 230–17**

Figure 230–17 | Overhead Service Conductors Below Openings 230.9(C)

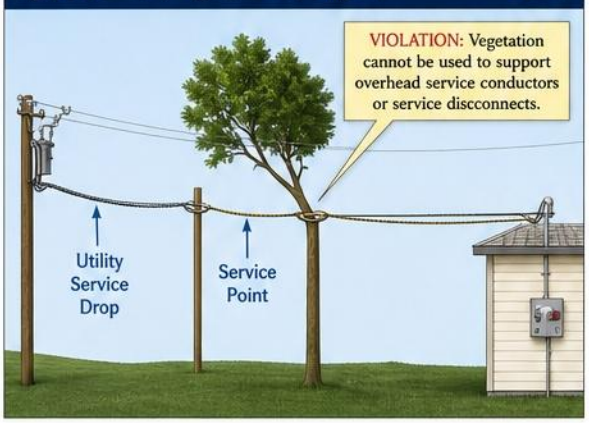


Overhead service conductors are prohibited from being installed over an opening where building materials could pass through or where such materials could block access to that opening.

230.10 Vegetation as Support

Trees or other vegetation are not allowed to be used to support overhead service conductors spans or service disconnects. **Figure 230–18**

Figure 230–18 | Vegetation as Support 230.10



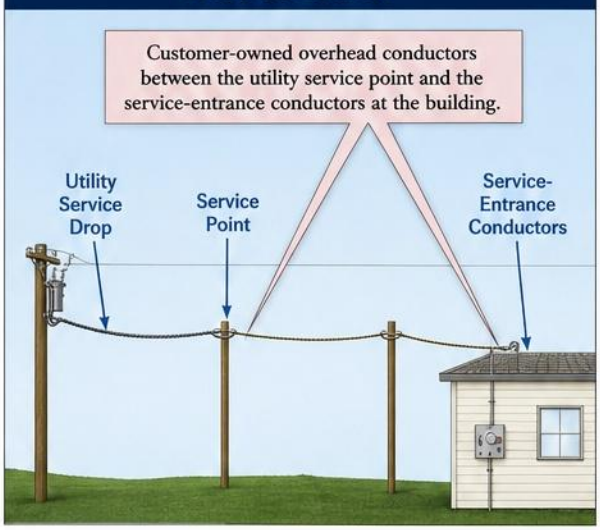
Part II. Overhead Service Conductors

230.23 Overhead Service Conductor Size and Ampacity

(A) General. Overhead service conductors must have an ampacity not less than the calculated load.

Service, Overhead Service Conductors. Customer-owned overhead conductors between the utility service point and the service-entrance conductors at the building. **Figure 230–19**

Figure 230–19 | Overhead Service Conductors Article 100 Definition



(B) Phase Conductor Size. Overhead service conductors cannot be smaller than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum.

Ex: Overhead service conductors can be as small as 12 AWG for limited-load installations.

(C) Neutral Conductor Size. The neutral conductor for overhead service conductors must be sized to carry the maximum unbalanced load in accordance with 120.61 and no smaller than required by 250.24(D)(1).

WARNING: The service neutral conductor size must not be smaller than that required by 250.24(D)(1). This ensures it has sufficiently low impedance and current-carrying capacity to safely carry fault current to assist in the operation of the overcurrent protective device [250.4(A)(5)].

230.24 Vertical Clearance for Overhead Service Conductors

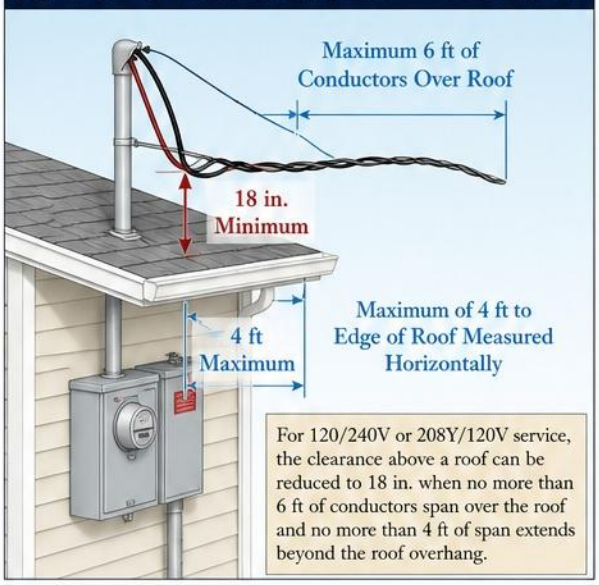
Overhead service conductor spans are required to maintain the following minimum vertical clearances:

(A) Above Roofs. The minimum vertical clearance above any roof surface is 8½ ft, and the minimum clearance in all horizontal directions from the roof edge is 3 ft.

Ex 2: When the roof slope exceeds 4 in. of vertical rise for every 12 in. of horizontal run, the 120/240V or 208Y/120V overhead service conductor clearances may be reduced to 3 ft above the roof.

Ex 3: For conductors supported by 120/240V or 208Y/120V service, the clearance above a roof may be reduced to 18 in. when no more than 6 ft of conductor span overhangs the roof, provided that no more than 4 ft of conductor span extends beyond the roof overhang.

Figure 230–20 Clearance Above Roofs 230.24(A) Ex 3



(B) Above Grade. Overhead service conductor spans must maintain the following minimum vertical clearances above final grade:

(1) 10 ft above final grade, sidewalks, platforms, or projections that allow people to contact 208Y/120V or 120/240V conductors

(2) 12 ft above residential property, residential driveways, or commercial locations not subject to truck traffic for 120/240V, 208Y/120V, or 480Y/277V conductors

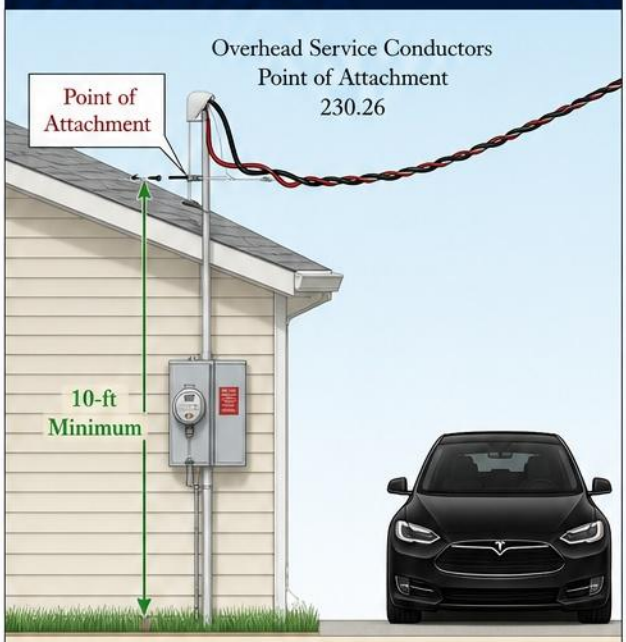
(4) 18 ft above public streets, alleys, roads, parking areas used by motor vehicles, driveways other than those on residential property that are subject to truck traffic, and areas traversed by vehicles (such as those used for farming, grazing, forestry, and orchards)

(D) Swimming Pools, Hot Tubs, and Fountains. Overhead service conductors above pools, outdoor hot tubs, and fountains must comply with the clearance requirements in 680.9.

230.26 Point of Attachment

The point where overhead service conductors connect is not permitted to be less than 10 ft above the finished grade. **Figure 230–21.**

Figure 230–21 Point of Attachment 230.26



The point of attachment for overhead service conductors must not be less than 10 ft above the finished grade.

230.27 Means of Attachment

Open conductors must be attached to fittings that are identified for use with service conductors.

230.28 Service Masts as Support

Masts used to support service conductors must meet the following conditions:

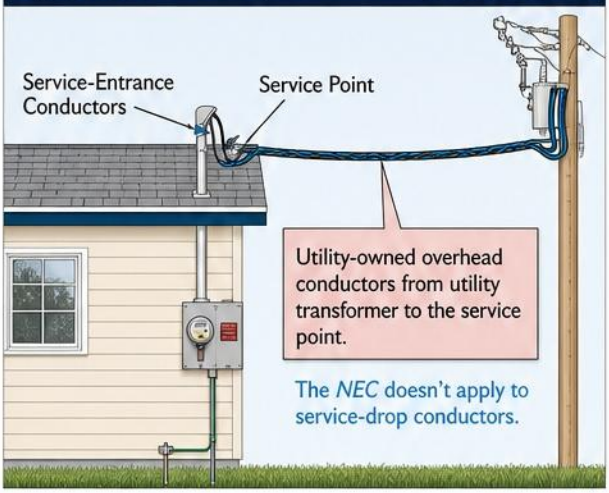
(A) Strength. When a mast supports customer overhead service conductors or utility service-drop conductors, it must have adequate strength, braces, or guy wires to withstand the mechanical stresses imposed by the conductors. **Figure 230–22.**

Figure 230-22 Overhead Service Conductors 230.28(A)

Service mast for overhead service conductors or service-drop conductors must have adequate strength, braces, or guy wires to withstand the strain caused by the conductors.

Service Drop Conductors. Utility-owned overhead conductors from utility transformer to the service point. ▶ Figure 230-23

Figure 230-23 Service Drop Conductors Article 100 Definition

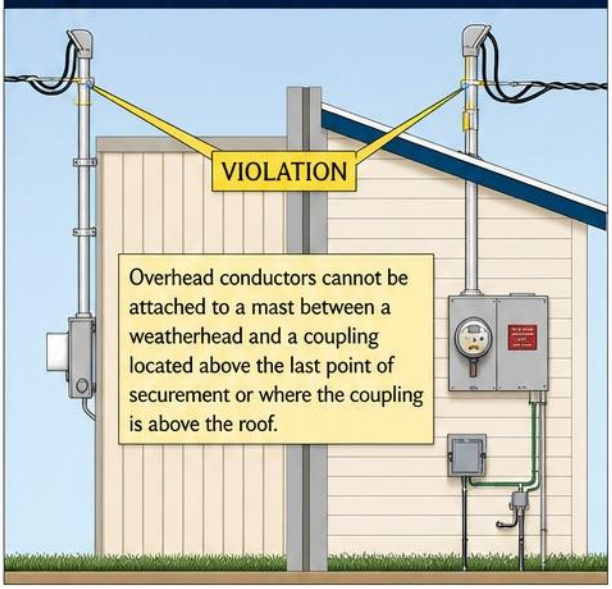


(B) Attachment. Overhead conductors cannot be attached to a mast between a weatherhead and a coupling located above the last point of securement or where the coupling is above the roof. ▶ Figure 230-24

Author's Comment:

- Many electric utilities contain specific requirements for the installation of the service mast.

Figure 230-24 Overhead Service Conductors 230.28(B)



Part III. Underground Service Conductors

230.30 Installation

(B) Wiring Methods. Underground service conductors can be installed in any of the following wiring methods:

(1) Rigid metal conduit

(2) Intermediate metal conduit

(5) Polyvinyl chloride conduit

(8) Underground service-entrance conductors or cables

(9) Metal clad cable

Service, Underground Service Conductors. Customer-owned underground conductors between the service point and the service-entrance conductors at the building. ▶ Figure 230-25

230.31 Underground Service Conductor Ampacity

(A) General. Underground service conductors must have an ampacity not less than the calculated load.

(B) Phase Conductor Size. Underground service conductors are not permitted to be smaller than 8 AWG copper, 6 AWG aluminum, or 6 AWG copper-clad aluminum.

Ex: Underground service conductors can be as small as 12 AWG for limited-load installations.

Figure 230–25 Service-Entrance Conductors — *Article 100 Definitions*

Customer-owned underground conductors located between the service point and the service-entrance conductors at the building.

(C) Neutral Conductor Size. The neutral conductor for underground service conductors must be sized to carry the maximum unbalanced load in accordance with 120.61, and not smaller than required by 250.24(D).

230.32 Protection Against Damage

Underground service conductors must be protected from physical damage in accordance with 300.7.

Part IV. Service-Entrance Conductors

230.42 Conductor Sizing

(A) General. Service entrance conductors must have an ampacity no less than the calculated load and must be sized to the larger of either 230.42(A)(1) or (2). ▶ Figure 230–26

> ***Service-Entrance Conductors.*** The service conductors between the terminals of the service equipment to the service drop, overhead service conductors, service lateral, or underground service conductors.

(1) Continuous and Noncontinuous Loads. Service entrance conductors must have an ampacity no less than 125 percent of the continuous loads, plus 100 percent of the noncontinuous loads. ▶ Figure 230–27

Figure 230–26 Service Entrance Conductor Ampacity — 230.42(A)

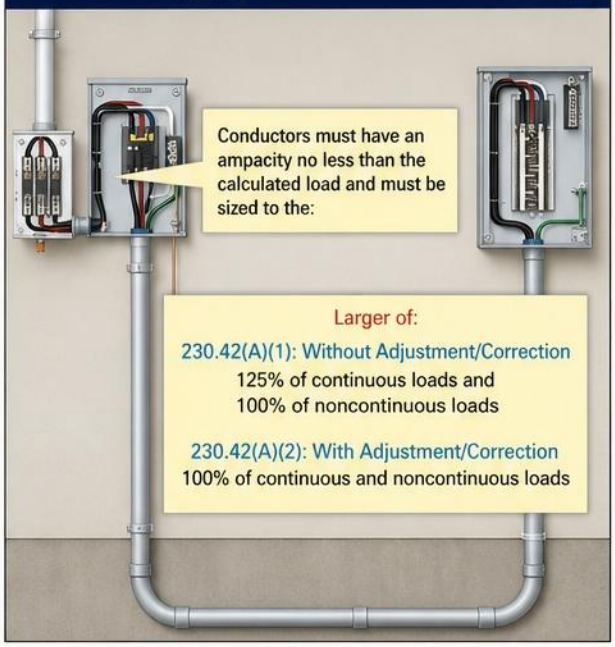
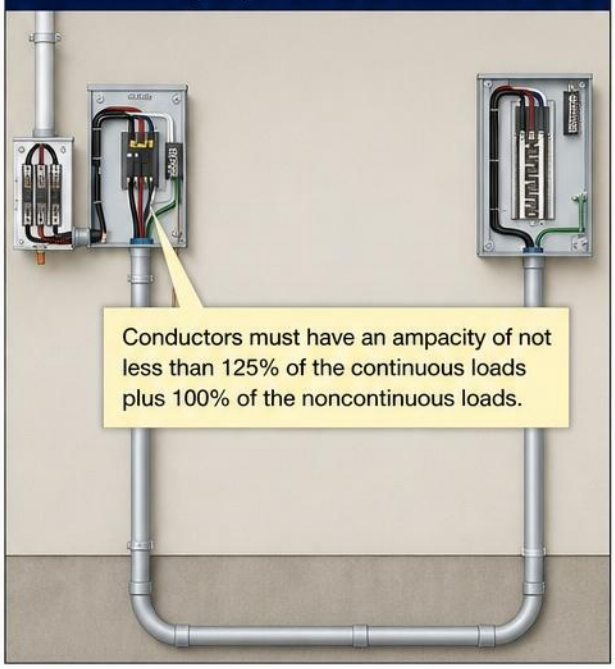


Figure 230–27 Service Entrance Conductor Ampacity, Continuous Loads — 230.42(A)(1)



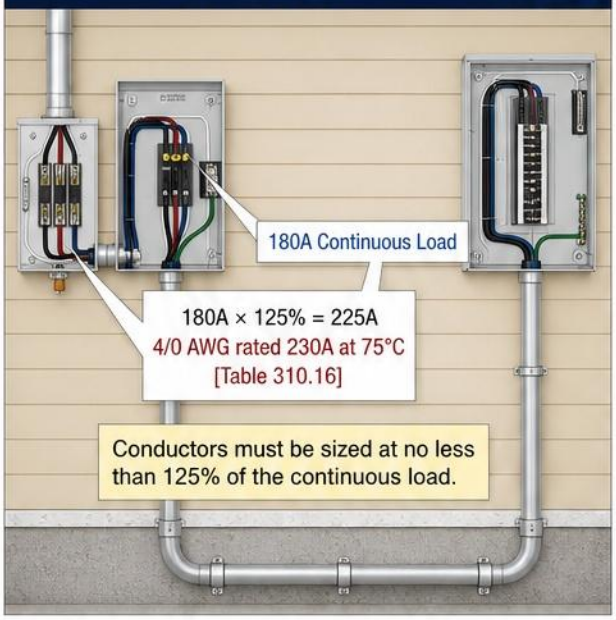
> ***Continuous Load.*** A load where the maximum current is expected for three hours or more continuously.

▶ Service Conductor Sizing [230.42(A)(1)] Example

Question: What size service conductors are required for a 180A continuous load? ▶Figures 230–28 and 230–29

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

Figure 230–28 Service Entrance Conductor Sizing Continuous Loads 230.42(A)(1)



Example: For a 180A continuous load, the minimum conductor size is 4/0 AWG.

Solution:

Step 1: *Determine the minimum conductor ampacity.*

Minimum Conductor Ampacity = 180A × 125%

Minimum Conductor Ampacity = 225A

Step 2: *Determine the conductor size.*

4/0 AWG, rated 230A at 75°C [Table 310.16]

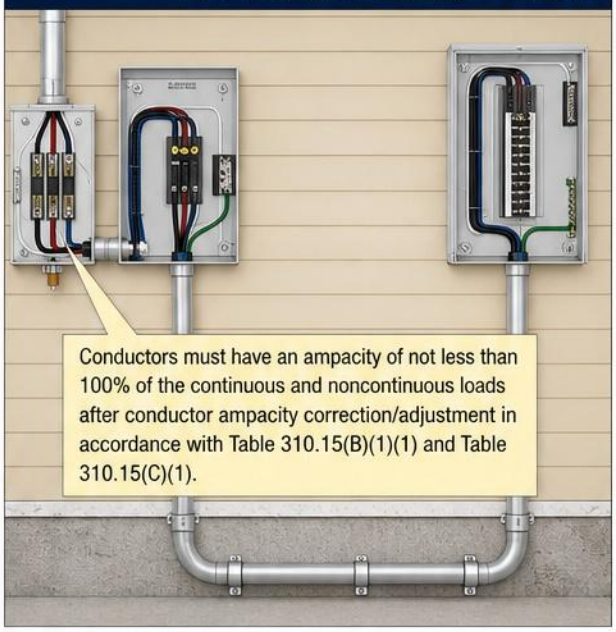
Answer: *(d) 4/0 AWG*

(2) Ampacity Correction and Adjustment Factors. Conductors must have an ampacity no less than 100 percent of the continuous and noncontinuous loads after conductor ampacity correction and/or adjustment in accordance with Table 310.15(B)(1)(1) and Table 310.15(C)(1). ▶Figure 230–29

Author's Comment:

▶ The temperature ampacity correction [310.15(B)(1)(1)] and ampacity adjustment factors [310.15(C)(1)] are applied to the ampacities listed in Table 310.16. This is based on the conductor insulation temperature rating, which is typically THWN-2, 90°C [310.15(A)].

Figure 230–29 Service Entrance Conductor Ampacity Correction and Adjustment Factors 230.42(A)(2)



After applying ampacity correction and adjustment factors in accordance with Table 310.15(B)(1)(1) and Table 310.15(C)(1), conductor ampacity must be at least 100% of the continuous and noncontinuous loads.

230.43 Wiring Methods

Service-entrance conductors can be installed in any of the following wiring methods:

(1) Open wiring on insulators

(3) Rigid metal conduit

(4) Intermediate metal conduit

(5) Electrical metallic tubing

(6) Electrical nonmetallic tubing

(7) Service-entrance cables

(8) Wireways

(11) Polyvinyl chloride conduit

(13) Metal clad cable

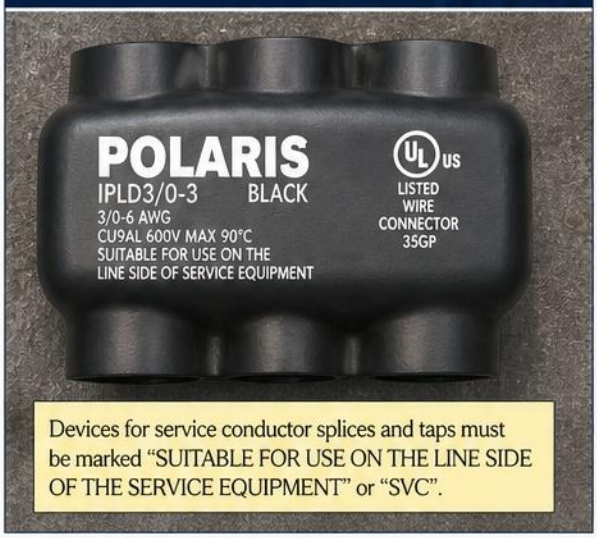
(15) Flexible metal conduit or liquidtight flexible metal conduit in lengths not longer than 6 ft

(16) Liquidtight flexible nonmetallic conduit ▶Figure 230–30

(20) TC-ER cable identified for use as service-entrance conductors

Figure 230–30 Service–Entrance Conductors Wiring Methods, LFNC 230.43(16)

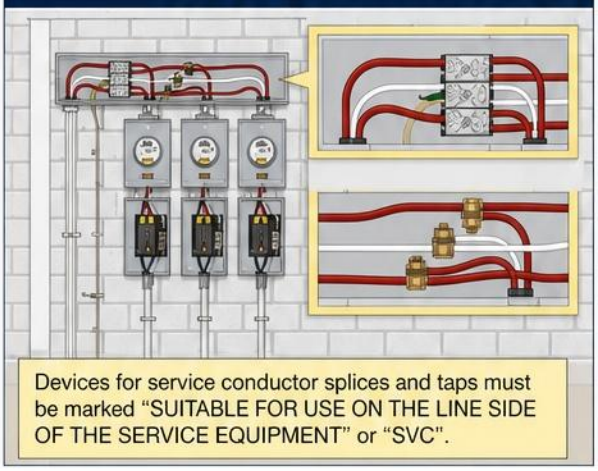
Figure 230–32 Service–Entrance Conductors Spliced and Tapped Connections 230.46 and Note



230.46 Spliced and Tapped Connections

Service-entrance conductors are permitted to be spliced or tapped in accordance with 110.14, 300.7(E), 300.15, and 300.17. Devices for service conductor splices and taps must be marked "suitable for use on the line side of the service equipment" or "SVC" for the following: Figure 230–31 and Figure 230–32.

Figure 230–31 Service–Entrance Conductors Spliced and Tapped Connections 230.46 and Note



(1) Power distribution blocks

(2) Pressure connectors

(3) Devices for splices and taps

Note: The marking "SVC" is considered equivalent to "Suitable for Use on the Line Side of Service Equipment."

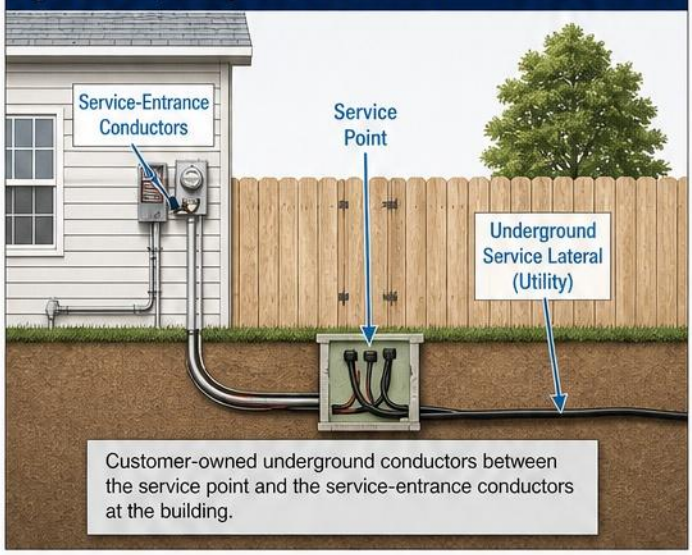
230.50 Protection Against Physical Damage

(A) Underground Service Conductors. Underground service *conductors* must be protected against physical damage as determined by the AHJ in accordance with 300.7. Figure 230–33.

Figure 230–33 Underground Service–Entrance Conductors Protection Against Physical Damage 230.50(A)

Service, Underground Service Conductors. Customer-owned underground conductors between the service point and the service-entrance conductors at the building. Figure 230–34.

Figure 230–34 | Underground Service Conductors *Article 100 Definitions*

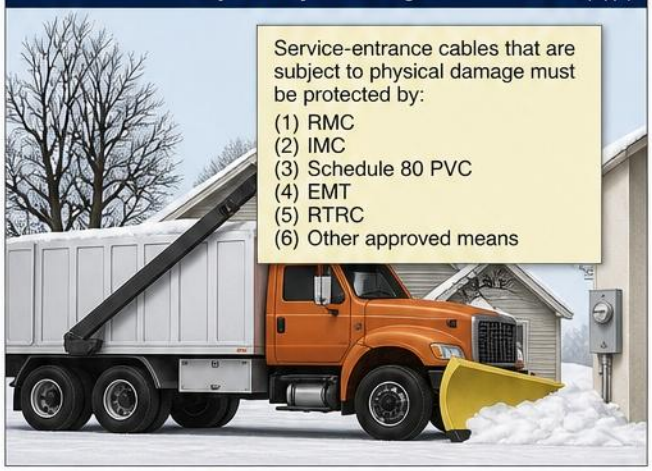


This illustration shows the path of customer-owned underground conductors between the utility service point and the service-entrance conductors located at the building.

(B) Service-Entrance Cables Subject to Physical Damage.

(1) Service-Entrance Cables. Service-entrance cables that are subject to physical damage as determined by the AHJ must be protected by any of the following: ▸ Figure 230–35

Figure 230–35 | Service-Entrance Cables, Subject to Physical Damage 230.50(B)(1)



Examples of protective raceways or methods that may be used to guard service-entrance cables from physical damage as required by the AHJ.

(1) Rigid metal conduit

(2) Intermediate metal conduit

(3) Schedule 80 polyvinyl chloride conduit

(4) Electrical metallic tubing

(5) Reinforced thermosetting resin conduit

(6) Other means approved by the authority having jurisdiction (AHJ)

230.51 Cable Supports

(A) Service-Entrance Cable Supports. Service-entrance cable must be supported within 1 ft of the weatherhead, gooseneck, or enclosure at intervals not exceeding 30 in.

230.53 Raceways to Drain

Where exposed to the weather or embedded in masonry, raceways enclosing service-entrance conductors must be listed or approved for use in wet locations.

230.54 Overhead Service Locations

(A) Raceway Weatherhead. Raceways containing service-entrance conductors connected to utility service-drop conductors or customer overhead service or overhead service conductors must have a weatherhead listed for wet locations.

(B) Cable Weatherhead. Service-entrance cables connected to utility service-drop conductors or customer overhead service conductors must be equipped with a service weatherhead listed for wet locations.

Ex: SE cable is permitted to be formed in a gooseneck and taped with a self-sealing weather-resistant thermoplastic.

(C) Above the Point of Attachment. Service weatherheads must be located above the point of attachment for utility service-drop conductors or customer overhead service conductors [230.26].

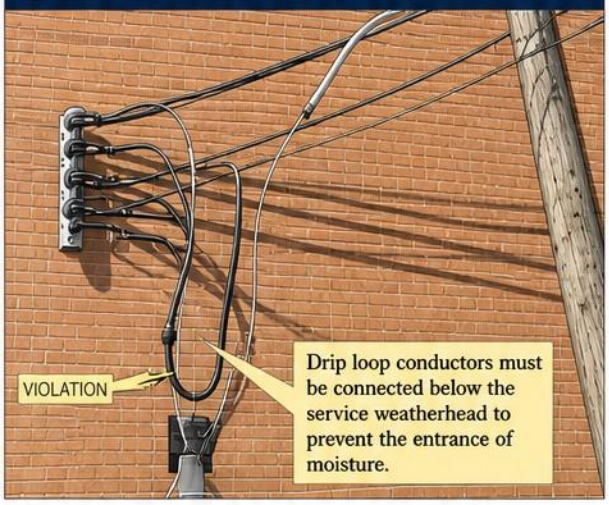
Figure 230–36 | Overhead Service Locations Above the Point of Attachment 230.54(C)

The weatherhead is installed above the point of attachment to protect the service connection from moisture.

Example: If it is impractical to locate the service weatherhead above the point of attachment, it must be within 2 ft of the point of attachment.

(F) Drip Loops. To prevent the entrance of moisture, drip loop conductors must be connected to the utility service-drip conductors or customer overhead service conductors below the service weatherhead. ▸230.54(F)

Figure 230–37 Overhead Service Locations—Drip Loops 230.54(F)



Drip loop connection is above the weatherhead, allowing moisture to enter.

Part V. Service Equipment (Disconnect)—General

230.62 Service Equipment—Barrier Placement

(C) Barriers. Identified barriers must be placed on energized uninsulated phase terminals of service equipment to prevent inadvertent contact when the service disconnect is in the open position. ▸230.38

Figure 230–38 Service Busbar or Terminals—Protective Barriers 230.62(C)

Barriers are installed over uninsulated phase terminals to *reduce the risk of accidental contact when the disconnect* is open.

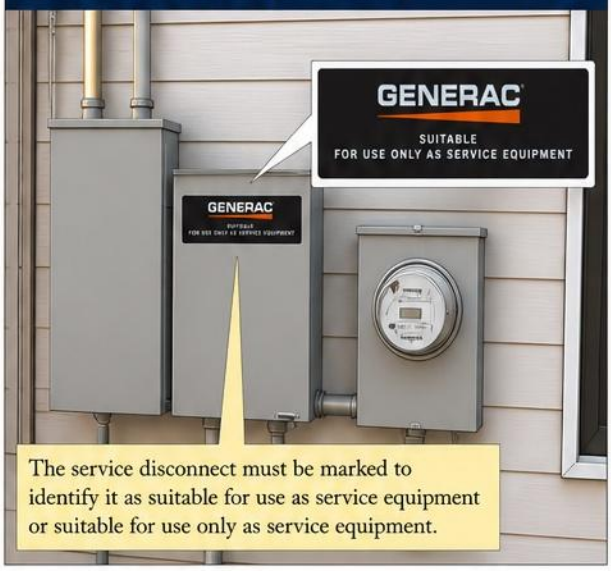
Author's Comment

- The line side of the service disconnect will have energized parts—even with the disconnect in the open position. Barriers provide some measure of safety against inadvertent contact with line-side energized parts.

230.66 Marking for Service Equipment

The service disconnect must be marked to identify it as "SUITABLE FOR USE AS SERVICE EQUIPMENT," or marked "SUITABLE FOR USE ONLY AS SERVICE EQUIPMENT." ▸230.39

Figure 230–39 Service Equipment Marking 230.66



Proper marking identifies the equipment as suitable for use as service equipment.

Author's Comment

- Equipment marked "Suitable for Use as Service Equipment" means that the main bonding jumper has been provided but not installed.
- Equipment marked "Suitable Only for Use as Service Equipment" means the neutral terminal bus is factory bonded to the frame of the service equipment enclosure.

230.67 Surge Protection

(A) Surge-Protective Device (SPD). An SPD is required for any of the following occupancies supplied by a service:

(1) Dwelling units

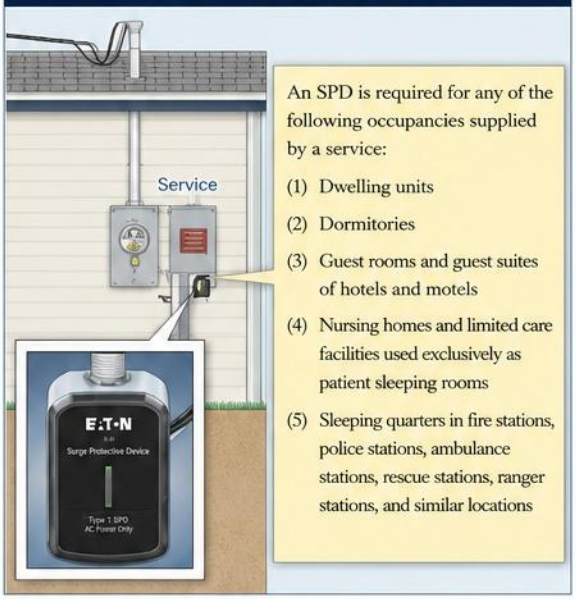
(2) Dormitories

(3) Guest rooms and guest suites of hotels and motels

(4) Areas of nursing homes and limited care facilities used exclusively as patient sleeping rooms

(5) Areas for sleeping quarters in fire stations, police stations, ambulance stations, rescue stations, ranger stations, and similar locations

Figure 230–40 Surge-Protective Device (SPD) Occupancies Supplied by a Service 230.67(A)



An SPD is required when a service supplies the listed occupancies.

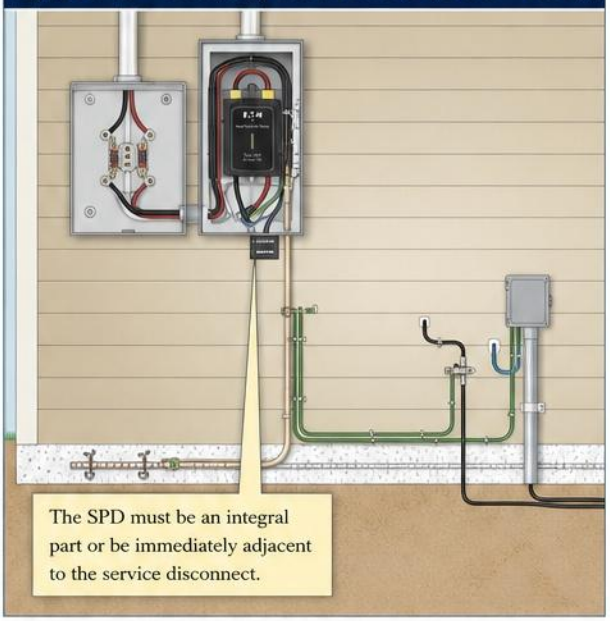
Author's Comment:

Sensitive electronics found in arc-fault circuit interrupters (AFCIs), ground-fault circuit interrupters (GFCIs), and smoke alarms used in the above locations require overvoltage protection from exposure to transient overvoltage. See Article 242, Overvoltage Protection for additional details.

(B) Surge-Protective Device (SPD) Location. The SPD must be an integral part of the service disconnect or located immediately adjacent to the service disconnect. Figure 230–41.

Ex: If the service supplies only feeders, the SPD is permitted to be located at the load side of each feeder.

Figure 230–41 Services, Surge Protective Device (SPD) Location 230.67(B)



The SPD must be integral with or directly next to the service disconnect.

Author's Comment:

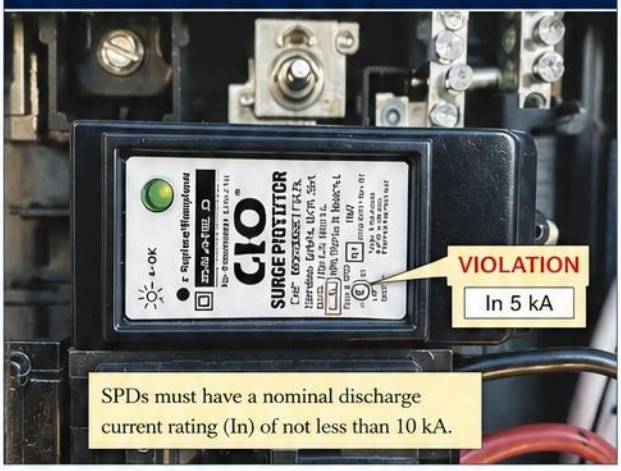
An exterior meter main that feeds an interior panel is an example of this exception. The SPD could be installed at the interior panel, but not at the service disconnect.

(C) Type. The SPD must be in accordance with Article 242.

(D) Service Equipment Replacement. Where service equipment is replaced, surge protection must be installed.

(E) SPD Discharge Current Rating. SPDs must have a nominal discharge current rating (In) no less than 10 kA. Figure 230–42.

Figure 230–42 Services, Surge-Protective Device (SPD) Discharge Current Rating (In) 230.67(E)



This SPD is noncompliant because its In rating is only 5 kA.

AUTHOR'S COMMENT:

- See Parts I and II of Article 242 for installation requirements that apply to SPDs.

230.68 METER SOCKET

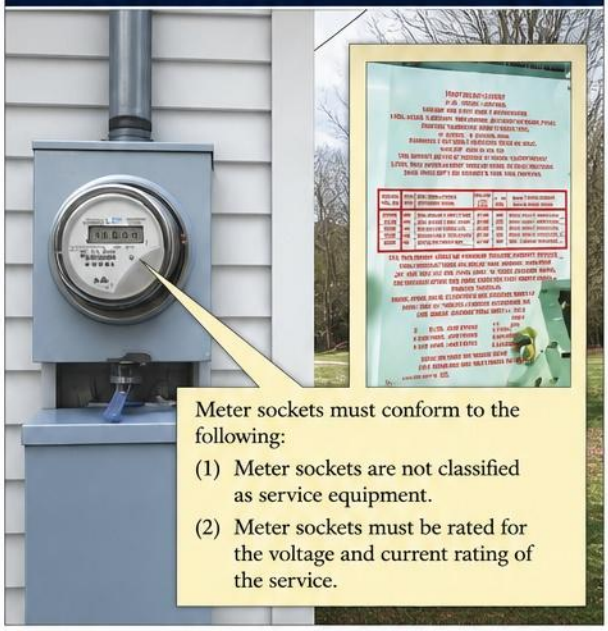
Meter sockets must comply with the following:

(1) They are not classified as service equipment.

(2) They must be rated for the voltage and current rating of the service.

▶ Figure 230–43

Figure 230–43 Meter Socket **230.68**



Meter sockets are not service equipment and must be rated for the voltage and current of the service.

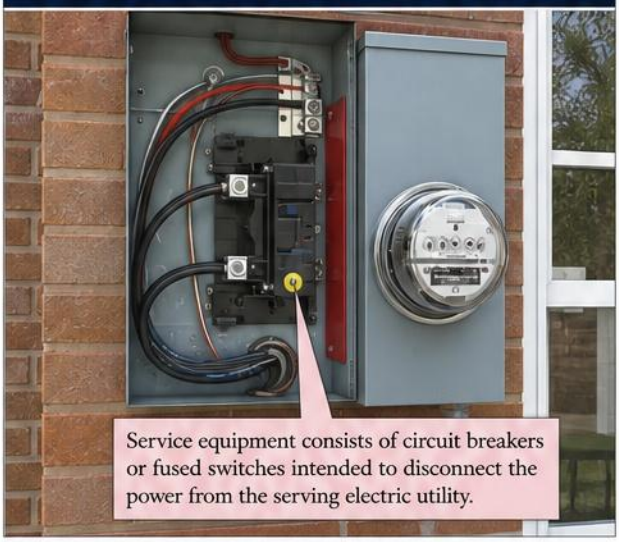
PART VI. SERVICE DISCONNECT—DISCONNECTING MEANS

230.70 SERVICE DISCONNECT REQUIREMENTS

(A) Service Disconnect Location. Service equipment that disconnects power must be installed in accordance with the following:

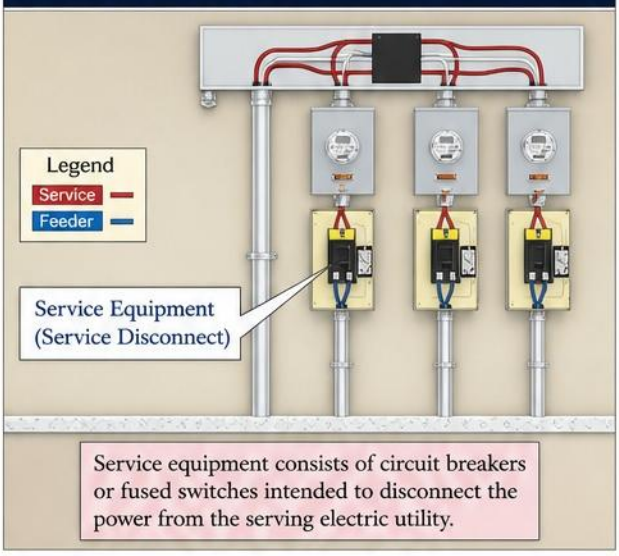
> ***Service equipment.*** Circuit breakers or fused switches intended to disconnect the power from the serving electric utility. ▶ Figure 230–44 and ▶ Figure 230–45

Figure 230–44 Service Equipment **Article 100 Definition**



Service equipment includes circuit breakers or fused switches that disconnect the power from the serving electric utility.

Figure 230–45 Service Equipment **Article 100 Definition**



Service equipment (service disconnects) disconnects power from the serving electric utility.

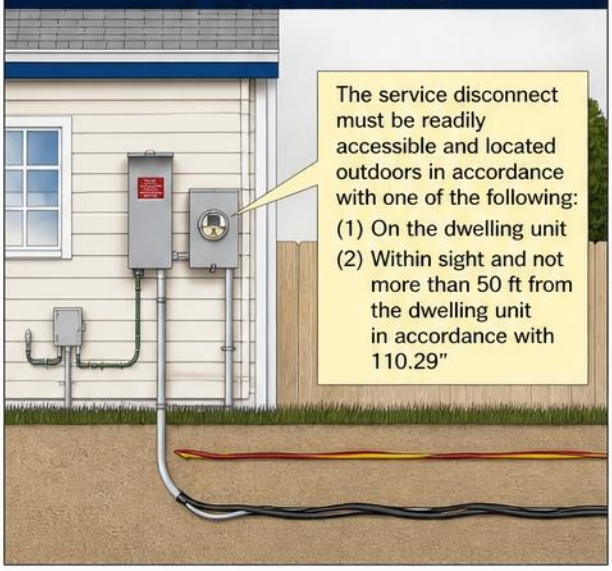
(1) One- and Two-Family Dwellings. The service disconnect must be readily accessible and located outdoors in accordance with the following:

(1) At the dwelling unit.

(2) Within sight and not more than 50 ft from the dwelling unit in accordance with 110.29. ▶ Figure 230–46

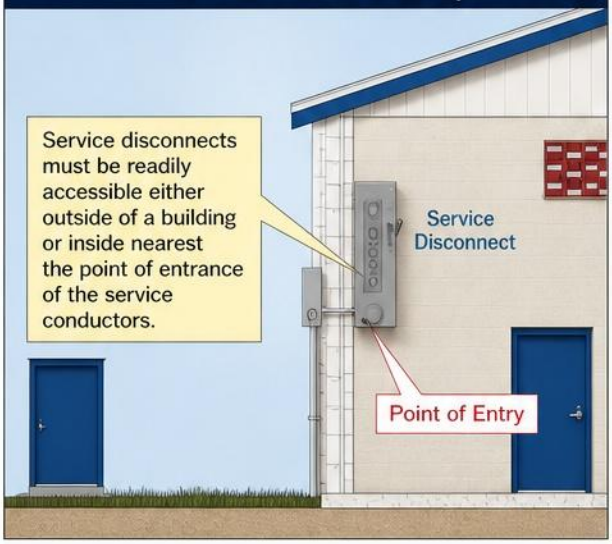
Ex: The outdoor service disconnect is not required to be within sight and not more than 50 ft from the dwelling unit if the outdoor feeder emergency disconnect is readily accessible, within sight, and not more than 50 ft from the dwelling unit in accordance with 225.41.

Figure 230–46 Service Disconnect Location One- and Two-Family Dwellings 230.70(A)(1)



(2) Other than One- and Two-Family Dwellings. Service disconnects must be readily accessible either outside of a building or inside nearest the point of entrance of the service conductors as determined by the AHJ.

Figure 230–47 Service Disconnect Location Other than One- and Two-Family 230.70(A)(2)



WARNING: Because service conductors do not have short-circuit or ground-fault protection, they must be limited in length when installed inside a building. Some local jurisdictions have a specific requirement as to the maximum length of service conductors that are permitted within a building.

(3) Bathroom. Service disconnects are not permitted in a bathroom.

Figure 230–48 Service Disconnects, Location Bathroom Areas 230.70(A)(3)

(B) SERVICE DISCONNECT MARKING

Service disconnects must be marked as follows:

(1) Marking, Other than One- and Two-Family Dwellings. Service disconnects must be marked "SERVICE DISCONNECT" on or adjacent to the service disconnect. The marking must be of sufficient durability to withstand the environment, cannot be handwritten, and must be permanently affixed to the equipment in accordance with 110.21(B).

Figure 230–49 Service Disconnect Marking Other than One- and Two-Family Dwellings 230.70(B)(1)

(2) Marking, One- and Two-Family Dwellings. Enclosures of disconnects for one- and two-family dwellings must be marked "EMERGENCY DISCONNECT." The marking must be of sufficient durability to withstand the environment, cannot be handwritten, and must be permanently affixed to the equipment in accordance with 110.21(B).

Figure 230–50 Service Disconnect Marking One- and Two-Family Dwellings 230.70(B)(2)

Disconnect enclosures for one- and two-family dwellings must have the required marking on the exterior.

(1) The required marking must be on the exterior face of the disconnect enclosure. The marking must have a red background with white lettering.

(2) Lettering must be at least ½ in. high.

(D) Identification of Source Disconnects. When the means of disconnecting the energy source is not installed next to the service disconnect, a permanently fixed plaque or directory that identifies the location of all energy source disconnecting means must be installed adjacent to the service disconnect.

Note: Examples of energy source system disconnection means are provided in 445.18, 480.7, 705.20, and 706.15.

(F) Remote Control. A remote-control device, such as a pushbutton used to trip a shunt-trip breaker, is not considered a means of service disconnecting.

Figure 230–51 Remote Control of Service Disconnect 230.70(F)

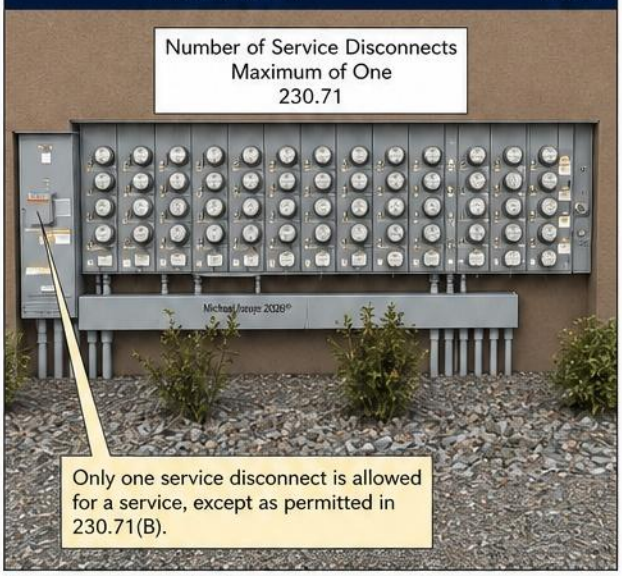
A remote-control device that opens the service disconnect is not considered a means of service disconnect.

230.71 Number of Service Disconnects

Only one service disconnect is permitted for a service, except as allowed in 230.71(B).

▶ Figure 230–52

Figure 230–52 Number of Service Disconnects Maximum of One 230.71



A service is permitted to have only one service disconnect.

(B) Two to Six Service Disconnects. A service can have up to six disconnects for each service permitted by 230.4.

CAUTION: This rule limits six disconnects for each service. For example, if the building has more than one service as permitted by 230.2, each service to the building can have no more than six service disconnects.

The two-to-six service disconnects can be installed in any of the following ways:

(1) Separate enclosures, each with a single service disconnect.
▶ Figure 230–53

(2) Switchboards with a service disconnect in each separate vertical section enclosure fitted with barriers.

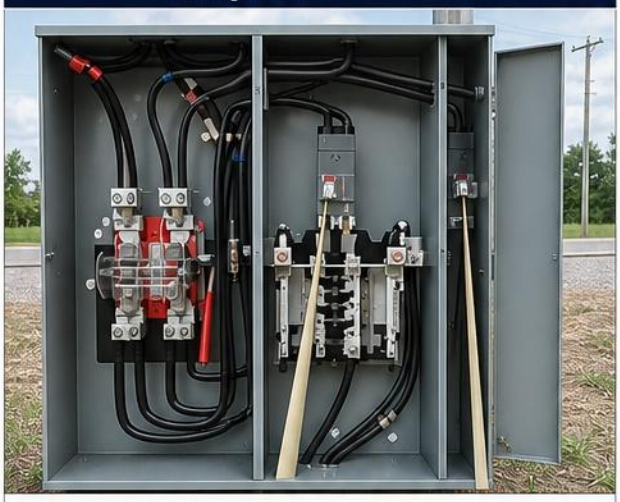
(3) Switchgear and transfer switches where each service disconnect is in a separate enclosure.

(4) Metering centers with each service disconnect located in a separate compartment or enclosure.
▶ Figure 230–54

Figure 230–53 Number of Service Disconnects Separate Enclosures 230.71(B)(1)

The two to six service disconnects can consist of separate enclosures with a single service disconnect in each enclosure.

Figure 230–54 Number of Service Disconnects Metering Centers 230.71(B)(4)

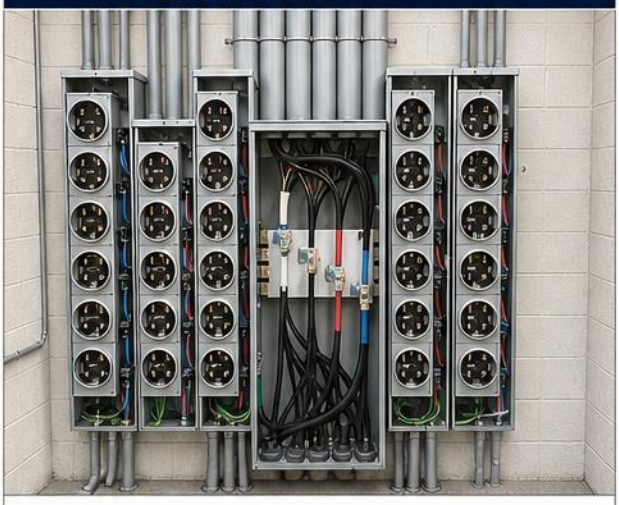


The two to six disconnects can consist of metering centers with each service disconnect located in a separate compartment or in separate enclosures.

Figure 230–55 Metering Centers *Article 100 Definitions* 230.71(B)(1)

Panelboards in enclosures also containing one or more meter sockets.

Figure 230–56 Metering Centers *Article 100 Definition* 230.71(B)(1)



Panelboards in enclosures also containing one or more meter sockets.

Metering Centers (Meter Center). Panelboards in enclosures also containing one or more meter sockets. See Figure 230–55 and Figure 230–56.

Author's Comment:

- When every service disconnect is installed in its own enclosure or compartment, the electrical worker is allowed to de-energize the load-side conductors within that compartment for that particular service disconnect. This improves safety by reducing the likelihood of an incident with energized conductors or circuit parts from the load-side of other service disconnects installed in the same compartment.

230.72 Grouping of Service Disconnects

(A) Two to Six Disconnects. The service disconnects for each service must be grouped and marked to indicate the load served. See Figure 230–57.

(B) Additional Service Disconnecting Means. To minimize simultaneous interruption of power, the service disconnect for fire pumps, emergency systems, legally required standby systems, or optional standby systems must be remote from the service disconnects for normal service.

Figure 230–57 **230.72(A)**
Service Disconnects, Grouping

Service disconnects that supply the same service must be grouped and identified to show the load they supply.

AUTHOR'S COMMENT:

The authority having jurisdiction (AHJ) is responsible for determining what a sufficiently remote distance is for an additional service disconnect.

230.79 RATING OF DISCONNECT

The service disconnect must be rated in amperes to be at least the calculated load and, in no case, less than:

(A) ONE-CIRCUIT INSTALLATION. For a single branch circuit, the disconnect must be rated in amperes not less than 15A.

(B) TWO-CIRCUIT INSTALLATION. For two 2-wire branch circuits, the disconnect must be rated in amperes not less than 30A.

(C) ONE-FAMILY DWELLING. For a one-family dwelling, the disconnect must be rated in amperes not less than 100A.

(D) OTHER INSTALLATIONS. For other installations, the disconnect must be rated in amperes not less than 60A.

230.82 CONNECTED ON SUPPLY SIDE OF THE SERVICE DISCONNECT

Only the following electrical equipment is permitted to be connected to the supply side of the service disconnect:

(1) Cable limiters are permitted to be connected to the supply side of the service disconnect

(2) Meters and meter sockets are permitted to be connected to the supply side of the service disconnect

(3) Meter disconnect switches are permitted to be connected to the supply side of the service disconnect if they comply with the following:

a. Have a short-circuit current rating equal to or greater than the available fault current

b. Have capability to interrupt the load served

c. Legibly field marked on the exterior in a manner suitable for the environment as follows: "METER DISCONNECT—NOT SERVICE EQUIPMENT"

See Figure 230–58.

Figure 230–58 **230.82(3)**
Supply Side of the Service Disconnect Meter Disconnect

AUTHOR'S COMMENT:

- Some electric utilities require a meter disconnect switch ahead of the meter enclosure for 277/480V services for the purpose of enhancing safety for the serving electric utility's personnel when they install or remove a meter.
- A meter disconnect switch is not a service disconnect. It is simply a load break switch designed to interrupt the load for the purpose of maintenance, disconnection, or connection of a meter.

(4) Meter-mounted transfer switches are permitted to be connected to the supply side of the service disconnect if they comply with the following:

a. Have a short-circuit current rating equal to or greater than the available fault current

b. Able to handle the load it is intended to supply.

c. Identified on the outside of the equipment as follows: "METER-MOUNTED TRANSFER SWITCH, NOT SERVICE EQUIPMENT."

Figure 230–59 230.82(4)
Supply Side of the Service Disconnect
Meter-Mounted Transfer Switch

Meter-mounted transfer switches can be connected to the supply side of the service disconnect if they:

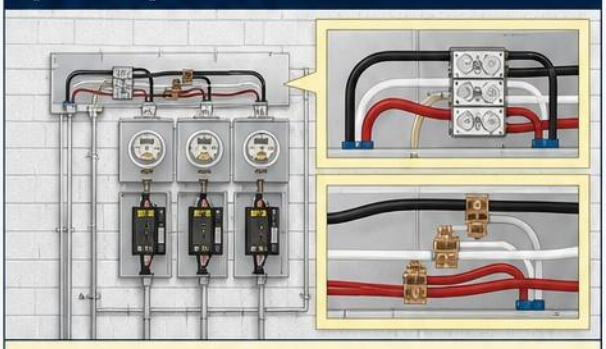
a. Have a short-circuit current rating equal to or greater than the available fault current.

b. Are able to handle the load served.

c. Are identified on the outside of the equipment as follows: "METER-MOUNTED TRANSFER SWITCH, NOT SERVICE EQUIPMENT."

(8) Power distribution blocks, pressure connectors, and devices for splices and taps in accordance with 230.46 may be connected to the supply side of the service disconnect.

Figure 230–60 230.82(8)
Supply Side of the Service Disconnect
Splice and Tap Connectors



Power distribution blocks, pressure connectors, and devices for splices and taps in accordance with 230.46 may be connected to the supply side of the service disconnect.

(10) Type 1 surge-protective devices are permitted to be connected to the supply side of the service disconnect.

Figure 230–61 230.82(10)
Supply Side of the Service Disconnect
Type 1 Surge Protective Device (SPD)

Type 1 SPDs are permitted to be connected to the supply side of the service disconnect.

(12) Permanently mounted absence of voltage testers (AVT) if labeled as "Suitable for Use on the Line Side" are permitted to be connected to the supply side of the service disconnect.

Figure 230–62 230.82(12)
Supply Side of the Service Disconnect
Absence of Voltage Testers (AVT)

Permanently mounted absence of voltage testers if labeled as "SUITABLE FOR USE ON THE LINE SIDE" are permitted to be connected to the supply side of the service disconnect.

Author's Comment:

- In accordance with *UL 1436*, an absence of voltage tester (AVT) is a permanently mounted test device that is used to verify that a circuit is de-energized prior to opening an electrical enclosure that contains energized electrical conductors or circuit paths. The AVT must test and provide an indication of the absence of phase-to-phase and phase-to-ground voltage.

(16) Conductors for energy management systems are permitted to be connected to the supply side of the service disconnect.

(17) Conductors for legally required and optional standby systems are permitted to be connected to the supply side of the service disconnect.

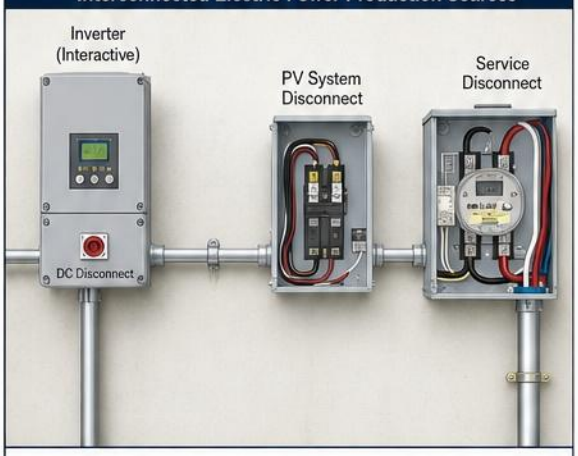
(18) Conductors for fire pump equipment are permitted to be connected to the supply side of the service disconnect.

(19) Conductors for fire and sprinkler alarms are permitted to be connected to the supply side of the service disconnect.

(20) Interconnected electric power production sources are permitted to be connected to the supply side of the service disconnect.

Figure 230-63 230.82(20)

Supply Side of the Service Disconnect Interconnected Electric Power Production Sources



Interconnected electric power production sources are allowed to be connected on the supply side of the service disconnect.

Part VII. Service Conductor Overcurrent Protection

230.90 Overload Protection—Where Required

Each service phase conductor must have overload protection. 230.90

(A) Overcurrent Protective Device Rating. The overcurrent protective device rating is not permitted to be greater than the ampacity of the service conductors. 230.90(A)

Ex 2: If the ampacity of the service conductors does not correspond with the standard rating of overcurrent protective devices as listed in 240.6(A), the next higher overcurrent protective device rating is permitted—if it does not exceed 800A [240.4(B)].
230.90(A) Ex 2

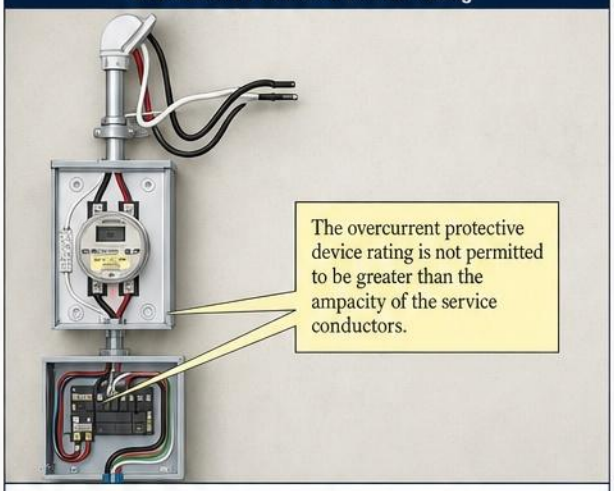
Figure 230-64 230.90

Service Conductor Overload Protection

Every service phase conductor is required to have overload protection.

Figure 230-65 230.90(A)

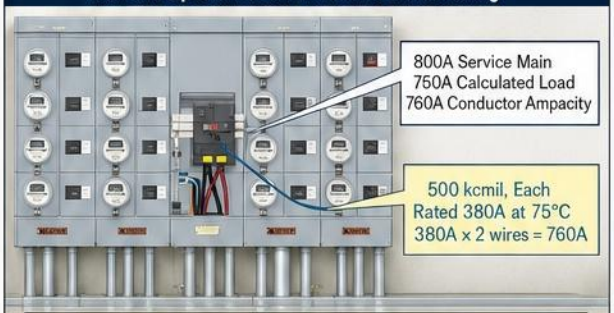
Service Conductor Overload Protection Overcurrent Protective Device Rating



The rating of the overcurrent protective device must not exceed the ampacity of the service conductors.

Figure 230-66 230.90(A) Ex 2

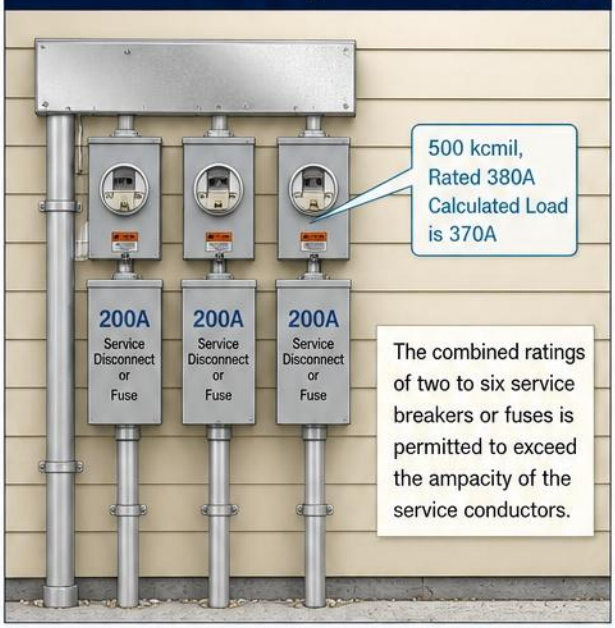
Service Conductor Overload Protection Next Size Up Overcurrent Protective Device Rating



If the ampacity of the service conductors does not correspond with the standard rating of overcurrent protective devices as listed in 240.6(A), the next higher overcurrent protective device rating is permitted if it does not exceed 800A.

Ex 3: The combined ratings of two to six service breakers or fuses is permitted to exceed the ampacity of the service conductors. Figure 230–67

Figure 230–67 Combined Service Breaker or Fuse Ratings 230.90(A) Ex 3



Three 200A service disconnects are supplied by conductors rated 380A. The calculated load is 370A. The combined rating of the breakers (600A total) is permitted to exceed the conductor ampacity.

Ex 5: Overload protection for dwelling unit services is permitted in accordance with the requirements 310.12. Figure 230–68

Figure 230–68 Overload Protection for Dwelling Unit Services 230.90(A) Ex 5

The main overcurrent device in the dwelling unit service equipment provides overload protection as allowed by 310.12.

ARTICLE

240 Overcurrent Protection

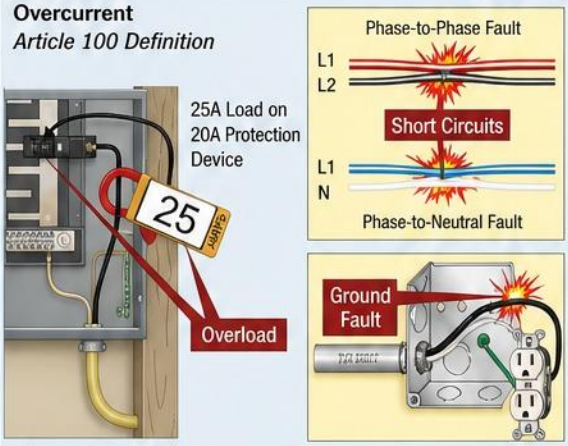
Introduction to Article 240—Overcurrent Protection

Article 240 establishes general requirements for *overcurrent protection* and *overcurrent protective devices* (typically circuit breakers or fuses). Overcurrent protection is installed to protect the circuit if the current reaches a value that will cause damage to conductors, conductor insulation, or equipment. An overcurrent condition consists of *overloads*, *short circuits*, or *ground faults*.

Overcurrent. Current that exceeds the equipment ampere rating or the conductor ampacity caused by an overload, short circuit, or ground fault.

Figure 240–1 NEC 240.4

Overcurrent
Article 100 Definition



Current that exceeds the equipment ampere rating or the conductor ampacity caused by an overload, short circuit, or ground fault.

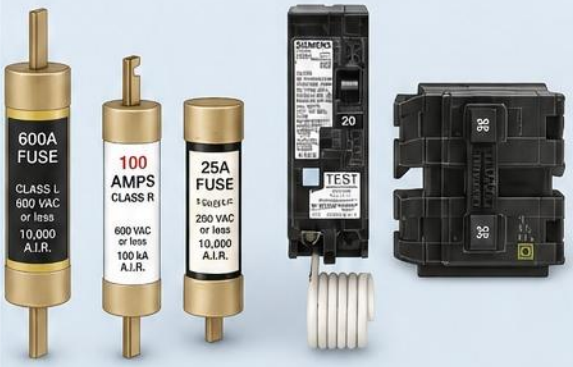
Overcurrent Protective Device (OCPD). A device that provides protection from an overcurrent condition (overload, short circuit, or ground fault).

Figure 240–3 NEC 240.3

Equipment operating above its ampere rating or current more than a conductor's ampacity for a length of time that would cause dangerous overheating. A short circuit or ground fault is not an overload.

Figure 240–2 NEC 240.3

Overcurrent Protective Device (OCPD)
Article 100 Definition



A device that provides protection from an overcurrent condition (overload, short-circuit, or ground-fault).

Overload. Equipment operating above its ampere rating or current more than a conductor's ampacity for a length of time that would cause dangerous overheating. A short circuit or ground fault is not an overload.

Short Circuit. An abnormal connection of low impedance between two or more points of different potential.

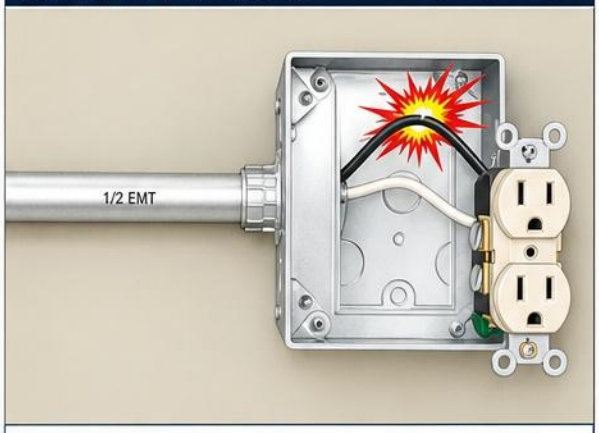
Figure 240–4 NEC 240.4

An abnormal connection of low impedance between two or more points of different potential.

Figure 240–3 | Overload *Article 100 Definition*

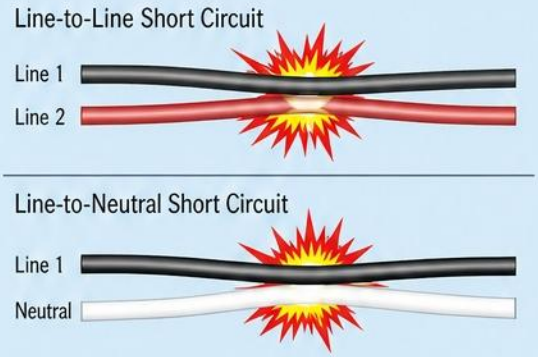
Equipment operating above its ampere rating or current more than a conductor's ampacity for a length of time that would cause dangerous overheating.

Figure 240–5 | Ground Fault *Article 100 Definition*



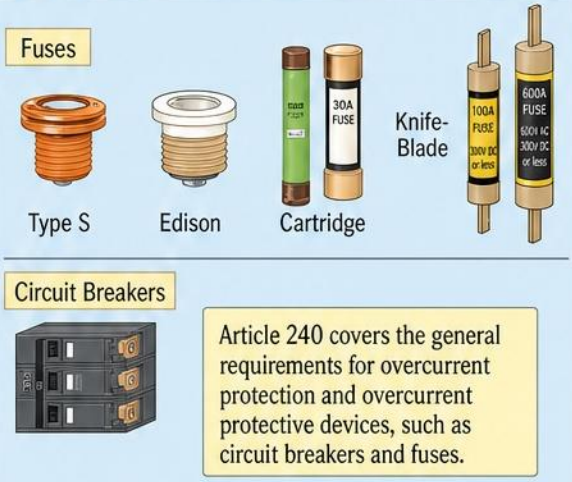
An unintentional electrical connection between a phase conductor and equipment grounding conductors, metal parts of enclosures, metal raceways, or metal equipment.

Figure 240–4 | Short Circuit *Article 100 Definition*



An abnormal connection of low impedance between two or more points of different potential.

Figure 240–6 | Overcurrent Protection *240.1 Scope*



Article 240 covers the general requirements for overcurrent protection and overcurrent protective devices, such as circuit breakers and fuses.

Ground Fault. An unintentional electrical connection between a phase conductor and equipment grounding conductors, mteal parts of enclosures, metal raceways, or metal equipment. Figure 240–5.

Part I. General

240.1 Scope

This article covers the general requirements for overcurrent protection and overcurrent protective devices, such as circuit breakers and fuses. Figure 240–6.

Note 1: Overcurrent protection for conductors and equipment is provided to open the circuit if the current reaches a value that will cause an excessive or dangerous temperature in conductors or conductor insulation.

240.2 Listing Requirements

The following must be listed:

(1) Overcurrent protective devices (OCPD)

(2) Relays and circuit breakers providing ground-fault protection of equipment

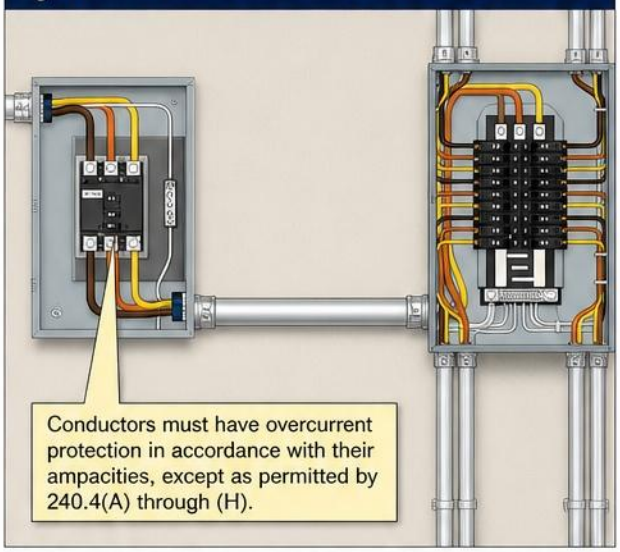
(3) Ground-fault circuit interrupter devices (GFCI)

(4) Fuse reducers

240.4 OVERCURRENT PROTECTION OF CONDUCTORS

Conductors must have overcurrent protection in accordance with their ampacities as specified in 310.14, except as permitted by 240.4(A) through (H).

Figure 240–7 Overcurrent Protection of Conductors 240.4

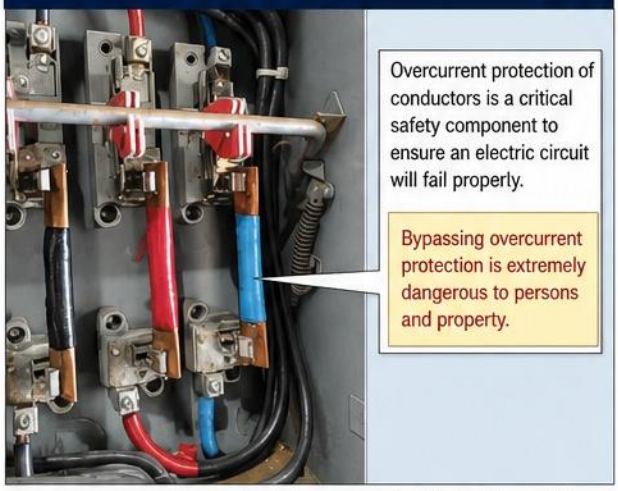


General rule: Conductors are protected based on their ampacity unless an exception in 240.4(A) through (H) applies.

Author's Comment:

- Overcurrent protection of conductors is a critical safety component to ensure that an electric circuit will fail properly. Bypassing overcurrent protection is extremely dangerous to persons and property.

Figure 240–8 Overcurrent Protection of Conductors (Author's Comment) 240.4



Proper overcurrent protection helps ensure that faults clear safely and equipment is protected.

(B) Overcurrent Protective Devices Rated 800A or Less. Where the ampacity of a conductor does not correspond to the ampere rating of a standard overcurrent protective device, the next higher standard overcurrent protective device rating is permitted, provided the following conditions are met:

(1) Conductors do not supply more than one receptacle

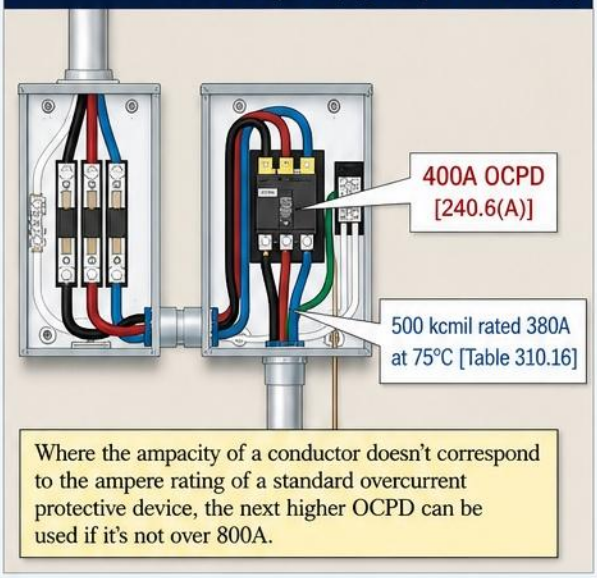
(3) Next higher standard overcurrent protective device rating does not exceed 800A

▶ OCPD Rated 800A or Less [240.4(B)] Example

Question: *According to Table 310.16, what is the maximum size overcurrent protective device that can be used to protect 500 kcmil conductors where each conductor has an ampacity of 380A at 75°C?* **Figure 240–9**

(a) 300A (b) 350A (c) 400A (d) 500A

Figure 240–9 Overcurrent Protection of Conductors 800A or Less [240.4(B)] Example 1 240.4(B)

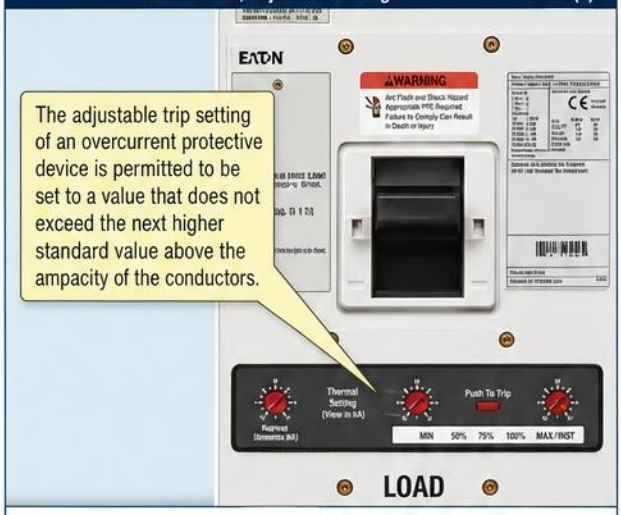


Answer: *(c) 400A [240.6(A)]*

If the overcurrent protective device has an adjustable trip setting, it is permitted to be set to a value that does not exceed the next higher standard value above the ampacity of the conductors being protected as shown in Table 240.6(A). **Figure 240–10**

(C) Overcurrent Protective Devices Rated Over 800A. If the circuit's overcurrent protective device exceeds 800A, the conductor ampacity must be equal to or greater than the standard ampere or setting rating of the overcurrent protective device as shown in Table 240.6(A).

Figure 240–10 Overcurrent Protection for Conductors 800A or Less, Adjustable Settings 240.4(B)



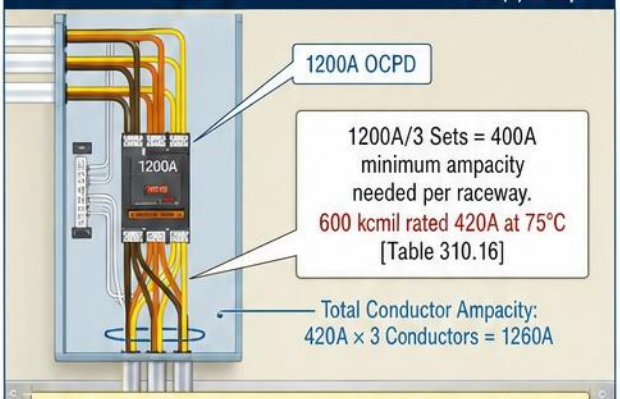
Adjustable trip settings may be set to a standard value that does not exceed the next higher rating above the conductor ampacity.

▶ OCPD Rated Over 800A [240.4(C)] Example

Question: *What is the minimum size of conductors (paralleled in three conductors per phase) allowed to be protected by a 1,200A overcurrent protective device? [240.4(C)]*

(a) 400 kcmil (b) 500 kcmil (c) 600 kcmil (d) 750 kcmil

Figure 240–11 Overcurrent Protection of Conductors Over 800A 240.4(C) Example



If the circuit's overcurrent protective device exceeds 800A, the conductor ampacity must be equal to or greater than the ampere or setting rating of the OCPD.

Solution:

The total ampacity of the three parallel conductor sets must be equal to/greater than 1,200A [240.4(C)]. The ampacity for each conductor within the parallel set must be equal to/greater than 400A (1,200A/3 raceways).

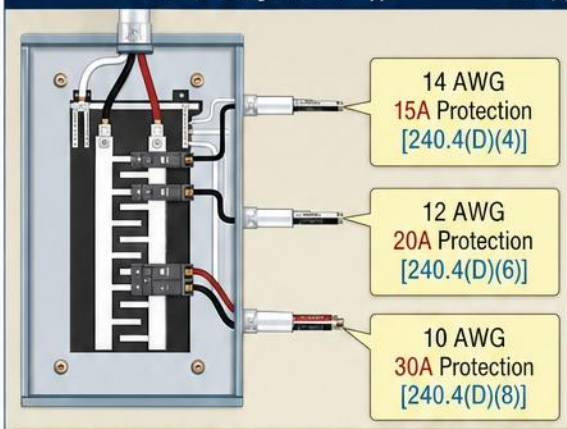
Conductor Size = 600 kcmil conductors per phase rated 420A at 75°C [110.14(C)(1)(b)(2) and Table 310.16]

Total Conductor Ampacity = 420A × 3 conductors
Total Conductor Ampacity = 1,260A (which is permitted for a 1,200A overcurrent protective device)

Answer: *(c) 600 kcmil*

(D) Conductors 18 AWG through 10 AWG. Overcurrent protection for conductors is not permitted to exceed the following values, except as permitted in 240.4(E) or (G): Figure 240–12

Figure 240–12 Overcurrent Protection of Conductors 14 AWG Through 10 AWG Copper 240.4(D)



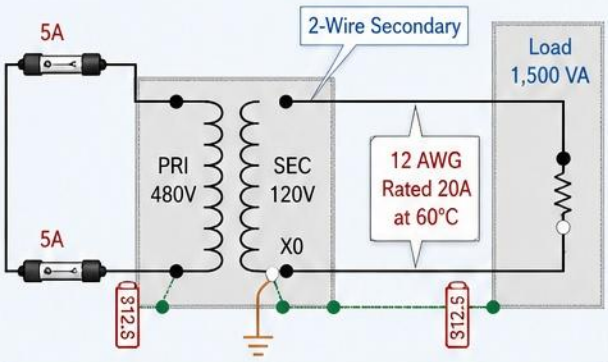
Except as permitted in 240.4(E) for tap conductors and 240.4(G) for specific equipment, overcurrent protection for conductors is not permitted to exceed as shown above.

(1) 18 AWG copper—7A
(2) 16 AWG copper—10A
(3) 14 AWG copper-clad aluminum—10A
(4) 14 AWG copper—15A
(5) 12 AWG aluminum and copper-clad aluminum—15A
(6) 12 AWG copper—20A
(7) 10 AWG aluminum and copper-clad aluminum—25A
(8) 10 AWG copper—30A

(F) Transformer Secondary Conductors. Transformer secondary conductors of a single-phase transformer having a 2-wire secondary is permitted to be protected by the primary overcurrent protection device in accordance with 450.5—if this rating does not exceed the value determined by multiplying the transformer secondary conductor ampacity by the secondary-to-primary transformer voltage ratio. Figure 240–13

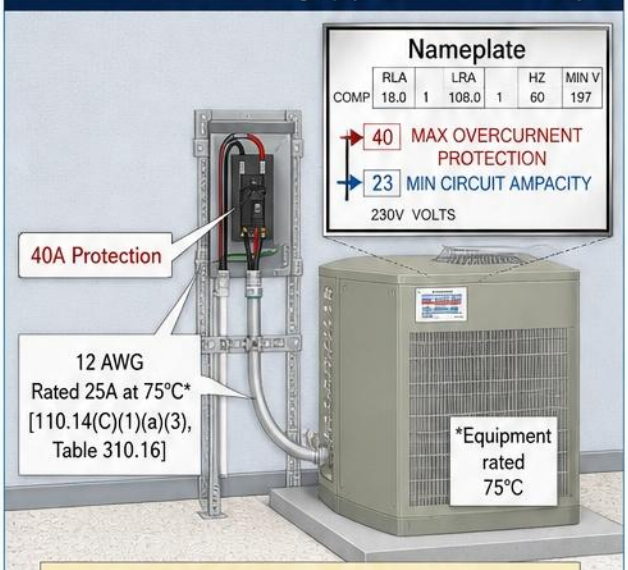
(G) Overcurrent Protection for Specific Applications. Overcurrent protection for conductors for specific equipment must comply with the requirements referenced in Table 240.4(G).

Figure 240–13 Overcurrent Protection of Conductors Transformer Secondary — 240.4(F) Example



Secondary ampacity required = Primary protection x voltage ratio
Primary protection = 3.13A x 167% = 5A, Ratio = 480/120 = 4 to 1
Secondary Ampacity = 5A, Primary protection x 4 = 20A
12 AWG rated 20A at 60°C [110.14(C)(1)(a)(2), Table 310.16]

Figure 240–14 Overcurrent Protection of Conductors Air-Conditioning Equipment — 240.4(G) Example



Overcurrent protection for air-conditioning equipment conductors is sized in accordance with 440.4 as referenced in Table 240.4(G).

Solution:

The nameplate values for listed air-conditioning equipment are used to size the branch-circuit conductors and short-circuit overcurrent protective device [440.4(B)]. No calculations are required.

Conductor Size: *A 12 AWG conductor is suitable because it has an ampacity of 25A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].*

Protection Size: *The air conditioner branch-circuit short-circuit protection is sized to the nameplate maximum overcurrent protection of 40A.*

A 40A circuit breaker is permitted to protect a 12 AWG conductor rated 25A at 75°C [110.14(C)(1)(a)(3), 240.4(G), and 440.4(B)].

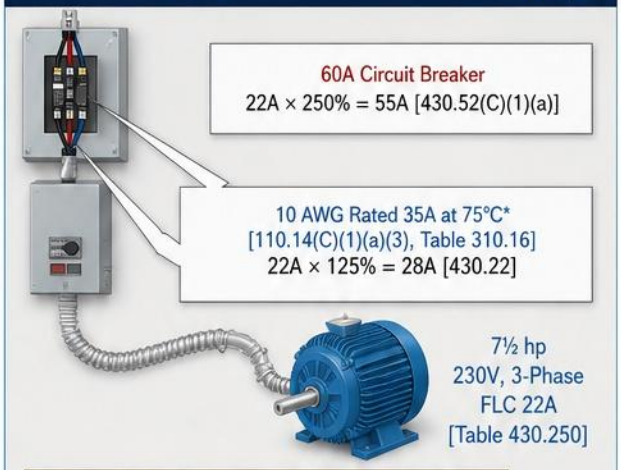
Answer: *(c) 12 AWG, 40A OCPD*

Air Conditioner Circuit [240.4(G)] Example

Question: *What size branch-circuit conductor and overcurrent protective device are required for an air conditioner where the nameplate indicates the minimum circuit ampacity is 24A, and the maximum overcurrent protection is 40A (for equipment rated for 75°C conductor sizing)?* Figure 240–14

(a) 12 AWG, 20A OCPD *(b) 12 AWG, 30A OCPD*
(c) 12 AWG, 40A OCPD *(d) 12 AWG, 50A OCPD*

Figure 240–15 Overcurrent Protection of Conductors Motors — 240.4(G) Example



Short-circuit and ground-fault protection for motor conductors is sized in accordance with 430.52 as referenced in Table 240.4(G).

Solution:

Step 1: *Determine the branch-circuit conductor size at 125 percent of the motor's full-load current [430.22 and Table 430.250].*

FLC = 22A [Table 430.250]

Conductor = 22A × 125% = 27.5A
Conductor = 28A [430.22]
Conductor = 10 AWG which is rated 35A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]

Step 2: *Determine the branch-circuit overcurrent protective device rating at 250 percent of the motor's full-load current [Table 430.250, Table 430.52(C)(1), and 430.52(C)(1)(a)].*

Inverse Time Circuit Breaker = 22A × 250%
Inverse Time Circuit Breaker = 55A

A 60A inverse time circuit breaker is allowed to protect the 10 AWG conductor [240.4(G), Table 430.52(CC)(1), and 430.52(C)(1)(a)].

Answer: *(d) 10 AWG, 60A OCPD*

(H) Dwelling Unit Service and Feeder Conductors. Service and feeder conductors for a dwelling unit are permitted overcurrent protection in accordance with 310.12.

240.5 Overcurrent Protection of Flexible Cords, Flexible Cables, and Fixture Wires

(A) Ampacities. Flexible cords must be provided with overcurrent protection in accordance with its ampacity as specified in Table 400.5(A)(1) and (A)(2).

240.6 Standard Ampere Ratings

(A) Fuses and Fixed-Trip Circuit Breakers. The standard ampere ratings for fuses and inverse time circuit breakers are shown in Table 240.6(A).

Figure 240–16 Standard Ampere Ratings 240.6(A)

Fuses and Circuit Breakers
Standard Ampere Ratings
240.6(A)

The standard ampere ratings for fuses and inverse time circuit breakers are shown in Table 240.6(A).

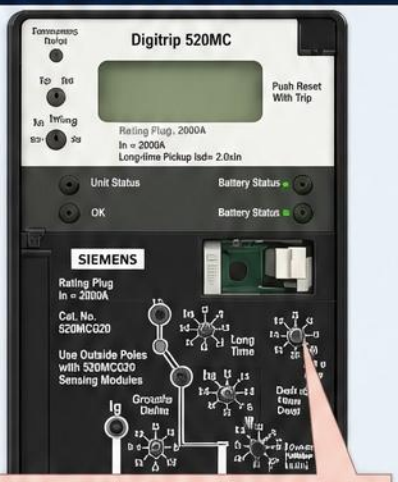
Table 240.6(A) Standard Ampere Ratings for Fuses and Inverse Time Circuit Breakers Standard Ampere Ratings

10A	15A	20A	25A	30A
35A	40A	45A	50A	60A
70A	80A	90A	100A	110A
125A	150A	175A	200A	225A
250A	300A	350A	400A	450A
500A	600A	700A	800A	1000A
1200A	1600A	2000A	2500A	3000A

(C) Local Restricted Access of Adjustable-Trip Circuit Breakers. The ampere rating of adjustable-trip circuit breakers that cannot be adjusted remotely must be equal to the adjusted current settings (long-time pickup). The adjusted current setting means must have restricted access by one of the following methods:

Circuit Breaker, Adjustable. Circuit breakers that can be set to trip at various values of current, time, or both within a predetermined range. ▶ Figure 240–17 and ▶ Figure 240–18

Figure 240–17 Adjustable-Trip Circuit Breaker 240.6(C)



Circuit breakers that can be set to trip at various values of current, time (or both), within a predetermined range.

(1) Located behind removable and sealable covers

(2) Located behind bolted equipment enclosure doors

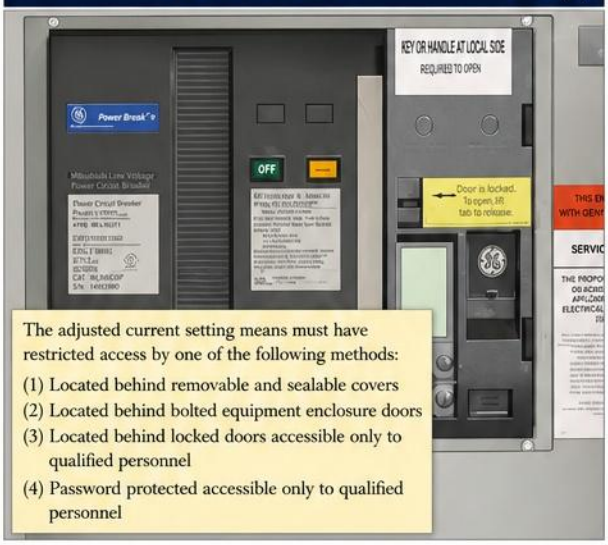
(3) Located behind locked doors accessible only to qualified personnel

(4) Password protected accessible only to qualified personnel ▶ Figure 240–19

Figure 240–18 Adjustable Circuit Breaker — Article 100 Definition

Circuit breakers that can be set to trip at various values of current, time (or both), within a predetermined range.

Figure 240–19 Adjustable-Trip Circuit Breakers Local Restricted Access — 240.6(C)



The adjusted current setting means must have restricted access by one of the following methods:

(1) Located behind removable and sealable covers
(2) Located behind bolted equipment enclosure doors
(3) Located behind locked doors accessible only to qualified personnel
(4) Password protected accessible only to qualified personnel

(D) Remotely Accessible Adjustable-Trip Circuit Breakers. The ampere rating of an adjustable circuit breaker that can be adjusted remotely to modify the current setting (long-time pickup) is equal to the adjusted current setting (long-time pickup) only when local restricted access to the adjustable circuit breaker. Remote access is achieved by one of the following methods:

(1) Connected directly through a local nonnetworked interface

(2) Connected through a networked interface complying with one of the following methods:

a. Circuit breaker and associated software for adjusting the settings are identified as being evaluated for cybersecurity.

b. Cybersecurity risk assessment of the network is completed. Documentation of the assessment and certification must be made available to those authorized to inspect, operate, and maintain the system.

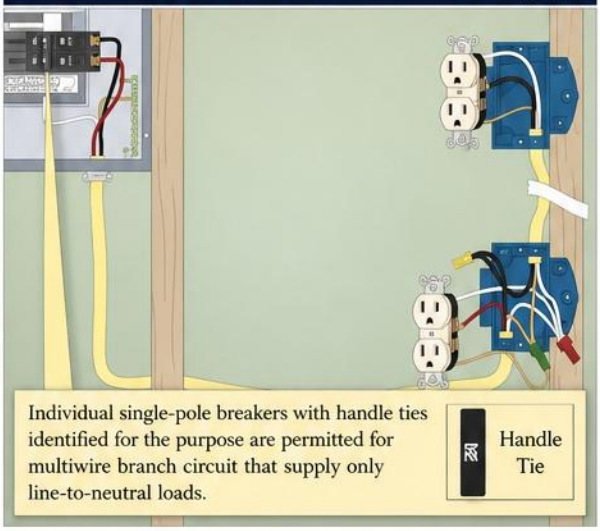
Note 3: Cybersecurity is a specialized field requiring constant, vigilant attention to security vulnerabilities that could arise due to software defects, system configuration changes, or user interactions. The installation of devices that can be secured is an important first step—but not sufficient to guarantee a secure system.

240.15 Circuit Breaker Handle Ties

(B) Circuit Breaker. Circuit breakers must automatically open all phase conductors of the circuit during an overcurrent condition, except as follows:

(1) Multiwire Branch Circuits. Individual single-pole breakers with handle ties *identified* for the purpose are permitted for each phase conductor of a *multiwire branch circuit* that supply only line-to-neutral loads. Figure 240–20

Figure 240–20 Overcurrent Protective Device Multiwire Branch Circuits — 240.15(B)(1)

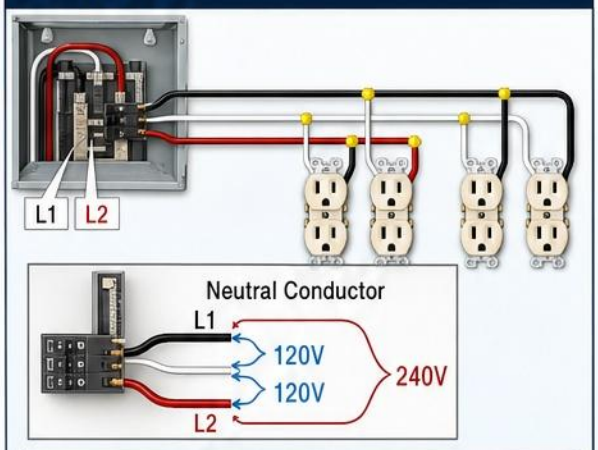


Individual single-pole breakers with handle ties identified for the purpose are permitted for multiwire branch circuit that supply only line-to-neutral loads.

Identified. Recognized as being suitable for a specific purpose, function, use, environment, or application.

Branch Circuit, Multiwire. A branch circuit consisting of two or more phase conductors with a neutral conductor having a voltage between the phase conductors and equal voltage from each phase conductor to the neutral conductor. Figure 240–21

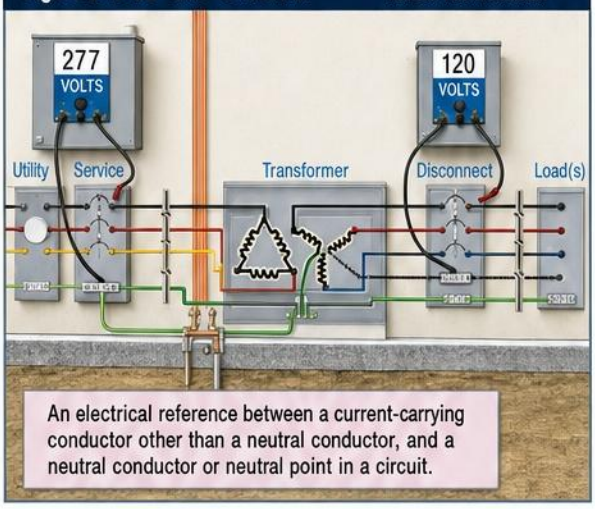
Figure 240–21 Multiwire Branch Circuit
Article 100 Definition



A branch circuit consisting of two or more phase conductors with a neutral conductor having a voltage between the phase conductors and equal voltage from each phase conductor to the neutral conductor.

Line-to-Neutral. An electrical reference between a current-carrying conductor other than a neutral conductor, and a neutral conductor or neutral point in a circuit. 240–22

Figure 240–22 Line-to-Neutral *Article 100 Definition*



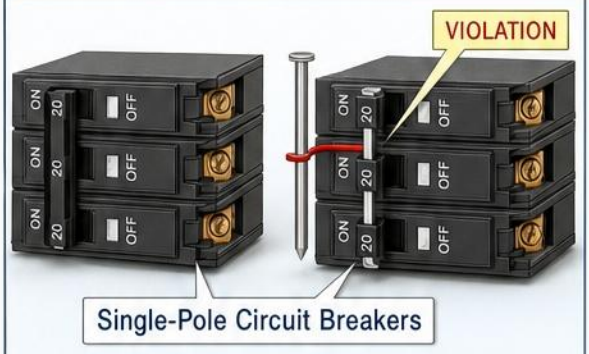
An electrical reference between a current-carrying conductor other than a neutral conductor, and a neutral conductor or neutral point in a circuit.

(2) Single-Phase Line-to-Line Loads. Individual single-pole circuit breakers rated 120/240V with handle ties identified for the purpose are permitted for each phase conductor of a single-phase circuit supplying *line-to-line* loads. 240–24

Author's Comment:

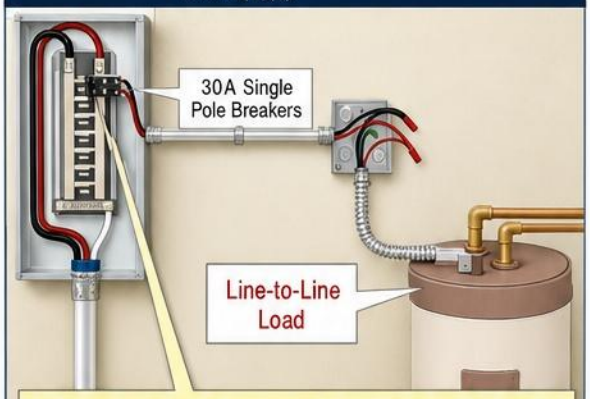
- Handle ties made from nails, screws, wires, or other nonconforming materials are not permitted to serve as a handle tie. 240–23

Figure 240–23 Overcurrent Protective Device Multiwire Branch Circuits
240.15(B)(1) Comment



Handle ties must be identified for the purpose, which means that those made from nails, screws, wires, or other nonconforming material aren't permitted.

Figure 240–24 Overcurrent Protective Device Single-Phase, Line-to-Line Loads
240.15(B)(2)



Individual single-pole circuit breakers rated 120/240V with handle ties identified for the purpose are permitted for single-phase circuit supplying line-to-line loads.

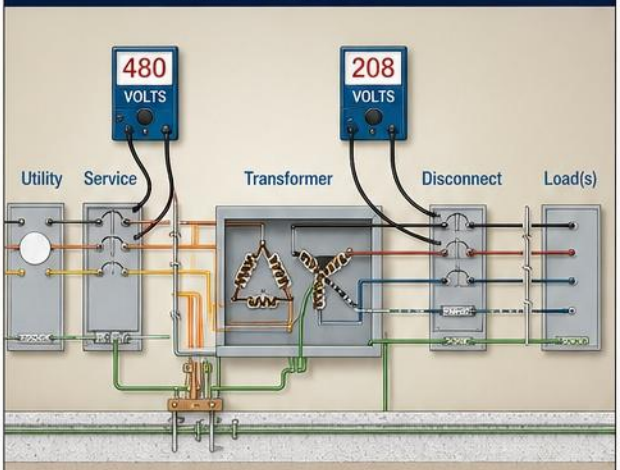
Line-to-Line. *An electrical reference between two current-carrying conductors in a circuit other than a neutral conductor.* 240–25

(3) Three-Phase Line-to-Line Loads. Individual single-pole circuit breakers rated 120/240V with handle ties identified for the purpose are permitted for each phase conductor of a three-phase circuit supplying *line-to-line* loads. 240–26

Author's Comment:

- Single-pole breakers are not permitted for circuits that supply both line-to-line and line-to-neutral loads (such as a dryer or range).
- Single-pole breakers are not permitted for 277V or 480V circuits supplying line-to-line or line-to-neutral loads.

Figure 240-25 Line-to-Line Article 100 Definition — Article 100 Definition



An electrical reference between two current-carrying conductors in a circuit other than a neutral conductor.

Figure 240-27 Overcurrent Protection Location in Circuit — 240.21

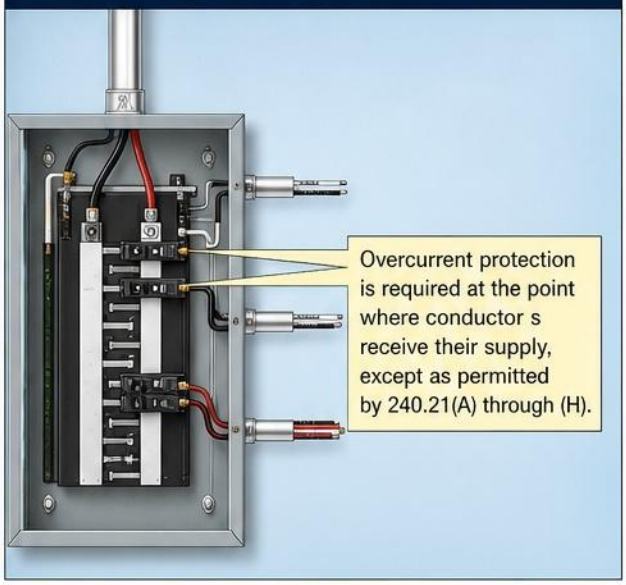


Figure 240-26 Overcurrent Protective Device Three-Phase, Line-to-Line Loads — 240.15(B)(3)

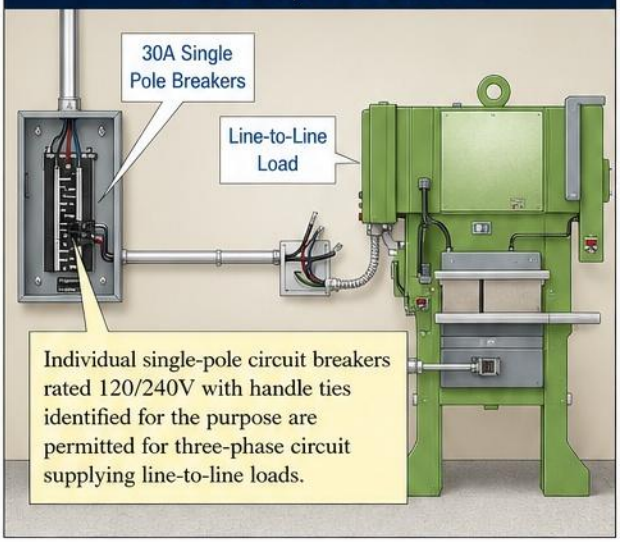
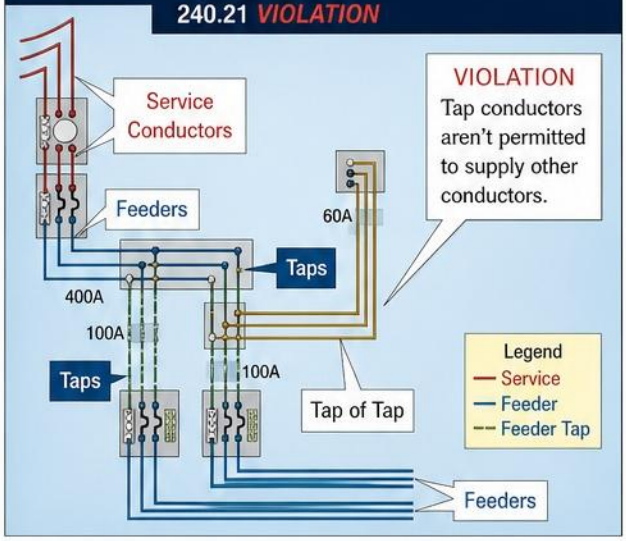


Figure 240-28 Overcurrent Protection, Location in Circuit Tap Conductors 240.21 *VIOLATION*



Part II. Location of Overcurrent Protective Device

240.21 Location of Overcurrent Protective Device in Circuit

Overcurrent protection is required at the point where conductors receive their supply, except as permitted by 240.21(A) through (H). ▸ Figure 240-27

Conductors supplied in accordance with 240.21(A) through (H) are not permitted to supply other conductors. ▸ Figure 240-28

(B) Feeder Taps. Feeder tap conductors are permitted in accordance with 240.21(B)(1) through (B)(5). ▸ Figure 240-29

Tap Conductors. A conductor, other than a service conductor, with overcurrent protection rated more than the ampacity of the conductor. ▸ Figure 240-30

The feeder tap is permitted at any point on the load side of the feeder overcurrent protective device, including the load terminals of the feeder overcurrent protective device. ▸ Figure 240-31

Figure 240–29 Feeder Taps, Overcurrent Protection 240.21(B)

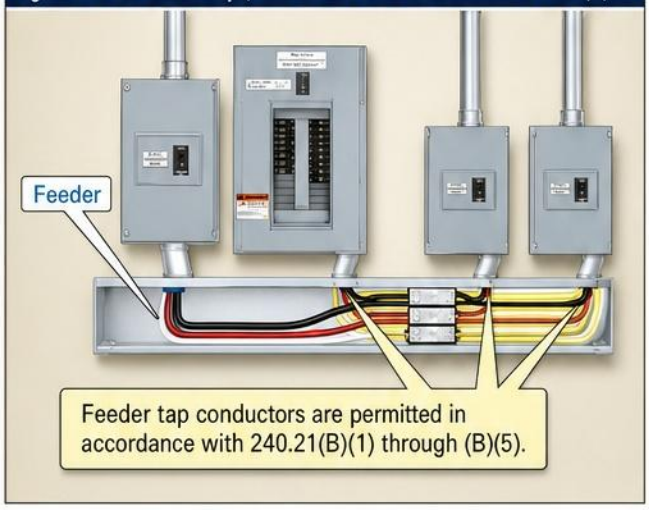


Figure 240–30 Tap Conductors—Article 100 Definition Article 100

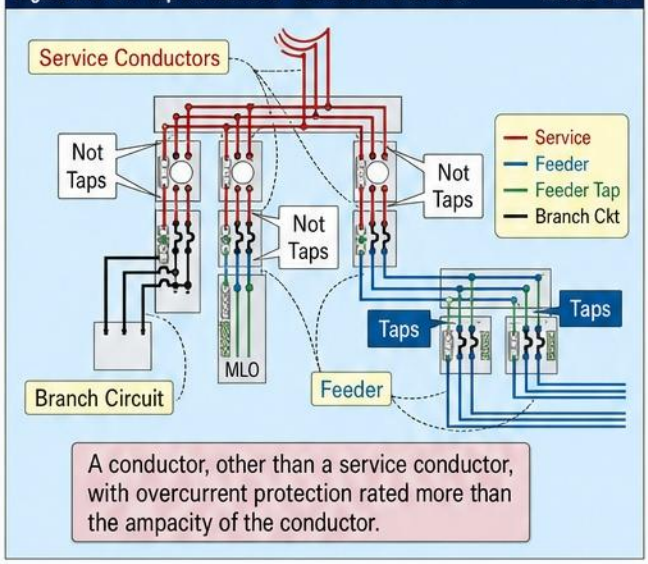
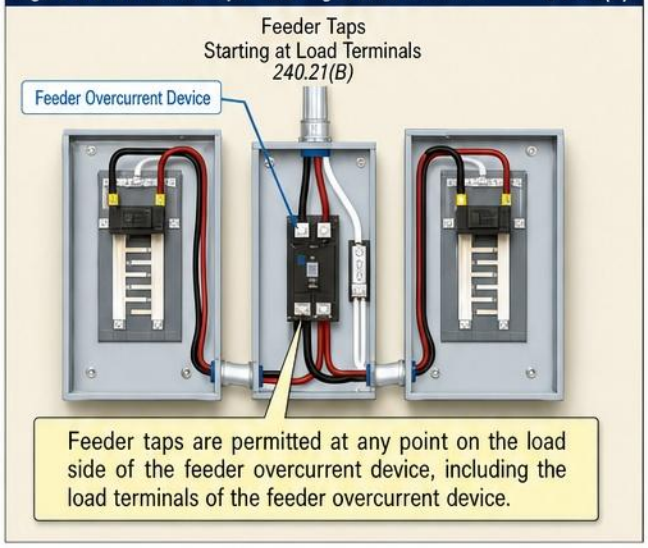


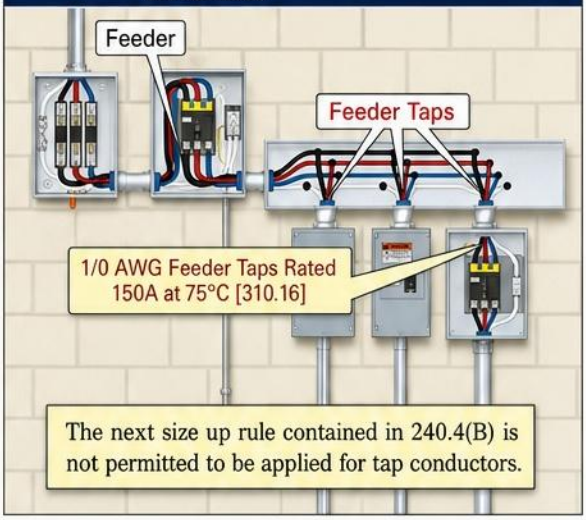
Figure 240–31 Feeder Taps—Starting at Load Terminals 240.21(B)



The next size up rurule contained in 240.4(B) is not permitted to be applied for tap conductors.

▶Figure 240-32

Figure 240–32 Feeder Taps, Next Size Up OCPD Not Permitted 240.21(B)



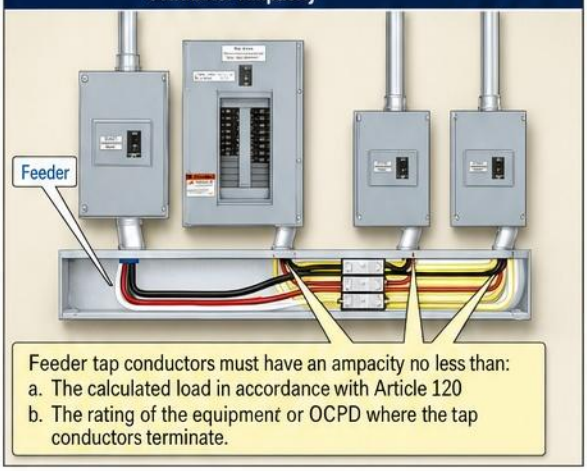
(1) Feeder Tap Not Over 10 Feet. Tap conductors up to 10 ft long are permitted when they comply with the following:

(1) Tap conductors must have an ampacity no less than both of the following:

a. Calculated load in accordance with Article 120

b. Rating of the equipment frame or overcurrent protective device where the tap conductors terminate ▶Figure 240-33

Figure 240–33 Feeder Taps Not over 10 Ft—Conductor Ampacity 240.21(B)(1)(1)

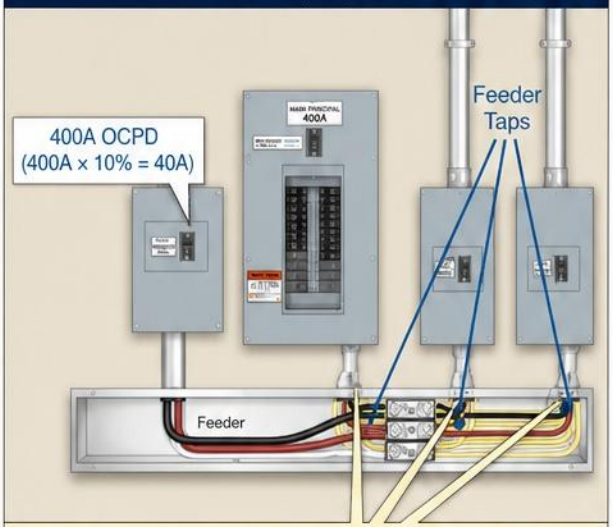


(2) The tap conductors do not extend beyond the equipment enclosure they supply.

(3) Except at the point of connection, tap conductors must be enclosed in a raceway.

(4) Tap conductors that leave the enclosure where the tap connection is made must have an ampacity no less than $^1/_{10}$ (10%) of the feeder overcurrent protective device rating **Figure 240–34**

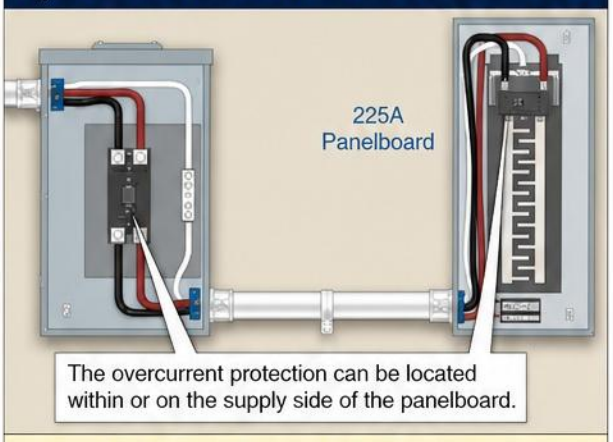
Figure 240–34 Feeder Taps Not Over 10 Ft Conductor Ampacity, 10% Rule 240.21(B)(1)(4)



Feeder tap conductors must have an ampacity no less than 1/10th (10%) of the feeder overcurrent protective device rating.

Note: If a tap supplies a panelboard, the tap conductors must terminate in an overcurrent protective device in accordance with 408.36. **Figure 240–35**

Figure 240–35 Panelboards Overcurrent Protection 408.36



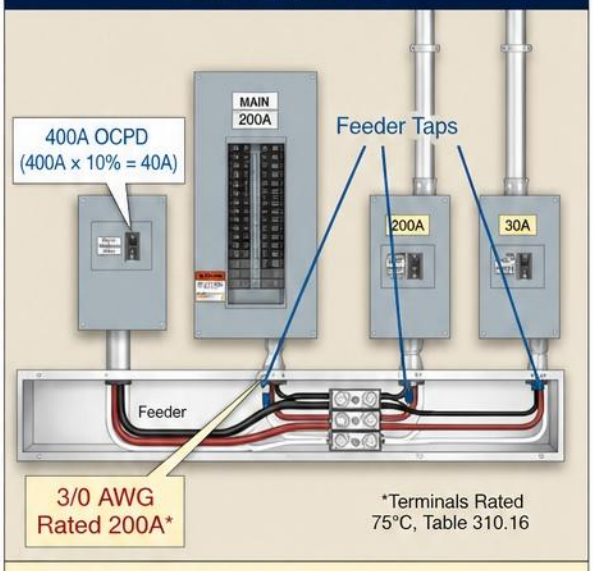
A panelboard must be provided with overcurrent protection having a rating not greater than that of the panelboard.

10-Foot Tap Rule [240.21(B)(1)(4)] Example 1

Question: *What size 10-ft tap conductor is needed from a 400A circuit breaker to supply a 200A OCPD in a panelboard where the equipment is rated for 75°C conductor?* **Figure 240–36**

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

Figure 240–36 Feeder Taps Not Over 10 Ft Conductor Ampacity, 10% Rule 240.21(B)(1)(4) Example 1



Feeder tap conductors must have an ampacity no less than 1/10th (10%) of the feeder overcurrent protective device rating.

Solution:

The tap conductors must have an ampacity at 75°C of no less than $^1/_{10}$ (10%) of 400A = 40A minimum conductor ampacity.

Tap Conductor Ampacity = 400A × 10%
Tap Conductor Ampacity = 40A

3/0 AWG is rated 200A at 75°C [110.14(C)(1)(b)(2) and Table 310.16] which is greater than $^1/_{10}$ (10%) of the rating of the 400A overcurrent protective device.

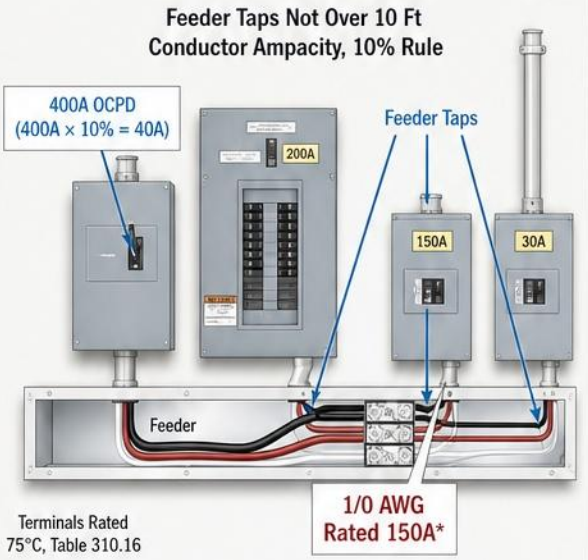
Answer: *(c) 3/0 AWG*

▶ 10-Foot Tap Rule [240.21(B)(1)(4)] Example 2

Question: *What size 10-ft tap conductor is needed from a 400A circuit breaker to supply a 150A OCPD in a feeder disconnect where the equipment is rated for 75°C conductor?* **Figure 240–37**

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

Figure 240–37 **240.21(B)(1)(4) Example 2**



Feeder tap conductors must have an ampacity no less than 1/10th (10%) of the feeder overcurrent protective device rating.

Solution:

The tap conductors must have an ampacity at 75°C of no less than 1/10t% of 400A = 40A minimum conductor ampacity

Tap Conductor Ampacity = 400A × 10%

Tap Conductor Ampacity = 40A

1/0 AWG is rated 150A at 75°C [110.14(C)(1)b)(2) and Table 310.16] which is greater than 1/10 (10%) of the rating of the 400A overcurrent protective device.

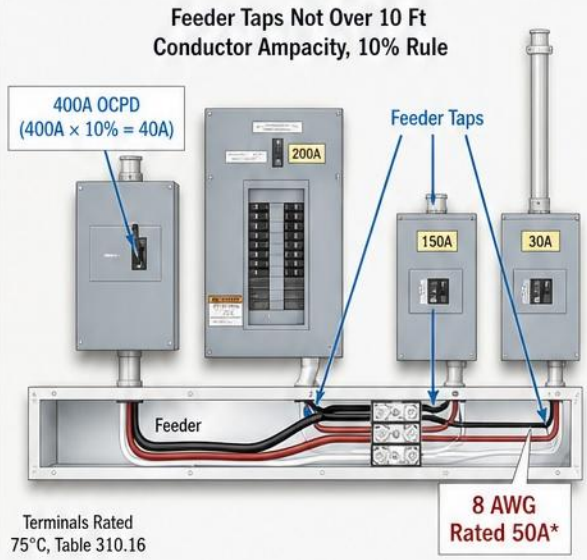
Answer: *(a) 1/0 AWG*

▶ 10-Foot Tap Rule [240.21(B)(1)(4)] Example 3

Question: *What size 10-ft tap conductor is needed from a 400A circuit breaker to supply a 30A OCPD in a feeder disconnect where the equipment is rated for 75°C conductor?* **Figure 240–38**

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 3 AWG

Figure 240–38 **240.21(B)(1)(4) Example 3**



Feeder tap conductors must have an ampacity no less than 1/10th (10%) of the feeder overcurrent protective device rating.

Solution:

The tap conductors must have an ampacity at 75°C of no less than 1/10t% of 400A = 40A minimum conductor ampacity

Tap Conductor Ampacity = 400A × 10%

Tap Conductor Ampacity = 40A. 8 AWG is rated 50A at 75°C [110.14(C)(1)(a)(3) and Table 310.16] which is greater than 1/10 (10%) of the rating of the 400A overcurrent protective device.

Answer: *(a) 8 AWG*

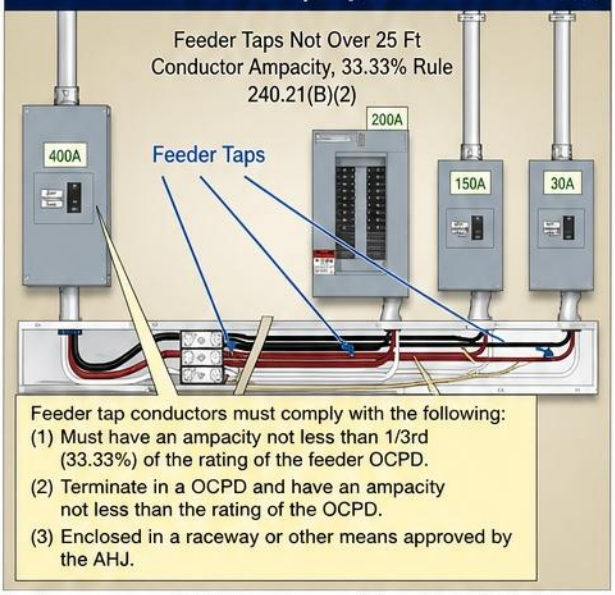
(2) Feeder Tap Not Over 25 Feet. Tap conductors up to 25 ft long are permitted when they comply with the following:

(1) Must have an ampacity not less than (one-third or 33.33%) of the rating of the feeder overcurrent protective device

(2) Terminate in a circuit breaker or set of fuses and have an ampacity not less than the rating of the overcurrent protective device

(3) Enclosed in a raceway or other means approved by the authority having jurisdiction (AHJ) **Figure 240–39**

Figure 240–39 Feeder Taps Not Over 25 Ft Conductor Ampacity, 33.33% Rule 240.21(B)(2)



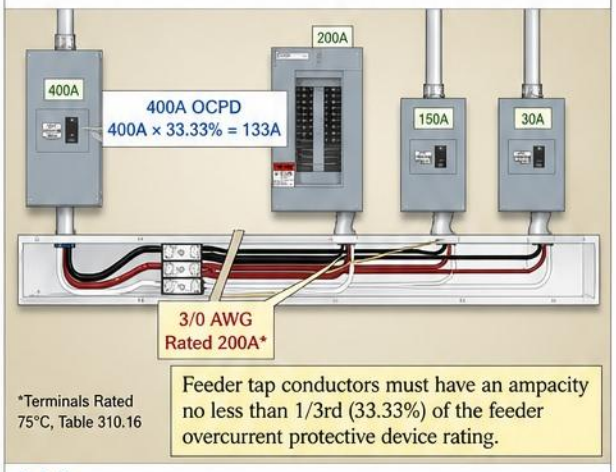
Feeder taps up to 25 ft in length must follow the 33.33% rule in 240.21(B)(2).

Figure 240–40 25-Foot Tap Rule [240.21(B)(2)] Example 1 240.21(B)(2)

Question:

What size 25-ft tap conductor is needed from a 400A circuit breaker to supply a 200A OCPD in a panelboard where the equipment is rated for 75°C conductor?

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



Solution:

The tap conductor must have an ampacity of no less than 133A (one-third or 33.33%) of the rating of the 400A overcurrent protective device.

Tap Conductor Ampacity = 400A × 33.33%
Tap Conductor Ampacity = 133A

3/0 AWG is rated 200A at 75°C [110.14(C)(1)(b) and Table 310.16] which is greater than 133A (one-third or 33.33%) the rating of the 400A overcurrent protective device) and equal to the 200A disconnect.

Answer: (c) *3/0 AWG*

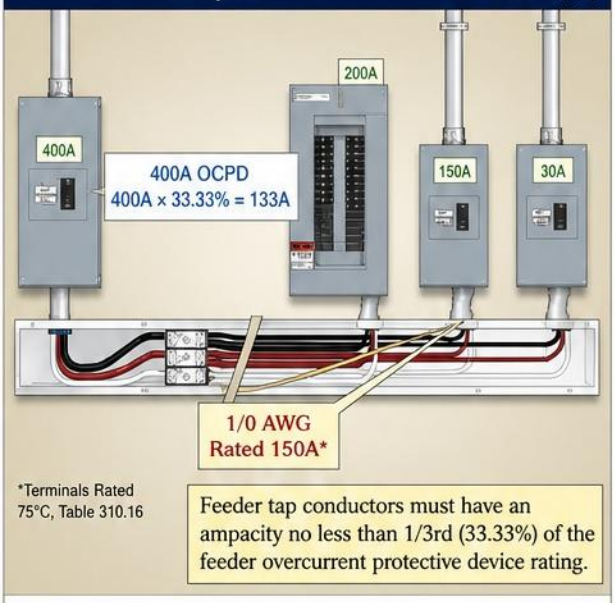
25-Foot Tap Rule [240.21(B)(2)] Example 2 240.21(B)(2)

Question:

What size 25-ft tap conductor is needed from a 400A circuit breaker to supply a 150A OCPD in a feeder disconnect where the equipment is rated for 75°C conductor?

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

Figure 240–41 Feeder Taps Not Over 25 Ft Conductor Ampacity, 33.33% Rule Example 2 240.21(B)(2)



Solution:

The tap conductor must have an ampacity of no less than 133A (one-third or 33.33%) of the rating of the 400A overcurrent protective device.

Tap Conductor Ampacity = 400A × 33.33%
Tap Conductor Ampacity = 133A

1/0 AWG is rated 150A at 75°C [110.14(C)(1)(b) and Table 310.16] which is greater than 133A (one-third or 33.33%) the rating of the 400A overcurrent protective device) and equal to the 150A disconnect.

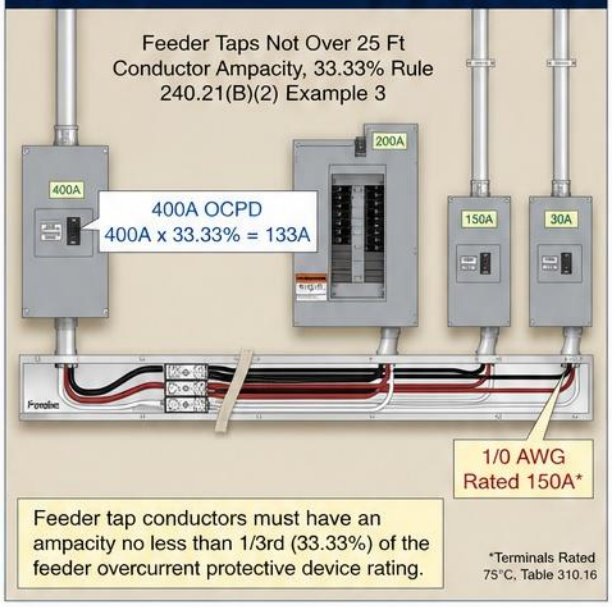
Answer: (a) *1/0 AWG*

25-Foot Tap Rule [240.21(B)(2)] Example 3

Question: What size 25-ft tap conductor is needed from a 400A circuit breaker to supply a 30A OCPD in a feeder disconnect where the equipment is rated for 75°C conductor? ▸Figure 240–42

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

Figure 240–42 **240.21(B)(2) Example 3**



Solution:

The tap conductor must have an ampacity of no less than 133A (one-third or 33.33%) of the rating of the 400A overcurrent protective device).

Tap Conductor Ampacity = 400A × 33.33%
Tap Conductor Ampacity = 133A

1/0 AWG is rated 150A at 75°C [110.14(C)(1)(a) and Table 310.16] which is greater than 133A (one-third or 33.33%) the rating of the 400A overcurrent protective device) and greater than the 30A disconnect main breaker.

Answer: *(d) 1/0 AWG*

Author's Comment:

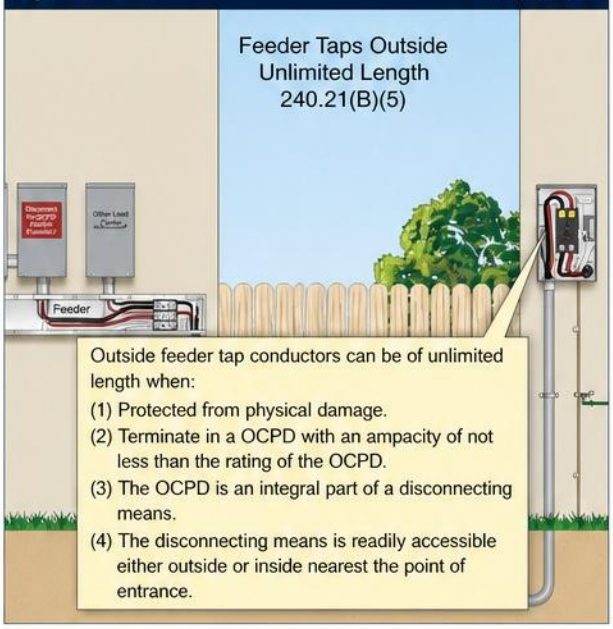
- If a tap supplies a panelboard, the tap conductors must terminate in an overcurrent protective device in accordance with 408.36.

(5) Outside Feeder Taps. Outside feeder tap conductors can be of unlimited length and must comply with the following: ▸Figure 240–43

(1) Protected from physical damage

(2) Terminate in a circuit breaker or set of fuses and has an ampacity no less than the rating of the overcurrent protective device

Figure 240–43 **240.21(B)(5)**



(3) Overcurrent protective device (circuit breaker or fuses) for the tap conductors is an integral part of a disconnecting means

(4) Disconnecting means for the tap conductors must be installed at a readily accessible location and comply with one of the following:

a. Outside of a building or structure

b. Inside and nearest the point of entrance of the tap conductors

c. Nearest the point of entrance of the tap conductors, where installed in accordance with [230.6]

Author's Comment:

- The feeder overcurrent protective device provides short-circuit and ground-fault protection for the tap conductors. The tap termination overcurrent protective device provides overload protection. ▸Figure 240–44

(C) Transformer Secondary Conductors. The secondary terminals of a transformer can supply multiple sets of transformer secondary conductors. ▸Figure 240–45

The next size up rule contained in 240.4(B) is not permitted to be applied to *transformer secondary conductors.*

Transformer Secondary Conductor. A conductor, other than a service conductor, that originates at the secondary winding terminals of a transformer. ▸Figure 240–46

Figure 240-44 Feeder Taps, Overcurrent Protection 240.21(B)

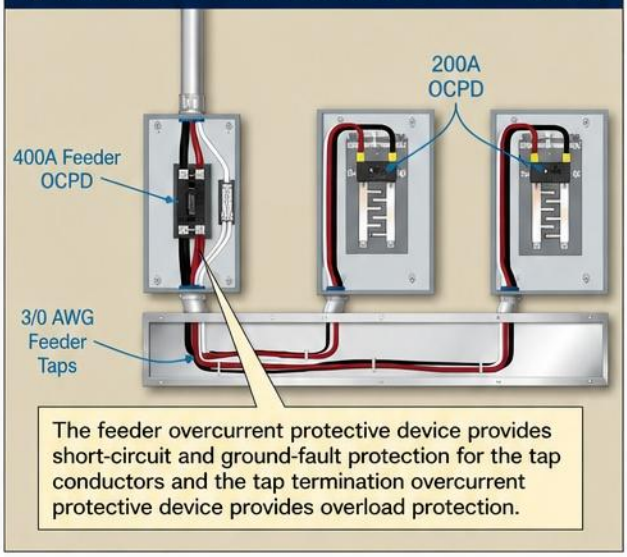
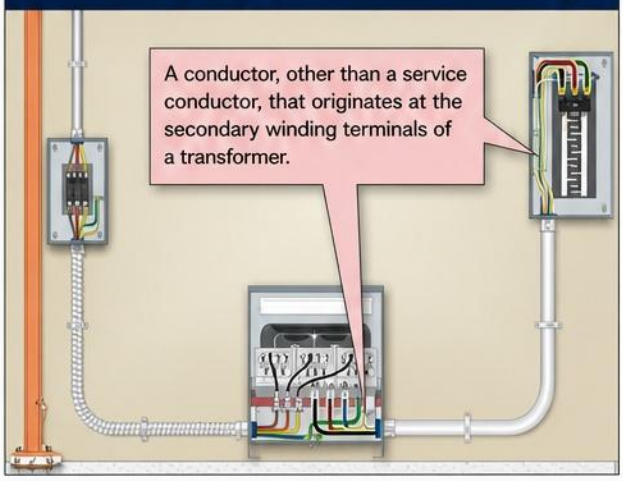


Figure 240-45 Transformer Secondary Conductors Multiple Sets 240.21(C)

Figure 240-46 Transformer Secondary Conductor Article 100 Definition 240.2

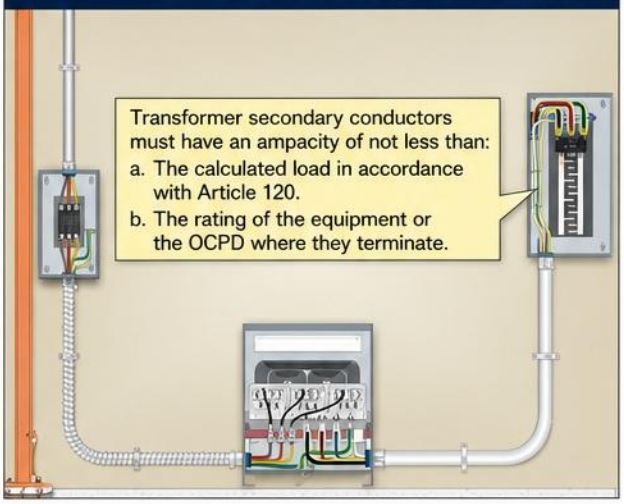


(2) Transformer Secondary Conductors Not Over 10 Feet.

Transformer secondary conductors up to 10 ft long are permitted when they comply with the following:

(1) Must have an ampacity no less than: ▶Figure 240-47

Figure 240-47 Transformer Secondary Conductors Not over 10 Ft, Conductor Ampacity 240.21(C)(2)(1)



a. Calculated load in accordance with Article 120

b. Rating of the equipment frame or overcurrent protective device where the transformer secondary conductors terminate

(2) Do not extend beyond the equipment enclosure they supply

(3) Are enclosed in a raceway

(4) Have an ampacity no less than 1/10 (10%) of the rating of the primary overcurrent protective device multiplied by the primary-to-secondary voltage ratio

Note: If the transformer secondary conductors supply a panelboard, the transformer secondary conductors must terminate in an overcurrent protective device in accordance with 408.36.

Author's Comment:

- When a panelboard is supplied from a transformer, the overcurrent protection for the panelboard must be on the secondary side of the transformer. The overcurrent protection can be in an enclosure ahead or within the panelboard. ▶**Figure 240-48** and ▶**Figure 240-49**

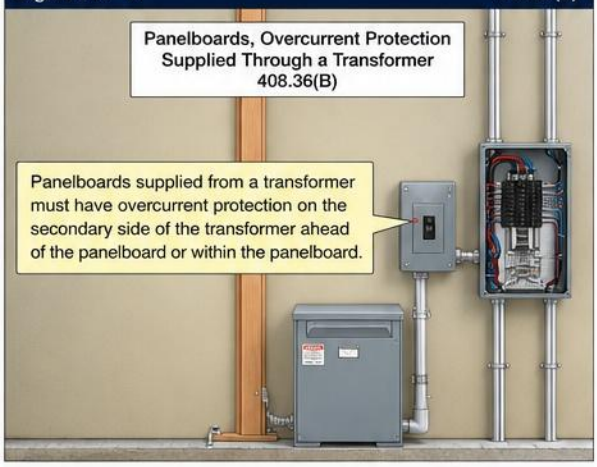
(4) Outside Transformer Secondary Conductors.

Outside transformer secondary conductors can be of unlimited length if they comply with the following: ▶Figure 240-50

Figure 240–48 408.36(B)

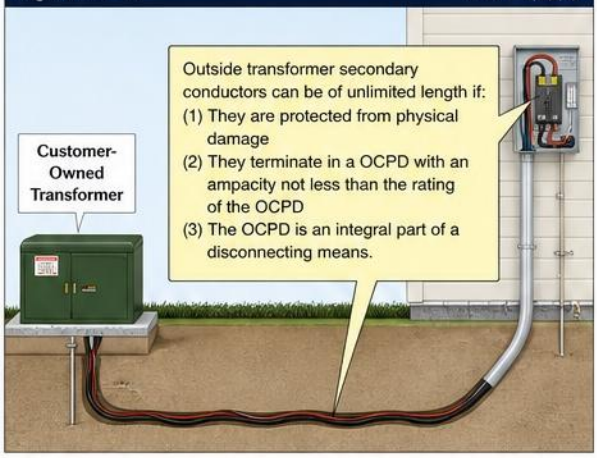
Overcurrent protection must be provided on the transformer secondary side ahead of the panelboard or within the panelboard.

Figure 240–49 408.36(B)



The required overcurrent protection must be located ahead of the panelboard on the transformer secondary side.

Figure 240–50 240.21(C)(4)



Outside transformer secondary conductors may be of unlimited length when all three conditions are met.

(1) Shielded from physical injury as determined by the AHJ

(2) Terminated at a circuit breaker or set of fuses that has an ampacity no less than the rating of the overcurrent protective device

(3) The overcurrent protective device (circuit breaker/fuses) forms an integral part of a disconnecting means

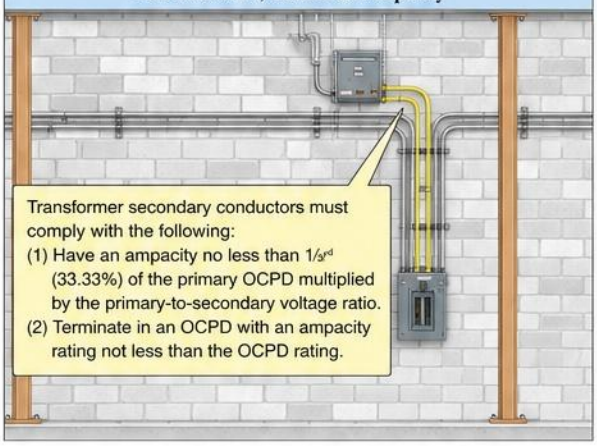
(6) Transformer Secondary Conductors Not Over 25 Feet. Transformer secondary conductors up to 25 ft long are permitted when they comply with the following:

(1) Have an ampacity no less than (one-third or 33.33%) of the rating of the primary overcurrent protective device multiplied by the primary-to-secondary voltage ratio

(2) Terminate in an overcurrent protective device with an ampacity rating not less than the overcurrent protective device rating • Figure 240–51

Figure 240–51 240.21(C)(6)

Transformer Secondary Conductors Not Over 25 Ft, Conductor Ampacity



Transformer secondary conductors up to 25 ft are allowed when both listed requirements are satisfied.

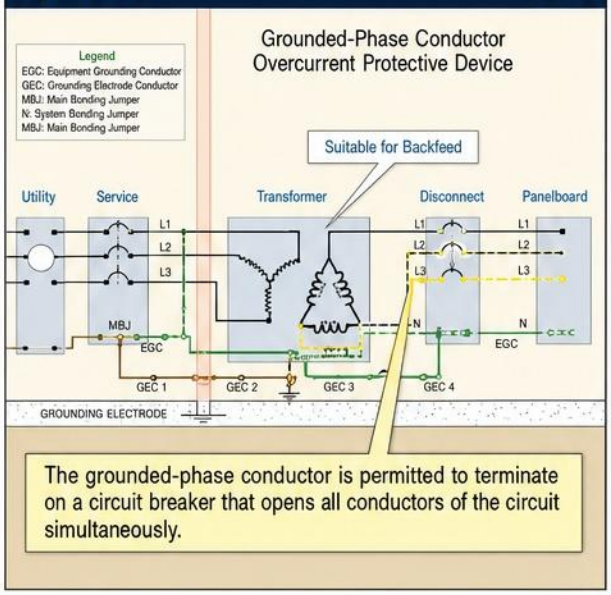
240.22 Grounded-Phase Conductor on Overcurrent Protective Device

The grounded-phase conductor is permitted to terminate on a circuit breaker that opens all conductors of the circuit simultaneously. Figure 240–52

Author's Comment:

- The grounded-phase conductor is not permitted to terminate to a fusible disconnect because it cannot be opened simultaneously with the other fuses in the disconnect.

Figure 240–52 240.22



240.24 Location of Overcurrent Protective Devices

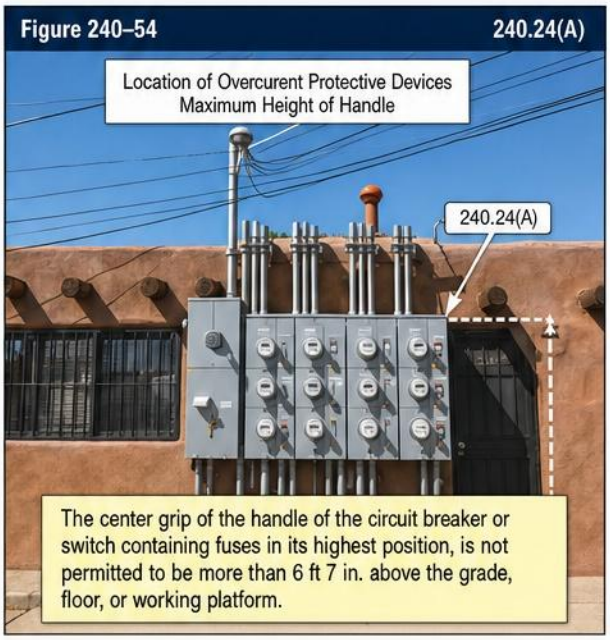
(A) Accessibility.

Readily accessible. Circuit breakers and switches containing fuses must be readily accessible.

Figure 240–53 240.24(A)

Maximum Height of Handle. The center grip of the handle of the circuit breaker or switch containing fuses in its highest position is not permitted to be more than 6 ft 7 in. above the grade, floor, or working platform except for: 240.24(A)

Figure 240–54 240.24(A)

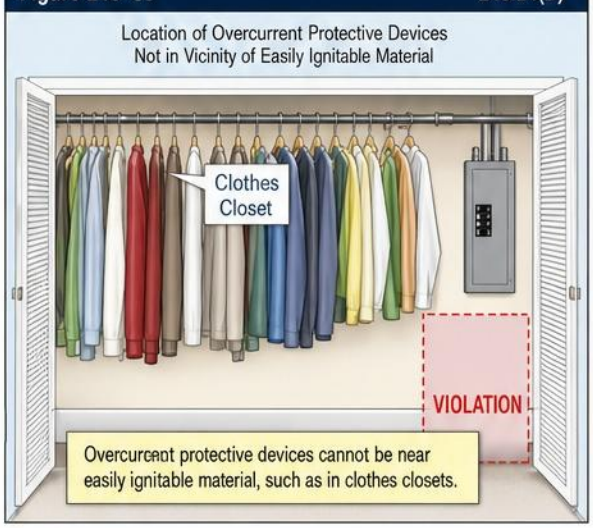


(4) Circuit breakers and switches containing fuses located next to the equipment they supply are not required to be readily accessible, or within 6 ft 7 in. of the grade, floor, or working platform

(C) Not Exposed to Physical Damage. Overcurrent protective devices are not permitted to be exposed to physical damage as determined by the AHJ.

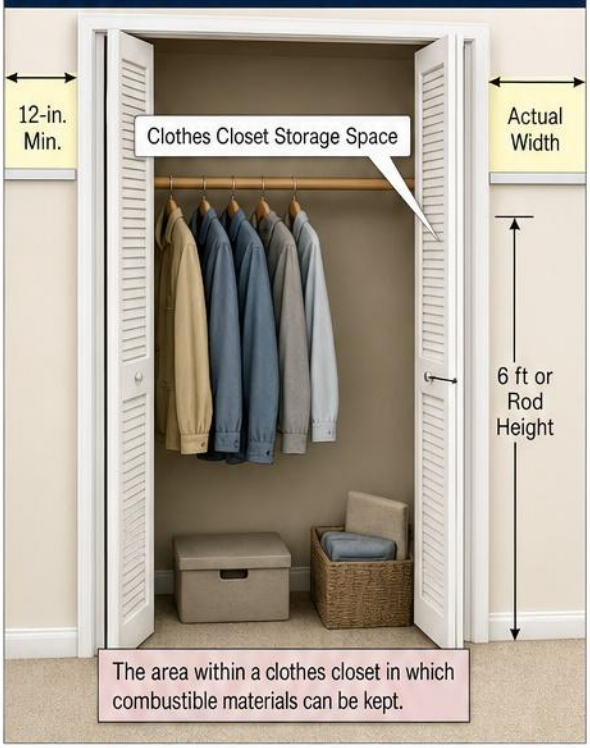
(D) Not in Vicinity of Easily Ignitable Material. Overcurrent protective devices cannot be near easily ignitable material as determined by the AHJ, such as in clothes closets.

Figure 240–55 240.24(D)



Clothes Closet Storage Space. *The area within a clothes closet in which combustible materials can be kept.* 240.24(D)

Figure 240–56 Clothes Closet Storage Space *Article 100 Definition*

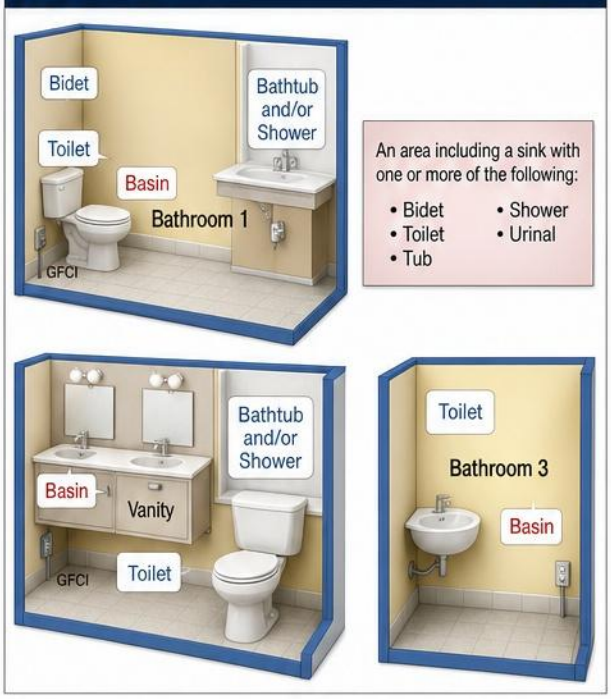


(E) Not in Bathroom. Overcurrent protective devices are not permitted to be in bathrooms, showering facilities, or locker rooms with showering facilities.

Figure 240–57 *Location of Overcurrent Protective Devices Not Permitted in Bathrooms* *240.24(E)*

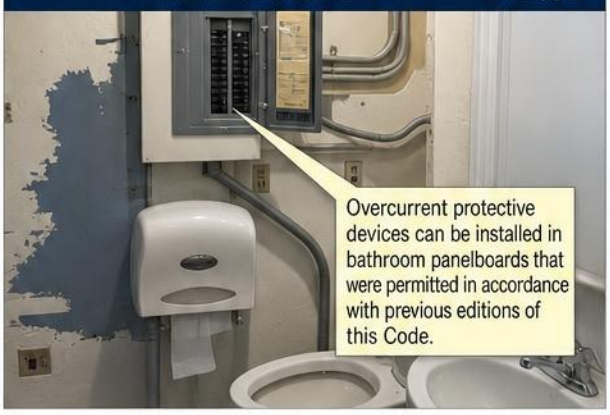
Ex: Overcurrent protective devices can be installed in bathroom panelboards that were permitted in accordance with previous editions of this Code.

Figure 240–58 Bathroom *Article 100 Definition*



Bathroom. An area including a sink with one or more of the following: a toilet, urinal, tub, shower, or bidet.

Figure 240–59 *Location of Overcurrent Protective Devices Not Permitted in Bathrooms* *240.24(E) Ex*



Author's Comment:
The service disconnect switch is not permitted to be installed in a bathroom area—even in commercial or industrial facilities [230.70(A)(3)].

(F) Not Over Steps. Overcurrent protective devices are not permitted to be located over stairway steps. **Figure 240–60**

Author's Comment:
The working space must be level and flat for the entire depth and width of the required working space in accordance with 110.26(A)(6). Clearly, it is difficult for electricians to safely work on electrical equipment that is on uneven surfaces (such as over stairways).

Figure 240-60 Location of Overcurrent Protective Devices Not Permitted Over Steps 240.24(F)

Circuit breakers or enclosures containing circuit breakers must not be installed horizontally above a stairway.

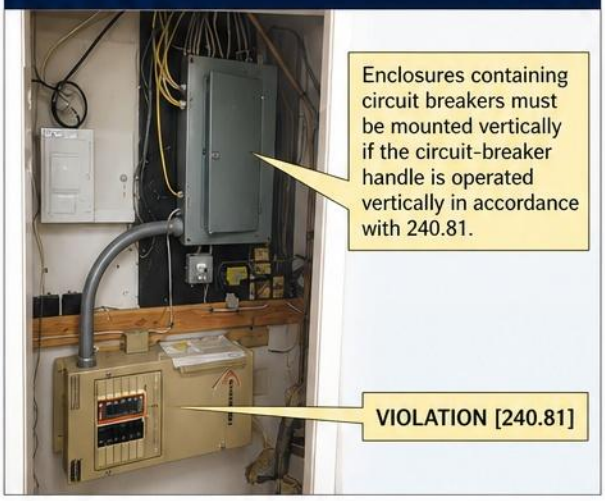
Part III. Enclosures Containing Overcurrent Protective Devices

240.33 Vertical Position of Enclosures

Fuses. Enclosures containing fuses must be mounted in a vertical position.

Circuit Breakers. Enclosures containing circuit breakers must be mounted vertically if the circuit-breaker handle is operated vertically in accordance with 240.81. Figure 240-61.

Figure 240-61 Overcurrent Device Enclosure Vertical Position 240.33



Circuit-breaker enclosures must be oriented vertically when the handle is operated in a vertical direction.

AUTHOR'S COMMENT:

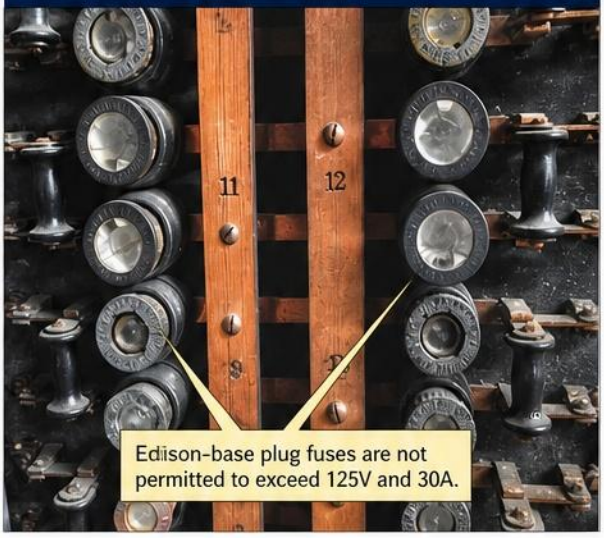
Section 240.81 specifies that where circuit-breaker handles are operated vertically, the "up" position of the handle must be the "on" position. In effect, an enclosure that contains one row of circuit breakers can be mounted horizontally, but an enclosure that contains a panelboard with multiple circuit breakers on opposite sides of each other must be mounted vertically.

Part V. Plug Fuses, Fuseholders, and Adapters

240.51 Edison-Base Fuses

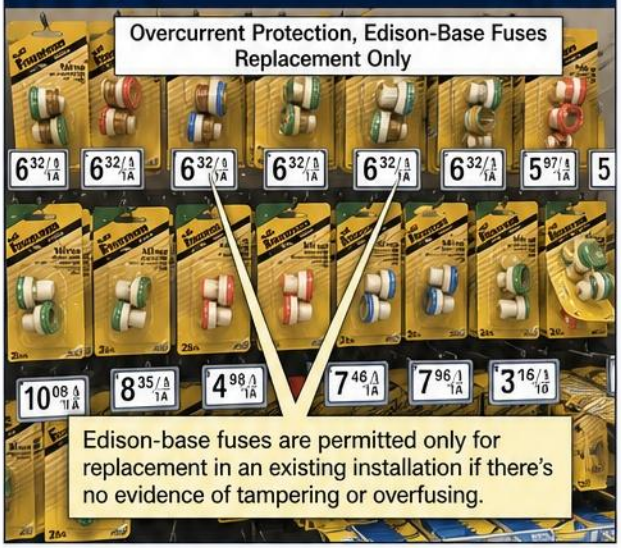
(A) Classification. Edison-base plug fuses are not permitted to exceed 125V and 30A. Figure 240-62.

Figure 240-62 Overcurrent Protection, Edison-Base Fuses Classification 240.51(A)



(B) Replacement Only. Edison-base fuses are permitted only for replacement in an existing installation—if there is no evidence of tampering or over fusing. Figure 240-63.

Figure 240–63 240.51(B)



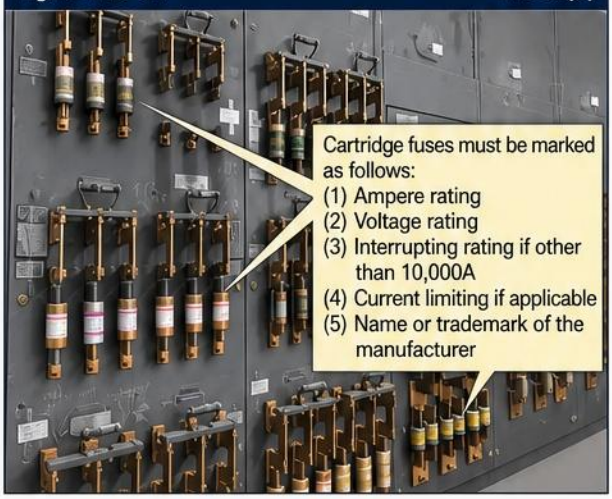
Edison-base fuses may be used only to replace fuses in an existing system when there is no sign of tampering or the use of oversized fuses.

Part VI. Cartridge Fuses

240.60 General

(C) Marking. Cartridge fuses must be marked as follows: Figure 240–64

Figure 240–64 240.60(C)



(1) Ampere rating
(2) Voltage rating
(3) Interrupting rating if other than 10,000A
(4) Current limiting if applicable
(5) Name or trademark of the manufacturer

WARNING: Fuses must have an interrupting rating sufficient for the short-circuit current available at the equipment line terminals. Using a fuse with an inadequate interrupting current rating can cause equipment to be destroyed from a line-to-line or ground fault which can result in death or severe injury. See 110.9.

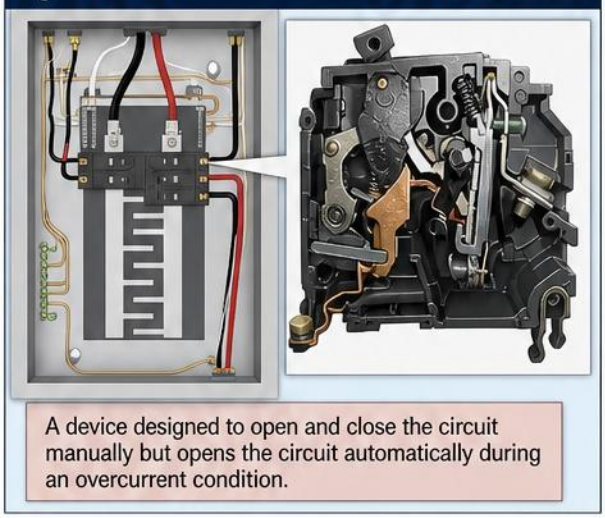
Part VII. Circuit Breakers

240.80 Method of Operation

Circuit breakers must trip free and be capable of being closed and opened by manual operation.

Circuit Breaker: A device designed to open and close the circuit manually but opens the circuit automatically during an overcurrent condition. Figure 240–65

Figure 240–65 Article 100 Definition



240.81 Indicating

When the handle of a circuit breaker is operated vertically, the "up" position of the handle must be in the "on" position. Figure 240–66

Figure 240–66 240.81

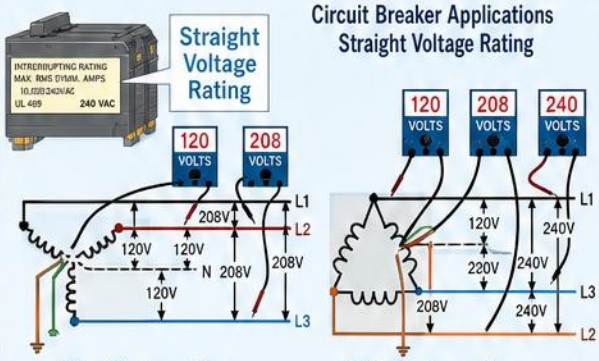
Figure 240–66 240.81

When the handle is operated vertically, the "up" position of the handle must be the "on" position.

240.85 Circuit Breaker Applications

(A) Straight Voltage Rating Circuit Breaker. A circuit breaker with a straight voltage marking (such as 240V or 480V) is permitted on a circuit if the nominal system voltage between any two conductors (*line-to-neutral* or *line-to-line*) does not exceed the circuit breakers' marked voltage rating.

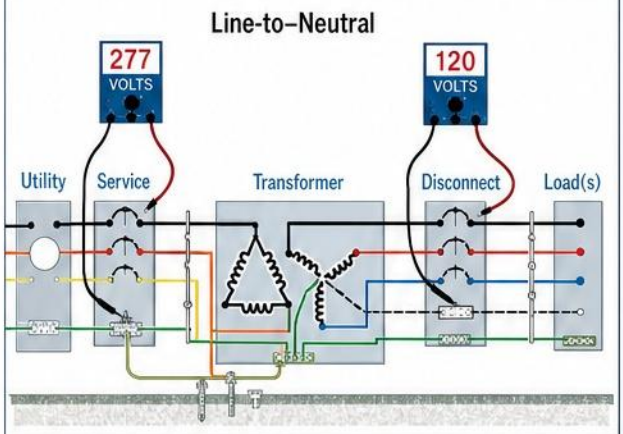
Figure 240–67 240.85(A)



A circuit breaker with a straight voltage marking is permitted on a circuit if the nominal system voltage between any two conductors does not exceed the circuit breakers' marked voltage rating.

Line-to-Neutral. An electrical reference between a current-carrying conductor other than a neutral conductor, and a neutral conductor or neutral point in a circuit.

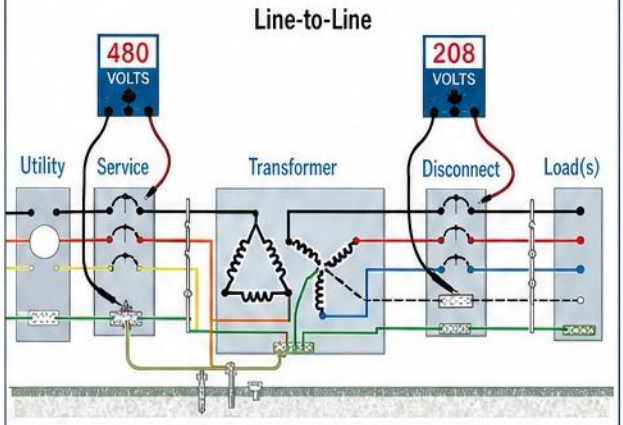
Figure 240–68 Article 100 Definition



An electrical reference between a current-carrying conductor other than a neutral conductor, and a neutral conductor or neutral point in a circuit.

Line-to-Line. An electrical reference between two current-carrying conductors in a circuit other than a neutral conductor.

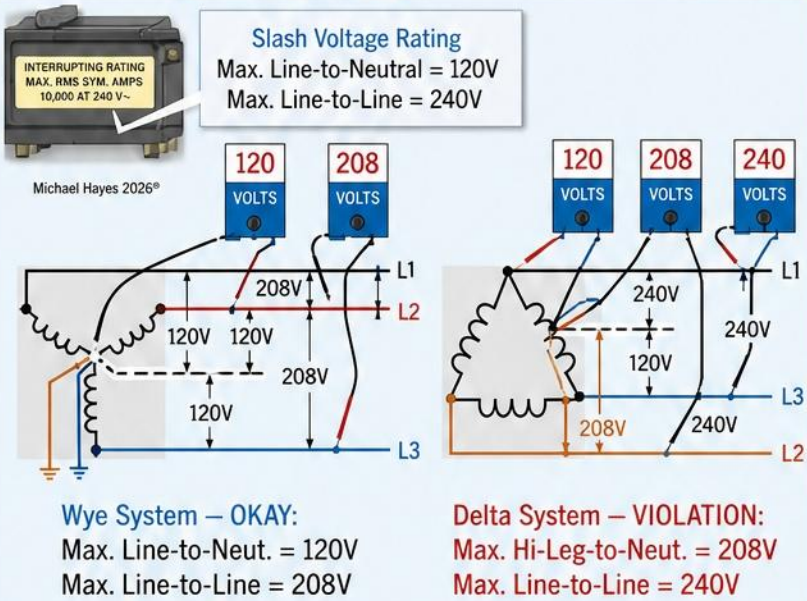
Figure 240–69 Article 100 Definition



An electrical reference between two current-carrying conductors in a circuit other than a neutral conductor.

(B) Slash Voltage Rating Circuit Breaker. A circuit breaker with a slash rating (such as 120/240V or 277/480V) marking is permitted if the nominal system voltage of any one conductor to ground does not exceed the lower voltage marking, and the nominal system voltage between any two conductors does not exceed the higher voltage marking.

Figure 240–70 Circuit Breaker Applications — Slash Voltage Rating **240.85(B)**



A circuit breaker with a slash rating marking is permitted if the nominal system voltage of any one conductor to ground does not exceed the lower voltage marking, and the nominal system voltage between any two conductors does not exceed the higher voltage marking.

Author's Comment:

A 120/240V slash circuit breaker is not permitted to be used on the high-leg of a 4-wire, three-phase, 120/240V delta-connected system because the line-to-ground voltage of the high-leg is 208V, which exceeds the 120V line-to-ground voltage rating of a 120/240V slash circuit breaker.

ARTICLE

242 Overvoltage Protection (SPD)

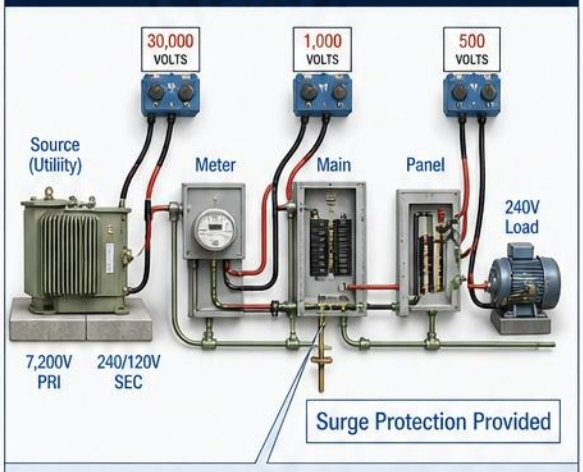
Introduction to Article 242—Overvoltage Protection (SPD)

This article establishes general installation and connection requirements for overvoltage protection and overvoltage protective devices (surge-protective devices). Surge-protective devices (SPD) are installed to reduce transient overvoltages and protect electronic safety equipment (such as smoke detectors, AFCIs, GFCIs, CO detectors, emergency systems, fire pump equipment, elevators, and electronic breakers) from damage.

Surge-protective devices are connected in parallel with the load. They use "metal-oxide varistors" (MOVs) to divert transient current and limit the overvoltage from a surge to the connected load (typically 150V for a 120V circuit). The surge-protective device MOVs function by changing the impedance from high (open) to low (closed). This is done to clamp transient overvoltage and current pulses to protect equipment from transient overvoltage.

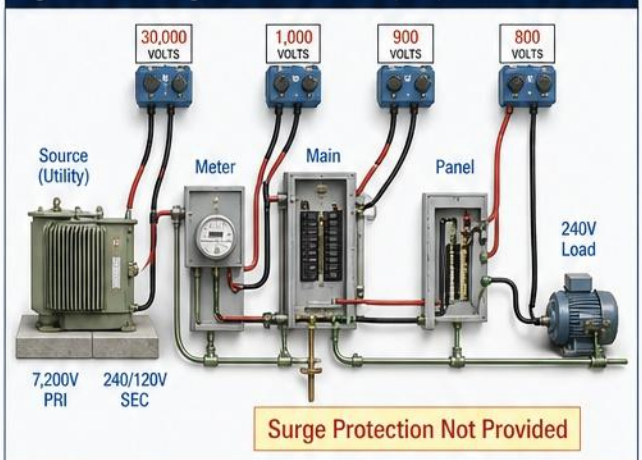
Surge-Protective Device (SPD). A protective device intended to limit transient voltages by diverting or limiting surge current. The device prevents continued flow while remaining capable of repeating these functions. SPDs can be designated as Type 1 and Type 2. ▶ Figure 242–1 ▶ Figure 242–2

Figure 242–1 Surge-Protective Device (SPD) NEC 242.1
Article 100 Definition



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 242–2 Surge-Protective Device (SPD) NEC 242.1



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.

Author's Comment:

- Surge-protective devices are designed to shunt transient overvoltages away from the load to protect equipment. They are arranged so the voltage to the load does not exceed the equipment's maximum voltage rating as designed by the manufacturer.

Part I. General

242.1 Scope

Part I of this article provides the general requirements for overvoltage protection and overvoltage protective devices.
▶ Figure 242–3

Figure 242–3 Overvoltage Protection 242.1 Scope

Article 242 establishes the general requirements for overvoltage protection and overvoltage protective devices.

Part II covers surge-protective devices permanently installed on premises wiring systems no more than 1000V, nominal.

Part II. Surge-Protective Devices (SPDs), Not over 1000V

242.2 Listing

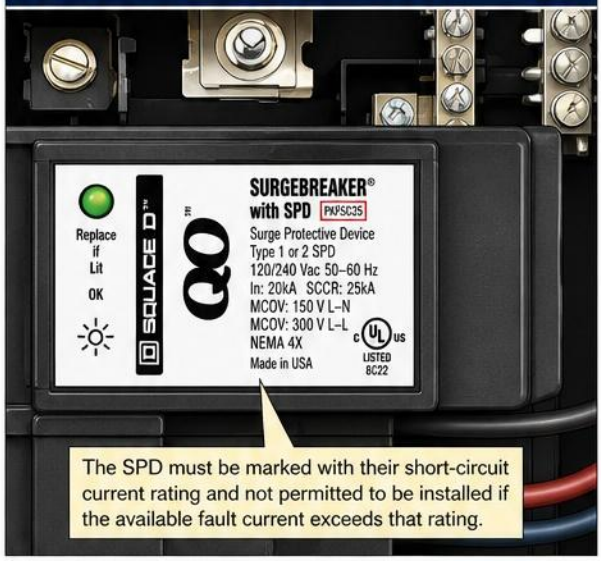
A surge-protective device (SPD) must be listed.

242.8 Short-Circuit Current Rating

Surge-protective device (SPD) must be marked with their short-circuit current rating and is not permitted to be installed if the available fault current exceeds that rating.
▶ Figure 242–4

WARNING: Surge-protective devices (SPDs) are susceptible to failure at high-fault currents. A hazardous condition is present if the short-circuit current rating of a surge-protective device is less than the available fault current. See 110.10.

Figure 242–4 Short-Circuit Current Rating 242.8

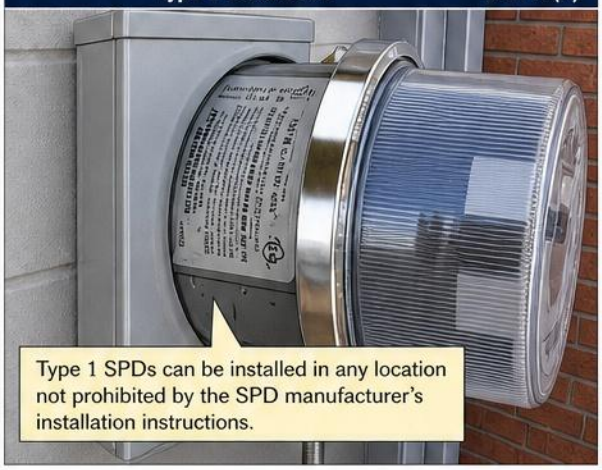


Short-Circuit Current Rating. The fault current at a nominal voltage to which equipment can be connected without sustaining damage exceeding defined acceptance criteria.

242.13 Type 1 Surge-Protective Device (SPD)—Supply Side of Service Equipment

(A) Installation. Type 1 SPDs can be installed in any location not prohibited by the SPD manufacturer's installation instructions. ▶ Figure 242–5

Figure 242–5 Surge Protection Device (SPD) Type 1 Installation 242.13(A)



Surge-Protective Device, Type 1. Type 1 surge-protective devices are listed to be installed at or on the supply side of the service disconnect.
▶ Figure 242–6

Figure 242-6 Article 100 Definition

Type 1 surge-protective devices are those specified to be attached either at or on the supply side of the service disconnect.

(B) At the Service. Where installed at services, Type 1 SPDs must be connected to one of the following:

(1) Service neutral conductor

(2) Grounding electrode conductor

(3) Grounding electrode for the service

(4) Equipment grounding terminal in the service equipment

242.14 Type 2 Surge-Protective Devices (SPD) Feeder Circuits

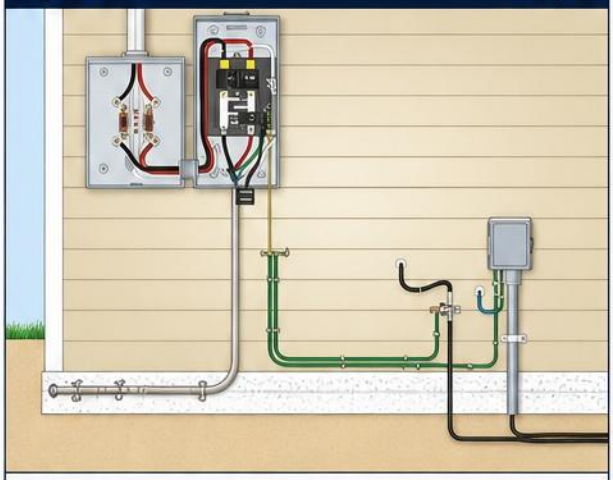
(A) Service-Supplied Buildings. Type 2 SPDs must be connected to the load side of the service disconnect. ▸Figure 242-7

Surge-Protective Device, Type 2. Type 2 surge-protective devices are those specified to be attached on the load side of the service disconnect. ▸Figure 242-8 and ▸Figure 242-9

Author's Comment:

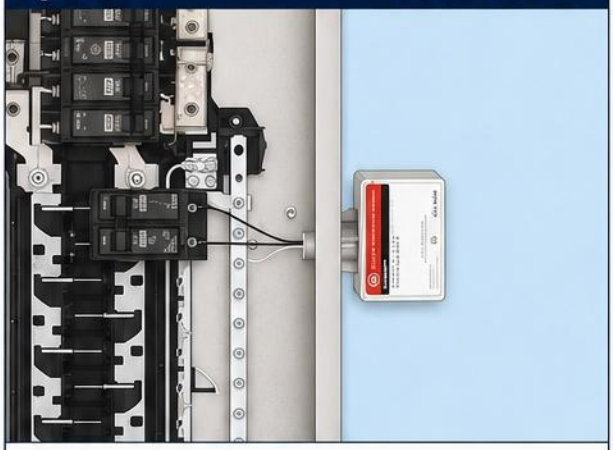
- Only one conductor can be connected to a terminal unless identified for multiple conductors [110.14(A)]. ▸Figure 242-10

Figure 242-7 242.14(A)



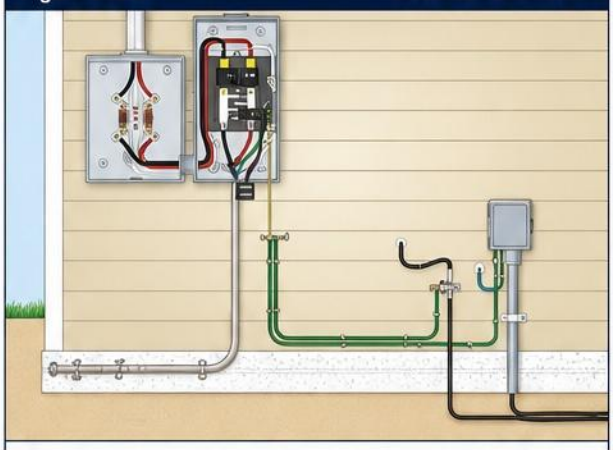
Type 2 SPDs must be connected on the load side of the service disconnect.

Figure 242-8 Article 100 Definition



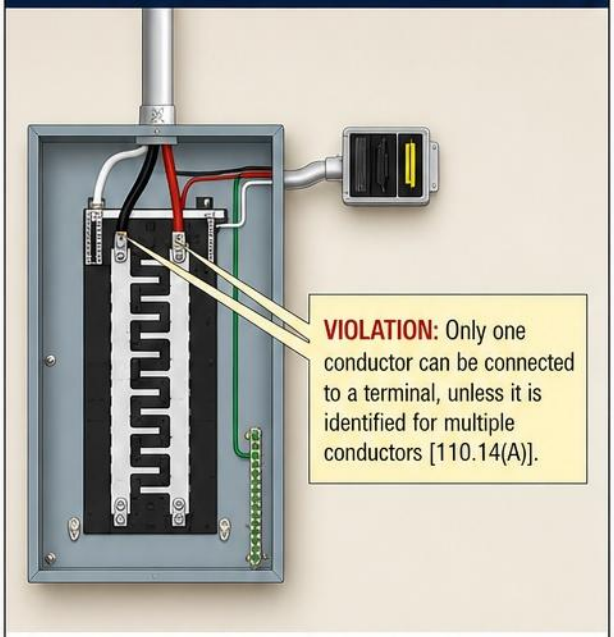
Type 2 surge-protective devices are those designated to be installed on the load side of the service disconnect.

Figure 242-9 Article 100 Definition



Type 2 surge-protective devices are those designated to be installed on the load side of the service disconnect.

Figure 242–10 Surge-Protective Devices, Type 2 Load Side of Service Disconnect 242.24(A)



More than one conductor is landed on the same terminal without that terminal being listed for multiple conductors, which is a violation of 110.14(A).

Figure 242–11 Surge-Protective Devices Routing of Conductors 242.24

Keep SPD leads as short as practical and avoid making unnecessary bends in the conductors.

(B) Feeder-Supplied Buildings. Type 2 SPDs can be connected anywhere on the load side of the feeder building disconnect.

242.24 ROUTING OF SURGE-PROTECTIVE DEVICE CONDUCTORS

Surge-protective device (SPD) conductors are not permitted to be any longer than necessary, and any unnecessary bends must be avoided. Figure 242–11

Author's Comment:

- Shorter conductors and minimal bends will improve the performance of the surge-protective device by reducing conductor impedance during high-frequency transient events.

ARTICLE

250 Grounding and Bonding

Introduction to Article 250—Grounding and Bonding

Article 250 covers the general requirements for bonding and grounding electrical installations. The terminology used in this article has been a source of much confusion over the years, so pay careful attention to the definitions (for example the term *ground*) pertaining to Article 250.

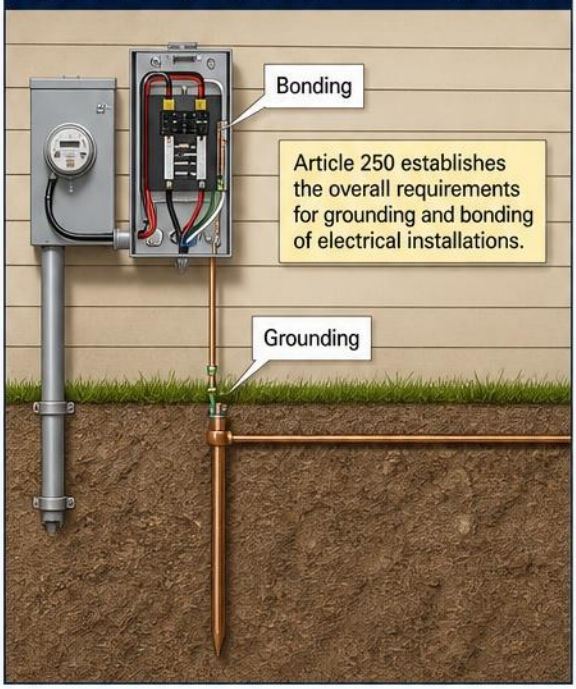
Understanding the difference between bonding and grounding of electrical systems and equipment will help you correctly apply the provisions of this article. Because of the massive size and scope of Article 250, *NEC* Figure 250.1 is provided as a reference for the locations of the different types of rules.

Part I. General

250.1 Scope

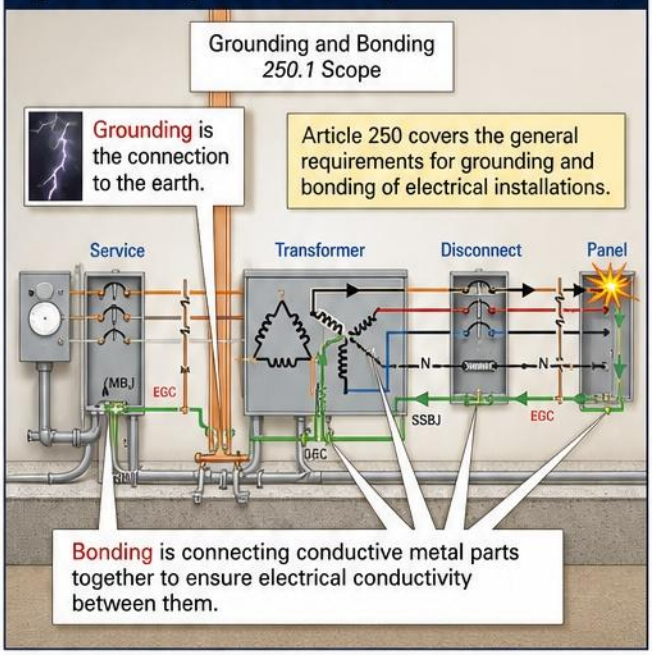
This article establishes the overall requirements for grounding and bonding of electrical installations. See **Figure 250-1** and **Figure 250-2**.

Figure 250-1 General Overview 250.1 Scope



This figure shows the two key concepts: grounding (connection to the earth) and bonding (connection of conductive metal parts together).

Figure 250-2 System Relationship 250.1 Scope



This figure illustrates how bonding unites conductive metal parts so that electrical continuity is maintained between them.

Author's Comment:

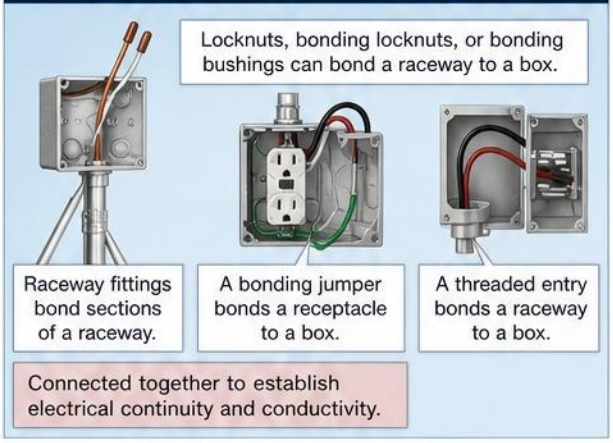
This article addresses two distinct concepts:

- **Grounding**. Grounding is the connection to the earth.
- **Bonding**. Bonding is connecting conductive metal parts together to ensure electrical conductivity between metal parts—especially when it is essential to establish an effective ground-fault current path.

Bonded (Bonding). Connected together to establish electrical continuity and conductivity.

NEC Figure 250–3

Figure 250–3 Bonded (Bonding) NEC Article 100 Definition

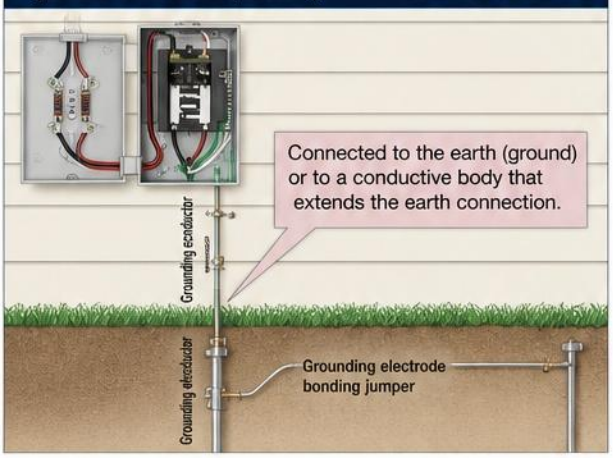


Bonding joins parts together so current can flow without interruption. This ensures electrical continuity and conductivity.

Grounded (Grounding). Connected to the earth (ground) or to a conductive body that extends the earth connection.

NEC Figure 250–4

Figure 250–4 Grounded (Grounding) NEC Article 100 Definition



Grounding connects electrical equipment to the earth or to a conductive body that extends that connection.

Figure 250–5 Ground NEC Article 100 Definition

Ground is the Earth.

Figure 250–5 Ground NEC Article 100 Definition

Ground refers to the Earth.

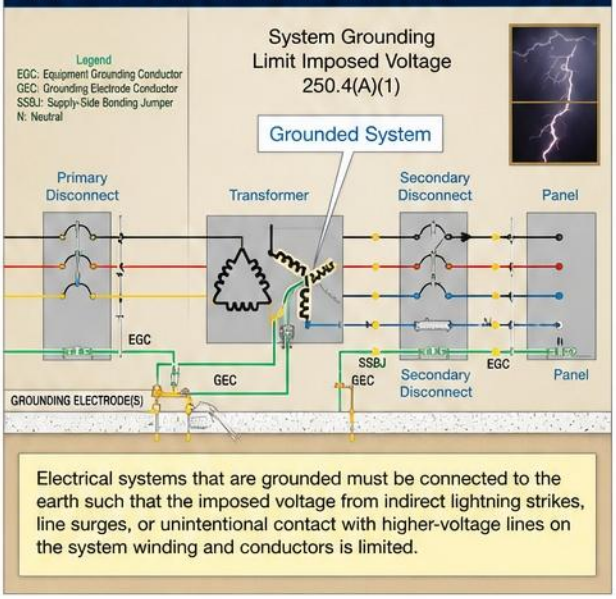
250.4 Performance Requirements for Grounding and Bonding

The following general requirements identify what grounding and bonding of electrical systems, electrical equipment, and electrically conductive materials are intended to accomplish. The prescriptive methods contained in this article must comply with the performance requirements of this section.

(A) Grounded Systems.

(1) System Grounding. Electrical systems that are grounded must be connected to the earth such that the imposed voltage from indirect lightning strikes, line surges, or unintentional contact with higher-voltage lines on the system winding and system conductors is limited. NEC Figure 250–6

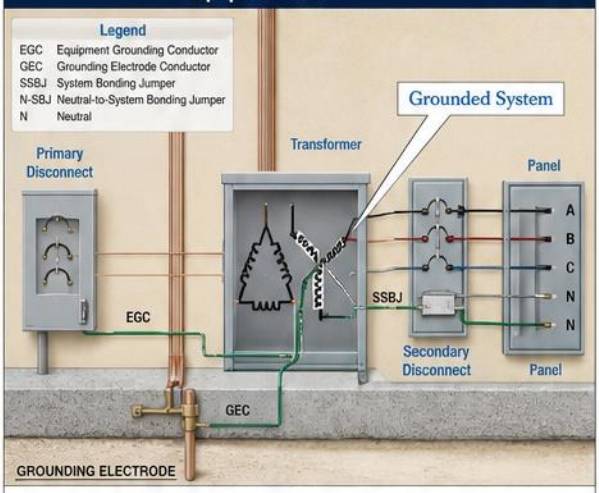
Figure 250–6 System Grounding Limit Imposed Voltage 250.4(A)(1)



Author's Comment:

- System grounding is performed at premises transformers in accordance with 250.30(A). System grounding limits imposed voltage from indirect lightning strikes, thereby ensuring longer insulation life for motors, transformers, and other electrical equipment. ▸Figure 250–7

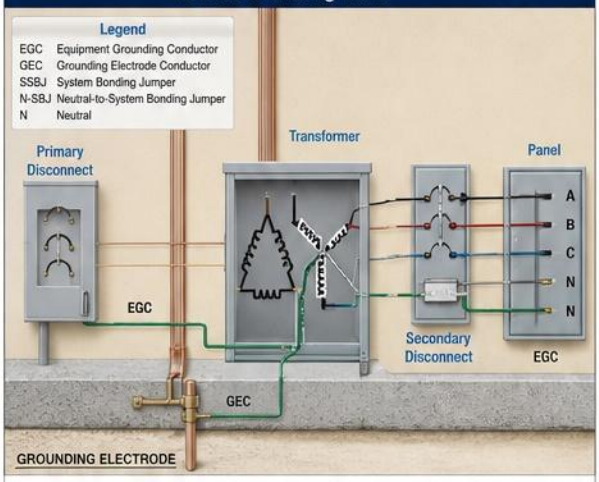
Figure 250–7 System Grounding Longer Equipment Life 250.4(A)(1) Comment



System grounding limits imposed voltage from indirect lightning strikes, thereby ensuring longer insulation life for motors, transformers, and other electrical equipment.

Note 1: To limit imposed voltage from indirect lightning strikes, the grounding electrode conductor and grounding electrode bonding jumpers should not be any longer than necessary, and unnecessary bends and loops should be avoided. ▸Figure 250–8

Figure 250–8 System Grounding Avoid Bends and Long Runs 250.4(A)(1) Note 1



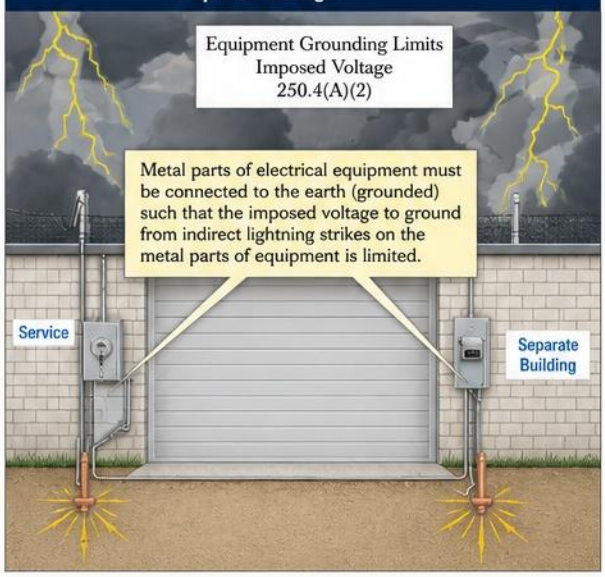
To limit imposed voltage from indirect lightning strikes, the grounding electrode conductor should not be any longer than necessary, and unnecessary bends and loops should be avoided.

Author's Comment:

- Lightning is a high-frequency event; therefore, the length and shape of the grounding electrode conductor are key factors in providing a low-impedance path to the grounding electrode.

(2) Equipment Grounding. Metal parts of electrical equipment must be connected to the earth (grounded) such that the induced voltage to ground from indirect lightning strikes on the metal parts of equipment is limited. ▸Figure 250–9

Figure 250–9 Equipment Grounding Limits Imposed Voltage 250.4(A)(2)



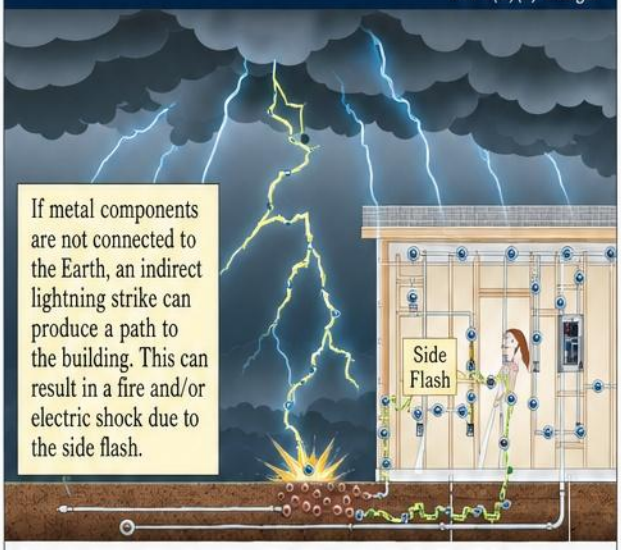
⚠ **DANGER:** Failure to ground metal parts to the earth can result in millions of volts of induced voltage on the metal parts generated by an indirect lightning strike. This energy seeks a path to the earth within the building—possibly resulting in fire or electric shock from a side flash. ▸Figure 250–10

Author's Comment:

- To reduce electric shock from induced voltage on the metal parts from indirect lightning strikes, equipment grounding is performed at:
  - Services [250.24(A)]
  - Transformers [250.30(A)]
  - Separate buildings supplied by a feeder [250.32(A)]

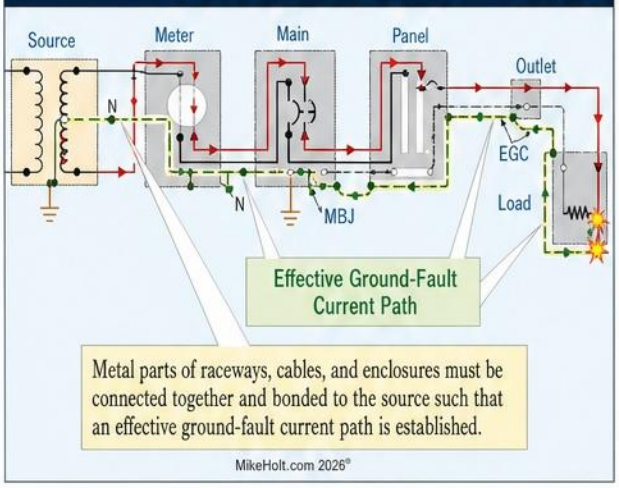
(3) Equipment Bonding. Metal parts of raceways, cables, and encosures must be connected together and bonded to the source such that an effective ground-fault current path is established. ▸Figure 250–11

Figure 250–10 | Equipment Grounding Potential Side Flash
250.4(A)(2) Danger



Failing to ground metal parts to the Earth can result in very high voltage from an indirect lightning strike seeking a path to the Earth within the building, possibly resulting in a fire and/or electric shock from a side flash.

Figure 250–11 | Equipment Bonding Effective Ground-Fault Current Path *250.4(A)(3)*

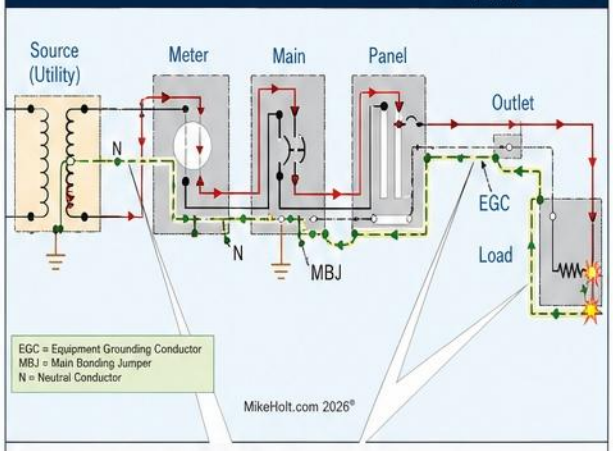


Ground-Fault Current Path, Effective Ground-Fault Current Path. An intentionally constructed low-impedance conductive path *designed to carry ground-fault current from the point of a ground fault in the wiring system to the power source to assist in opening the circuit overcurrent protective device.* 250.4(A)(2)

(4) Bonding Conductive Materials and Other Equipment. *Conductive materials such as metal piping systems and exposed structural steel that is likely to become energized must be connected together and bonded to the source such that an effective ground-fault current path is established.* 250.4(A)(4)

(5) Effective Ground-Fault Current Path.

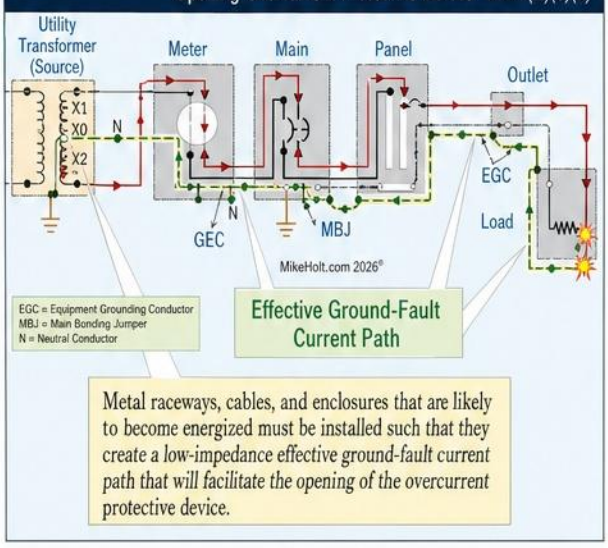
Figure 250–12 | Effective Ground-Fault Current Path
250.4(A)(2) Definition



An intentionally constructed low-impedance conductive path designed to carry ground-fault current from the point of a ground fault in the wiring system to the power source to assist opening the circuit overcurrent protective device.

(a) Opening Overcurrent Protective Device. Metal raceways, cables, and enclosures that are likely to become energized must be installed such that they create a low-impedance effective ground-fault current path that will facilitate the opening of the overcurrent protective device. *250.4(A)(5)(a)*

Figure 250–13 | Effective Ground-Fault Current Paths Opening Overcurrent Protective Device *250.4(A)(5)(a)*



(b) Carrying Ground-Fault Current. The effective ground-fault current path must be capable of carrying the ground-fault current from any point on the wiring system to the source. 250.4(A)(5)(b)

Figure 250–14 Effective Ground-Fault Current Path Carrying Ground-Fault Current *250.4(A)(5)(b)*

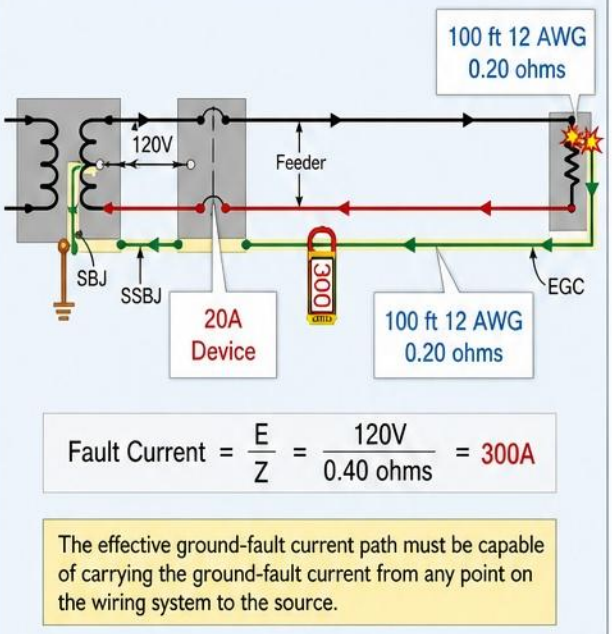
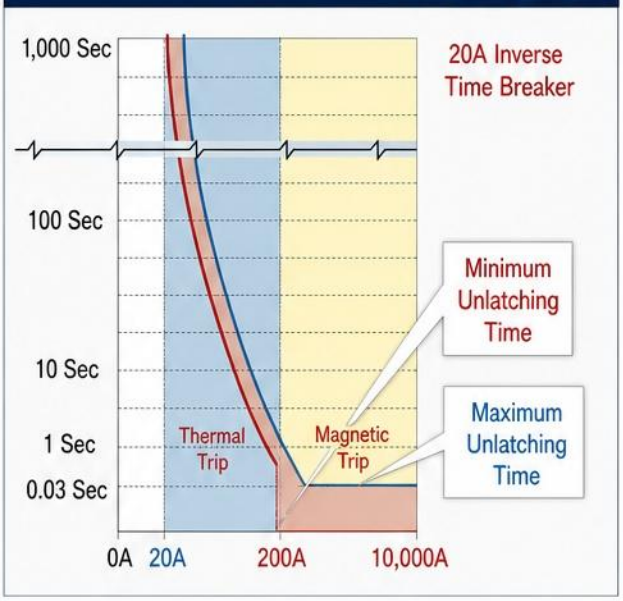


Figure 250–15 Effective Ground-Fault Current Path Time-Current Curve, 20A Inverse Time Breaker *250.4(A)(5)(b) Comment*



The time it takes for an overcurrent protective device to open depends on the magnitude of the fault current.

AUTHOR'S COMMENT:

- The purpose of the effective ground-fault current path is to quickly remove dangerous voltage on metal parts from a ground fault. The effective ground-fault current path must have sufficiently low impedance to the source so that the fault current will quickly rise to a level that will open the circuit overcurrent protective device.

- The time it takes for an overcurrent protective device to open is dependent on the magnitude of the fault current. A higher fault current value will result in a shorter clearing time for the overcurrent protective device. For example, a 20A overcurrent protective device with an overload of 40A (two times the 20A rating) takes 25 to 150 seconds to open. The same device at 100A (five times the 20A rating) trips in 5 to 20 seconds. All brands of breakers have their own and specific time trip curves. See **Figure 250–15**.

(c) Use of Earth. The earth cannot serve as an effective ground-fault current path. **See Figure 250–16.**

Figure 250–16 Earth Not Suitable as Effective Ground-Fault Current Path *250.4(A)(5)(c)*

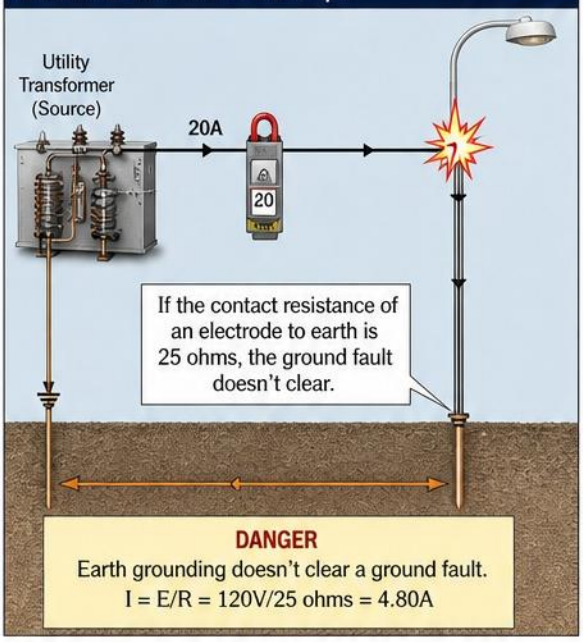
The earth cannot serve as an effective ground-fault current path.

▶ Earth Not Suitable as EGFCP [250.4(A)(5)(c)] Example

Question: *What will the maximum fault current be when there is a 120V ground fault to the metal parts of a light pole (that is grounded to a 25Ω ground rod), but not bonded to an effective ground-fault current path?* ▶ Figure 250–17

(a) 3.70A *(b) 4.80A* *(c) 5.20A* *(d) 6.40A*

Figure 250–17 Earth Not Suitable as Effective Ground-Fault Current Path Example 250.4(A)(5)(c)



If the electrode-to-earth contact resistance is 25 ohms, the ground fault will not clear.

Solution:

I = Volts/Resistance

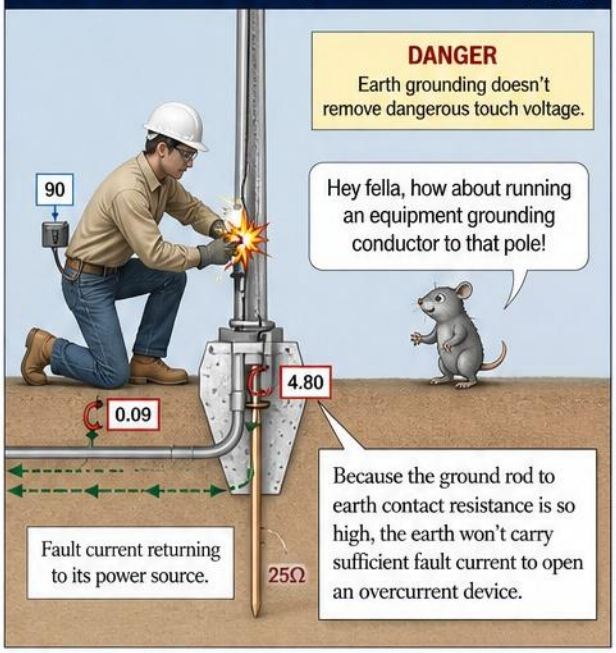
I = 120V/25Ω

I = 4.80A

Answer: *(b) 4.80A*

DANGER: Using the earth as an effective ground-fault current path does not remove dangerous touch voltage because the fault return path is so high, that little fault current returns to the source. As a result, the circuit overcurrent protective device will not open, and metal parts associated with the electrical installation, metal piping, and structural building steel will become—and remain—energized. ▶ Figure 250–18

Figure 250–18 Earth Not Suitable as Effective Ground-Fault Current Path Example 250.4(A)(5)(c)



High ground-rod contact resistance prevents enough fault current from flowing to trip an overcurrent device.

Earth Shells

According to *ANSI/IEEE 142, Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book) [4.1.1]*, the resistance of the soil outward from a 10-ft ground rod is equal to the sum of the series resistances of the earth shells. The shell nearest the ground rod has the highest resistance, and each shell further out has progressively larger areas and lower resistances. Do not be concerned if you do not understand this statement; just review the table below.

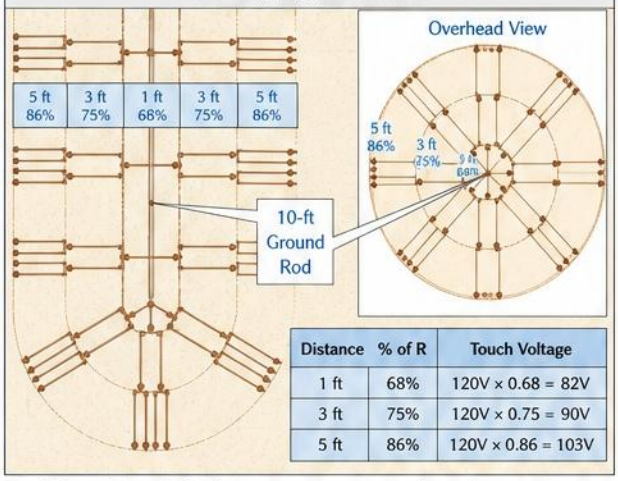
Distance from Rod	Soil Contact Resistance
1 ft (Shell 1)	68% of Total Contact Resistance
3 ft (Shells 1 and 2)	75% of Total Contact Resistance
5 ft (Shells 1, 2, and 3)	86% of Total Contact Resistance

Contact Resistance. The earth is an excellent conductor due to an almost limitless number of parallel paths over which electrons can flow. However, the problem lies in the contact resistance between the grounding electrode and the earth. The surface area of the electrode contacting the earth is minimal compared to the earth itself.

Since voltage is directly proportional to resistance (Ohm's Law), the voltage gradient of the earth around an energized rod (assuming a 120V ground fault) will be as follows: ▶ Figure 250–19 and ▶ Figure 250–20

Figure 250–19 250.4(A)(5)(c)

Earth Not Suitable as Effective Ground-Fault Current Path
Contact Resistance
250.4(A)(5)(c) Comment

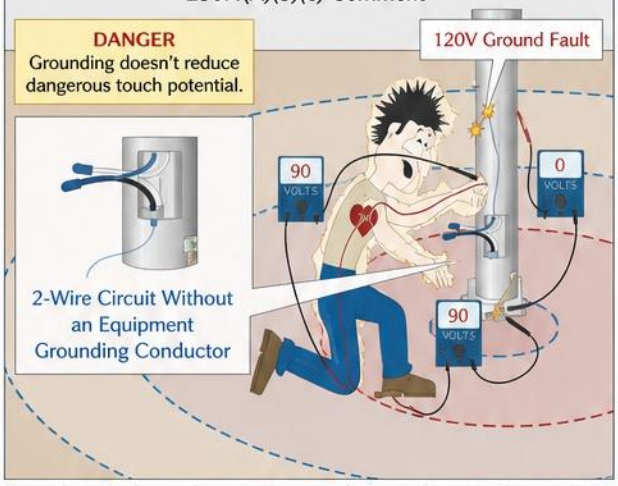


Distance	% of R	Touch Voltage
1 ft	68%	120V × 0.68 = 82V
3 ft	75%	120V × 0.75 = 90V
5 ft	86%	120V × 0.86 = 103V

Earth has relatively high resistance compared to a low-resistance conductor, resulting in elevated touch voltages relative to the faulted point.

Figure 250–20 250.4(A)(5)(c) Comment

Earth Not Suitable as Effective Ground-Fault Current Path
Earth Voltage Gradient
250.4(A)(5)(c) Comment



Even though the equipment is grounded, a voltage gradient exists in the surrounding earth. This condition can result in dangerous touch voltages.

Figure 250–20 (Table) 250.4(A)(5)(c) Comment

Distance from Rod	Soil Contact Resistance	Voltage Gradient
1 ft (Shell 1)	68%	82V
3 ft (Shells 1 and 2)	75%	90V
5 ft (Shells 1, 2, and 3)	86%	103V

Resistance and voltage gradient values increase with distance from the ground rod because the earth is not an effective conductor.

250.6 OBJECTIONABLE CURRENT (GROUND LOOP)

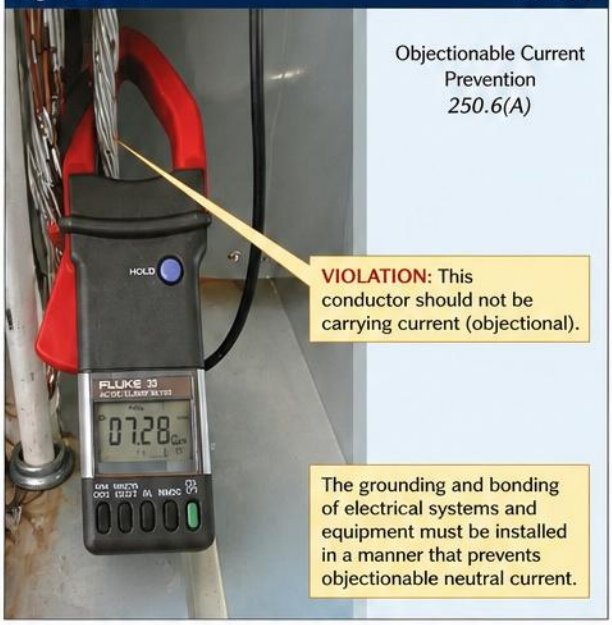
Author's Comment:

According to IEEE 1100 Recommended Practice for Powering and Grounding Electronic Equipment, Section 2.2.33, a ground loop is defined as a potentially detrimental loop formed when two or more points in an electrical system that are nominally at ground potential are connected by a conducting path such that either or both points are not at the same ground potential.

(A) Arranged to Prevent Objectionable Current. The grounding and bonding of electrical systems and equipment must be installed in a manner that prevents objectionable neutral current as determined by the AHJ.

250–21

Figure 250–21 250.6(A)



A current on this bonding conductor indicates that the installation does not comply with 250.6(A).

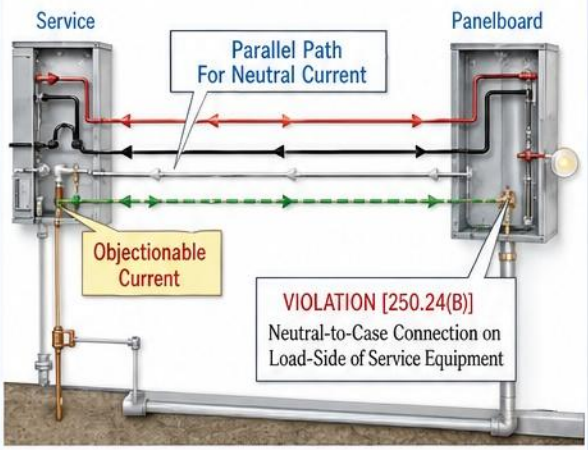
(C) Currents Not Classified as Objectionable Currents. Currents resulting from abnormal conditions such as ground faults, and from currents resulting from required grounding and bonding connections are not classified as objectionable current.

Objectionable Neutral Currents

An objectionable neutral current exists when improper neutral-to-case connections or wiring errors cause a violation of 250.24(B).

Panelboards. Objectionable neutral current will flow on metal parts and the equipment grounding conductor whenever the neutral conductor is connected to the metal case of a panelboard on the load side of the service equipment in violation of 250.24(B).

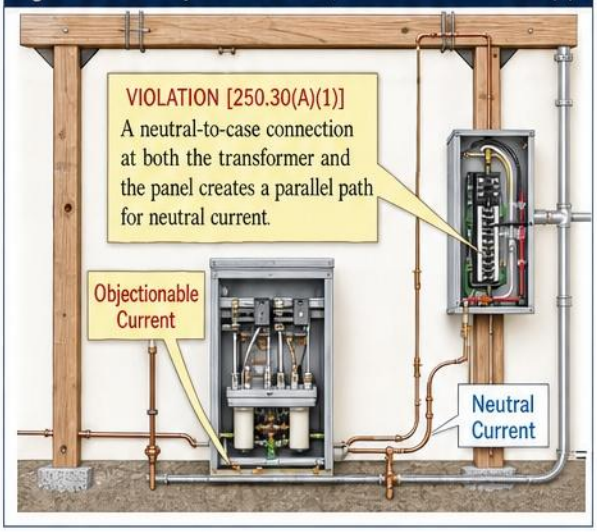
Figure 250–22 Objectionable Current, Panelboards **250.6(A)**



A neutral-to-case connection at both the service disconnect enclosure and a load-side panelboard creates parallel paths for neutral current.

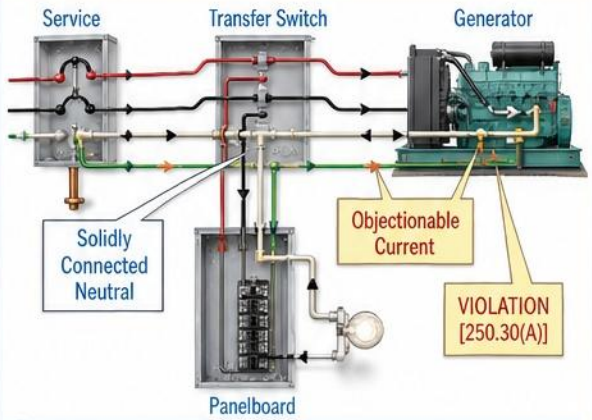
Transformers. Objectionable neutral current will flow on metal parts if the neutral conductor is connected to the circuit equipment grounding conductor at both the transformer and any other location on the load side of the system bonding jumper in violation of 250.30(A)(1).

Figure 250–23 Objectionable Current, Transformers **250.6(A)**



Generators. Objectionable neutral current will flow on metal parts and the equipment grounding conductor if a generator is connected to a transfer switch with a solidly-connected neutral, and a neutral-to-case connection is made at the generator in violation of 250.30(A).

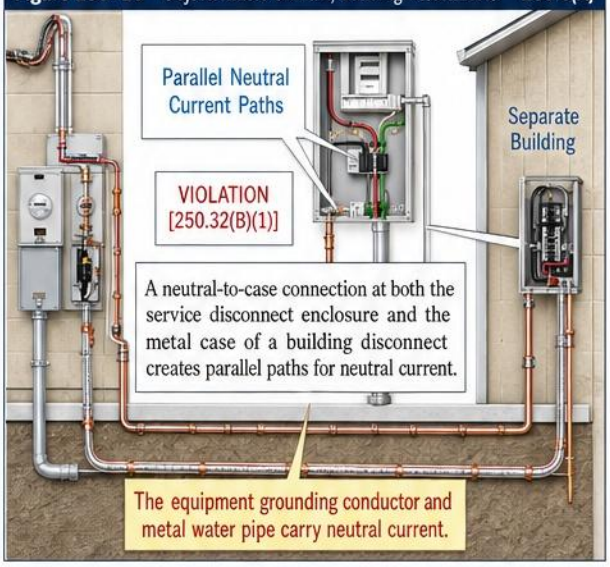
Figure 250–24 Objectionable Current, Generators **250.6(A)**



A neutral-to-case connection at both the service disconnect enclosure and the metal case of a generator connected to a transfer switch with a solidly-connected neutral, creates a parallel path for neutral current.

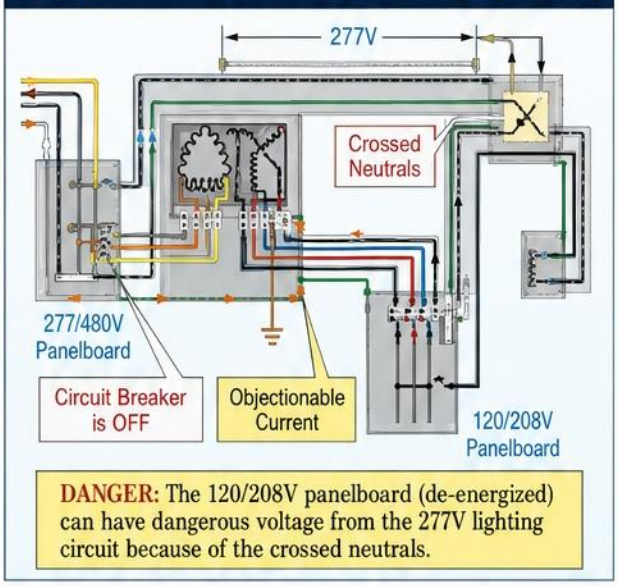
Building Disconnects. Objectionable neutral current will flow on metal parts and the equipment grounding conductor if the neutral conductor is connected to the metal case of a building disconnect that is not part of the service disconnect in violation of 250.32(B)(1).

Figure 250–25 Objectionable Current, Building Disconnects **250.6(A)**



Neutral Wiring Errors. Objectionable neutral current will flow on metal parts and equipment grounding conductors if the neutral conductor from one system is used as the neutral conductor for a different system.

Figure 250–26 Objectionable Current Neutral Wiring Error 250.6(A)

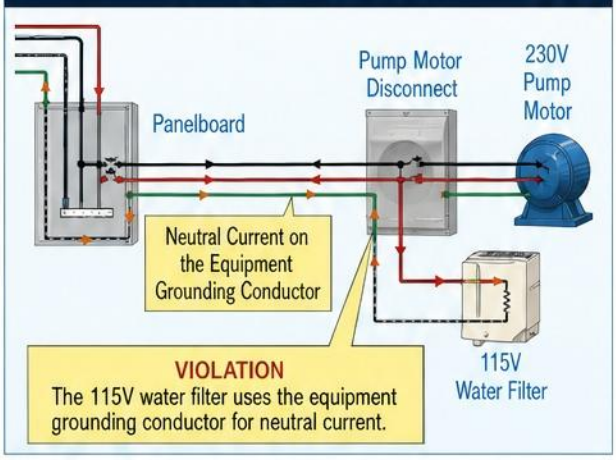


A neutral wiring mistake that causes objectionable current. If the circuit equipment grounding conductor is connected and used as a neutral conductor, objectionable neutral current can flow on the equipment grounding conductor.

Improper Wiring. Objectionable neutral current will flow on the equipment grounding conductor if the circuit equipment grounding conductor is used as a neutral conductor.

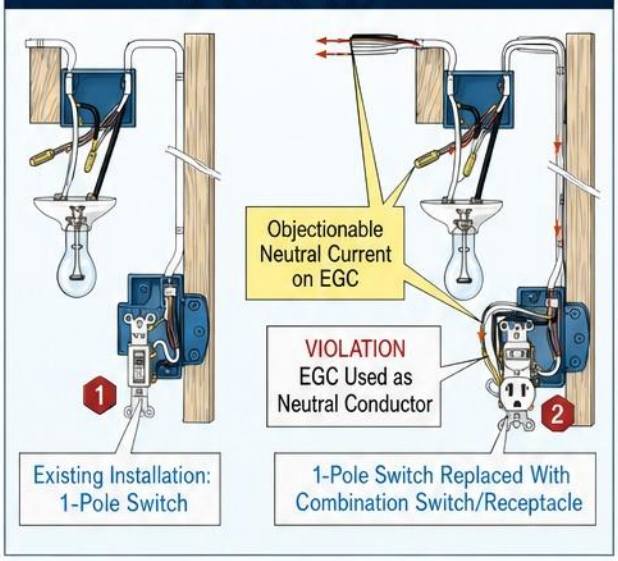
- A 230V time-clock motor is replaced with a 115V time-clock motor, and the circuit equipment grounding conductor is used for neutral return current.
- A 115V water filter is wired to a 240V well-pump motor circuit, and the circuit equipment grounding conductor is used for neutral return current. (See Figure 250–27.)

Figure 250–27 *Objectionable Current, Improper Wiring EGC as the Neutral Conductor* 250.6(A)



Using the circuit equipment grounding conductor as a neutral return path can create objectionable neutral current. (See Figure 250–28.)

Figure 250–28 Objectionable Current, Improper Wiring EGC as Neutral Conductor 250.6(A)

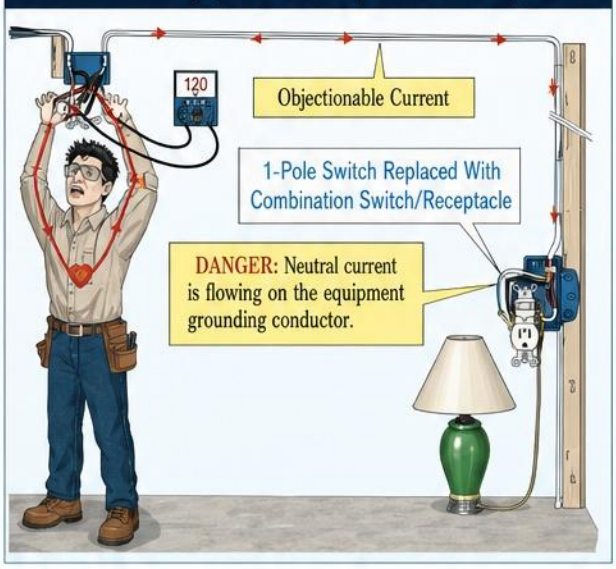


Using an equipment grounding conductor (EGC) as a neutral conductor can result in objectionable neutral current flowing on the EGC.

Dangers of Objectionable Current

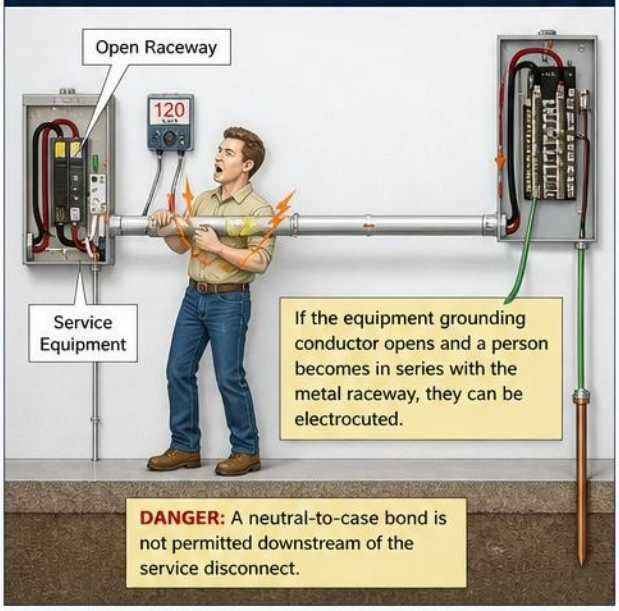
Shock Hazard. When objectionable neutral current flows on metal parts or the equipment grounding conductor, electric shock—and even death—can occur if the neutral conductor is compromised. (See Figure 250–29 and Figure 250–30.)

Figure 250–29 Objectionable Current, Shock Hazard Equipment Grounding Conductor 250.6(A) *DANGER*



Objectionable neutral current on the equipment grounding conductor creates a shock hazard to anyone who contacts metal parts or the EGC.

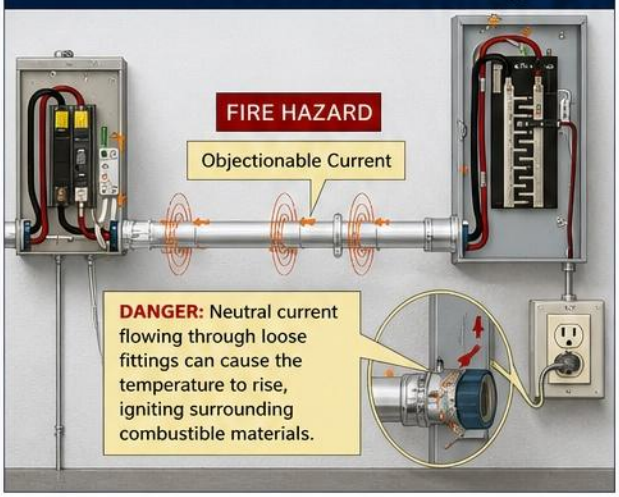
Figure 250–30 Objectionable Current, Shock Hazard 250.6(A)



Fire Hazard. When objectionable neutral current flows on metal parts, a fire can ignite adjacent combustible material. Heat is generated whenever current flows, particularly over high-resistance parts. In addition, arcing at loose connections is especially dangerous in areas containing easily ignitable and explosive gases, vapors, or dust.

▸ Figure 250–31

Figure 250–31 Objectionable Current, Shock Hazard Neutral Current on Metal Parts 250.6(A) *HAZARD*



Operation of Overcurrent Protective Devices. When objectionable neutral current travels on metal parts, electronic overcurrent protective devices equipped with ground-fault protection can trip. This is because some neutral current flows on the circuit equipment grounding conductor instead of on the neutral conductor.

250.8 Connection of Grounding and Bonding Conductors and Terminals

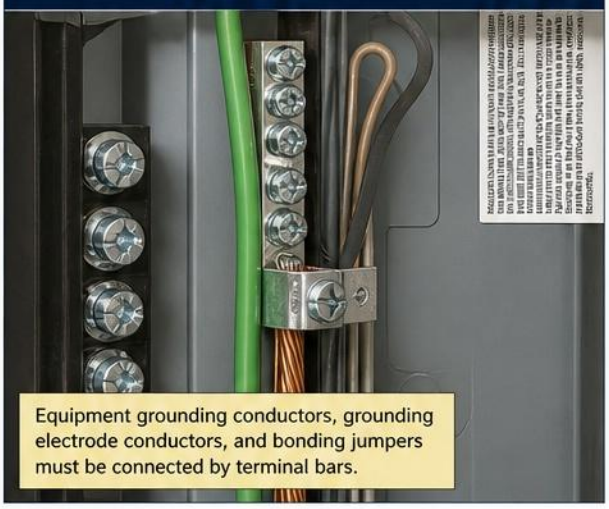
(A) Permitted Methods. Equipment grounding conductors, grounding electrode conductors, bonding jumpers, and grounding and bonding terminations must be connected by one or more of the following methods:

(1) Listed pressure connectors ▸ Figure 250–32

Figure 250–32 Connection of Grounding and Bonding Conductors Listed Pressure Connectors 250.8(A)(1)

(2) Terminal bars ▸ Figure 250–33

Figure 250–33 Connection of Grounding and Bonding Conductors Terminal Bars 250.8(A)(2)



(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) Thread-forming machine screws that engage at least two threads in the enclosure ▶ NEC Figure 250–34

Figure 250–34 Connection of Grounding and Bonding Terminals Using Thread-Forming Machine Screws *NEC 250.8(A)(6)*

Equipment grounding and bonding terminations must be connected by thread-forming machine screws that engage at least two threads in the enclosure.

(7) Connections that are part of a listed assembly

(8) Other listed means

250.10 Protection of Ground Clamps and Fittings

Ground clamps and fittings must be protected from physical damage as determined by the AHJ. ▶ NEC Figure 250–35

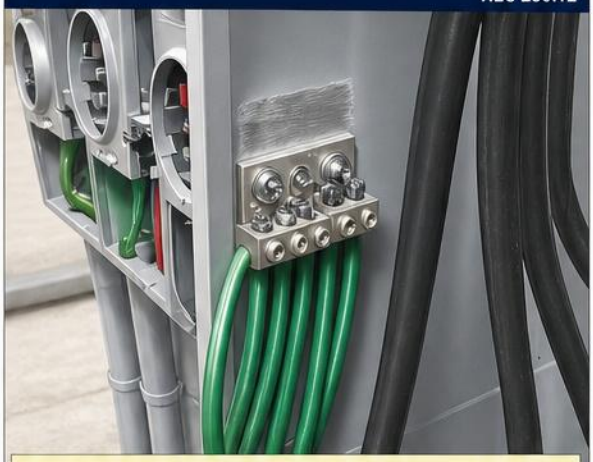
Figure 250–35 Ground Clamps and Fittings Protection from Physical Damage *NEC 250.10*

Ground clamps and ground fittings must be protected from physical damage.

250.12 Clean Surfaces

Nonconductive coatings (such as paint) on equipment must be removed to ensure electrical continuity, or the termination fittings must be designed to make such removal unnecessary. ▶ NEC Figure 250–36

Figure 250–36 Grounding and Bonding Clean Surfaces *NEC 250.12*



Nonconductive coatings (such as paint) on equipment must be removed to ensure electrical continuity, or the termination fittings must be designed to make such removal unnecessary.

Author's Comment:

- Fittings (such as locknuts) are designed to cut through nonconductive coatings and establish the intended electrical continuity when they are properly installed.
- The tarnish on copper water pipe need not be removed before making a termination because copper-oxide does not interfere with conductivity.

Part II. System Grounding and Bonding

250.20 Systems Required to be Grounded

(A) Systems Below 50V. The secondary of a transformer operating below 50V is not required to be grounded unless the transformer's primary supply is from:

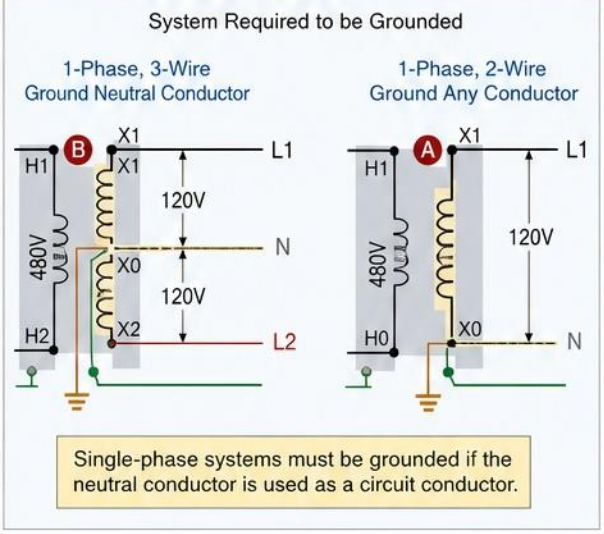
(1) System exceeding 150V to ground (277V or 480V system)

(2) Ungrounded system

(B) Systems 50V to 1000V. The following systems must be grounded if the neutral conductor is used as a circuit conductor:

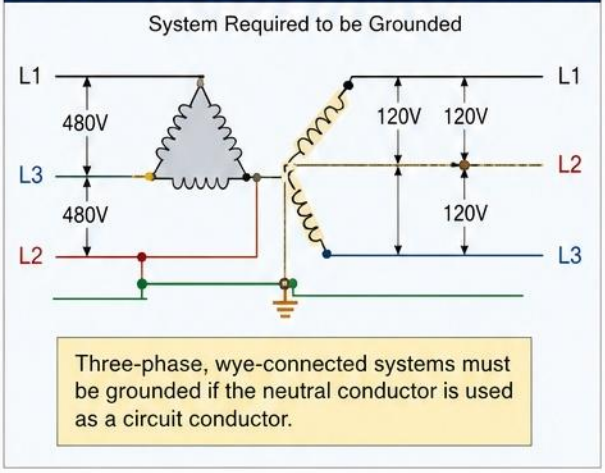
(1) Single-phase systems ▶ NEC Figure 250–37

Figure 250–37 Single-Phase Systems 250.20(B)(1)



(2) Three-phase, wye-connected systems

Figure 250–38 Three-Phase, Wye-Connected Systems 250.20(B)(2)



(3) Three-phase, high-leg delta-connected systems (See Figure 250–39.)

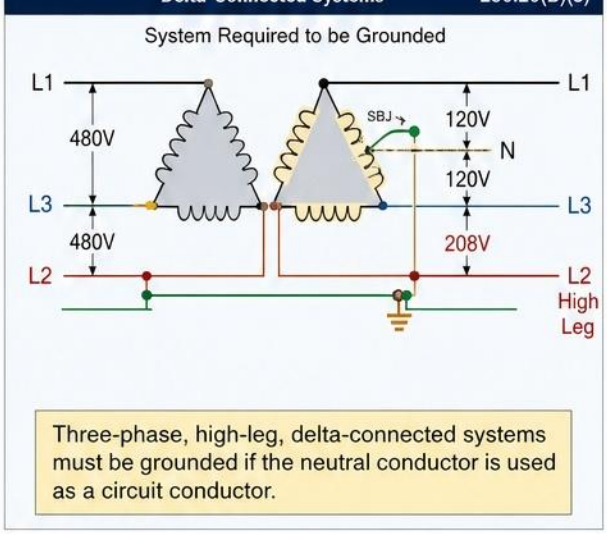
Author's Comment:

- Grounding of these systems must comply with 250.30(A).

250.24 Service Grounding

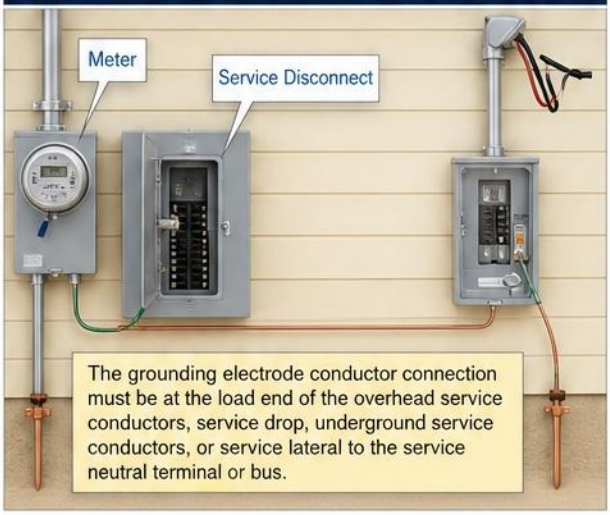
(A) Service Equipment, Grounding. Services must have a grounding electrode conductor connected to the service neutral conductor in accordance with the following:

Figure 250–39 Three-Phase, High-Leg, Delta-Connected Systems 250.20(B)(3)



(1) General. The grounding electrode conductor connection to the neutral conductor for a service must be made at the load end of the customer overhead service conductors, utility service-drop conductors, customer underground service conductors, or utility service lateral to the terminal/bus to which the service neutral conductor is connected at the service disconnect. (See Figure 250–40.)

Figure 250–40 Service Equipment, Grounding Electrode Conductor Connection 250.24(A)(1)

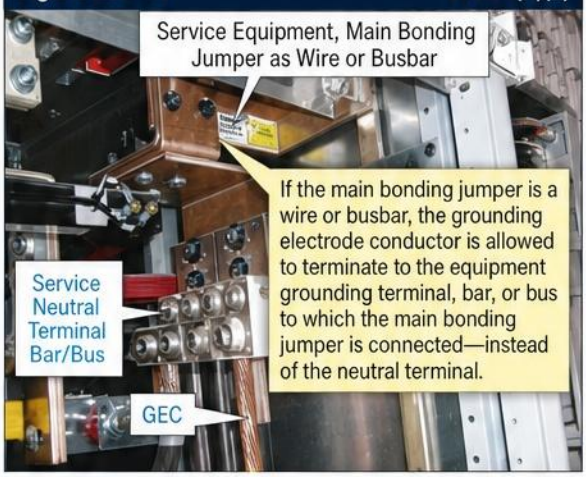


Author's Comment:

- Some inspectors require the grounding electrode conductor connection to the service neutral conductor to be made at the meter socket enclosure. Others insist the connection be made only within the service disconnect. The connection of the grounding electrode conductor at either location complies with this rule, but be sure you know the local utility company's policy on connections inside the meter socket.

(4) Service Equipment, Main Bonding Jumper. If the main bonding jumper specified in 250.28 is a wire or busbar, the grounding electrode conductor is allowed to be connected to the equipment grounding terminal, bar, or bus to which the main bonding jumper is connected—in place of the neutral terminal.

Figure 250–41 250.24(A)(4)

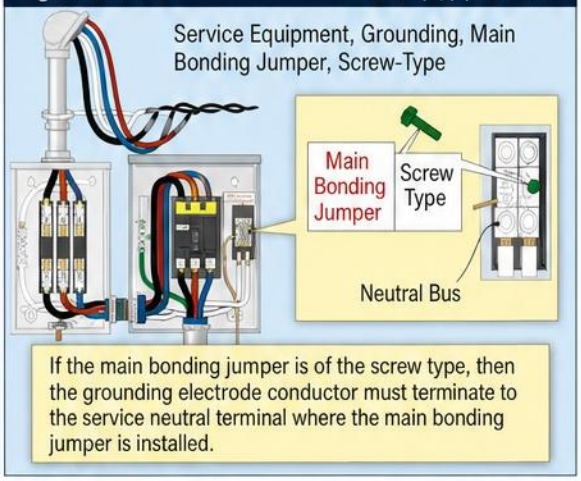


Permitted connection of the grounding electrode conductor when the main bonding jumper is a wire or busbar.

Author's Comment:

- When the main bonding jumper is the screw type, the grounding electrode conductor must terminate to the service neutral terminal where the main bonding jumper *is installed.* **250.24(A)(4)**

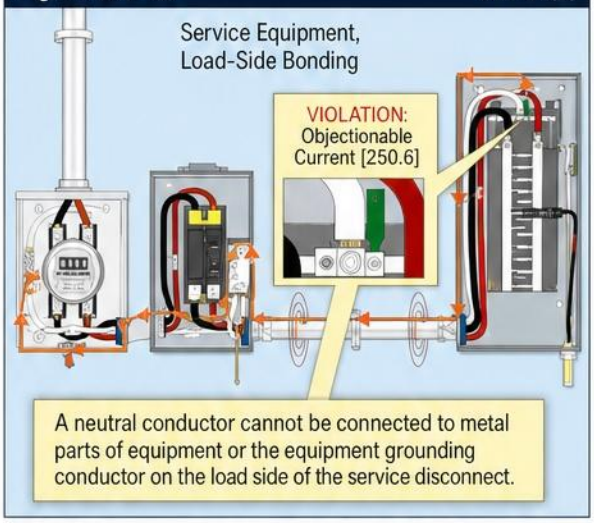
Figure 250–42 250.24(A)(4) Comment



Required connection of the grounding electrode conductor when the main bonding jumper is the screw type.

(B) Load-Side Bonding Connections. A neutral conductor cannot be connected to metal parts of equipment or the *equipment grounding conductor(s)* on the load side of the service disconnect. **250.24(B)**

Figure 250–43 250.24(B)

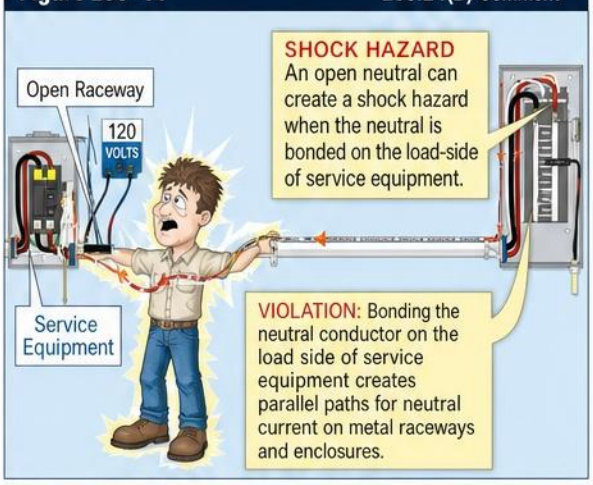


Neutral-to-case connection on the load side of the service disconnect is not allowed.

Author's Comment:

- If a neutral-to-case connection is made on the load side of the service disconnect, objectionable neutral current will flow on conductive metal parts of electrical equipment [250.6(A)]. Objectionable neutral current on metal parts of electrical equipment can be extremely dangerous. **250.24(B)**

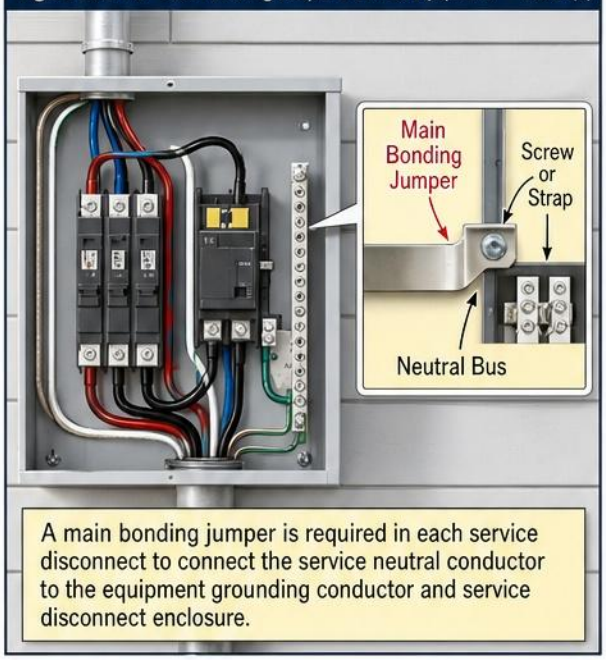
Figure 250–44 250.24(B) Comment



Neutral bonding on the load side can create hazardous shock conditions due to parallel neutral current paths.

(C) Main Bonding Jumper. A main bonding jumper is required in each service disconnect to connect the service neutral conductor to the equipment grounding conductor and service disconnect enclosure in accordance with 250.28. Figure 250–45

Figure 250–45 Main Bonding Jumper in Service Equipment 250.24(C)



Author's Comment:

- The main bonding jumper is a vital component of the effective ground-fault current path. It facilitates the operation of overcurrent protective devices and is a critical part of the grounding system. It bonds the neutral conductor, service enclosure, and equipment grounding conductor to the grounding electrode system via the grounding electrode conductor.

(D) Neutral Conductor Brought to Service Equipment. A service neutral conductor must be brought to each service and connected to the neutral terminal or bus at each service disconnect enclosure. Figure 250–46 and Figure 250–47

DANGER: If the service neutral is opened, dangerous voltage may be present on metal parts under normal conditions, resulting in the potential for electric shock. Figure 250–48

Figure 250–46 Service Equipment Neutral Conductor Required 250.24(D)

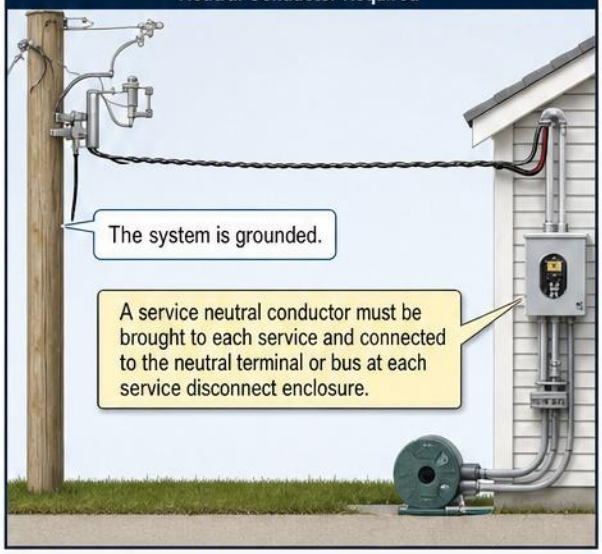


Figure 250–47 Service Equipment Neutral Conductor Required 250.24(D)

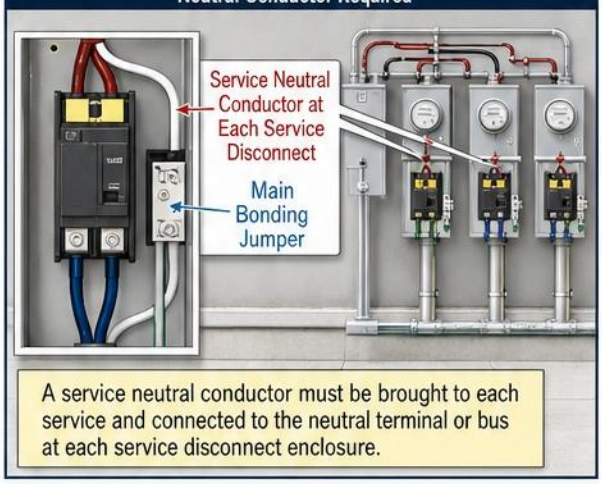
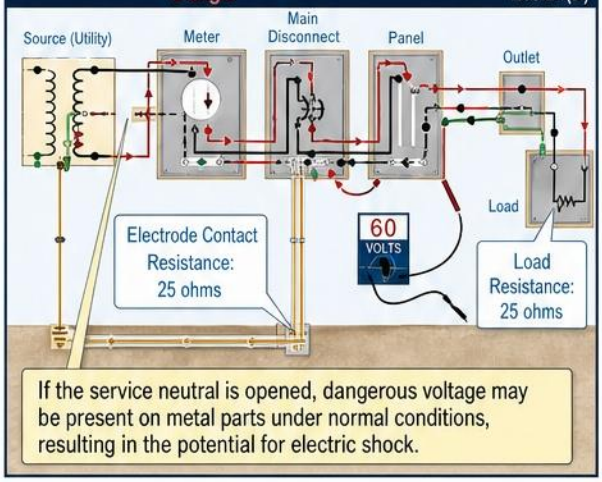
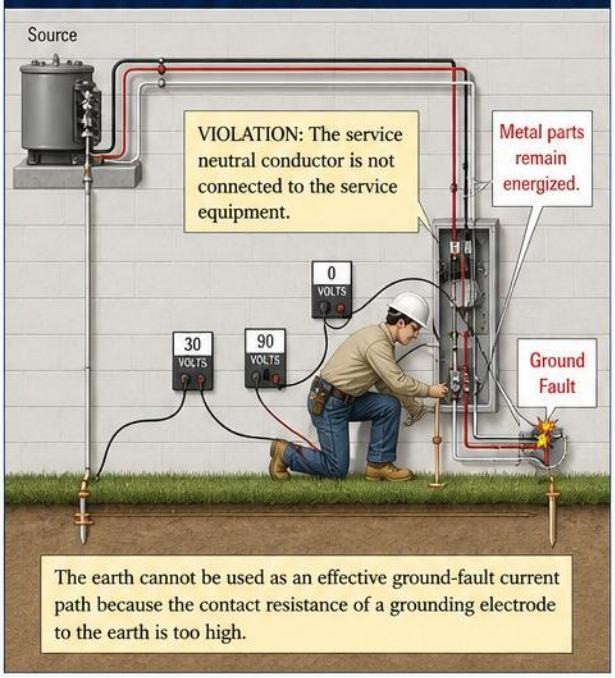


Figure 250–48 Service Equipment, Open Neutral Conductor *Danger* 250.24(D)



DANGER: Hazardous voltage from a ground fault will remain metal parts, metal piping, and structural steel unless they are removed from the service neutral conductor. If the service disconnect enclosure is not bonded to the service neutral conductor, the low resistance of the grounding electrode to earth can cause enough ground-fault current to return through the source to make the only available ground-fault current return path sufficient to trip the circuit overcurrent protective device. See Figure 250–49.

Figure 250–49 **250.24(D)**
Service Equipment—Open Neutral Conductor **Danger**

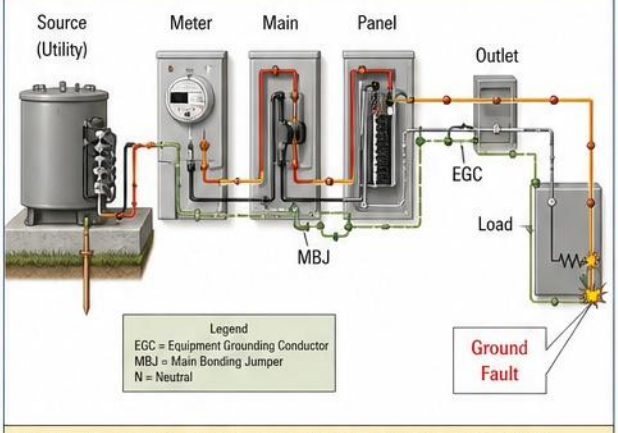


Author's Comment:

- A neutral conductor must be routed with the phase conductors and connected to the neutral conductor terminal or bus at each service disconnect enclosure—regardless of whether line-to-neutral loads are supplied.
- The service neutral conductor provides the effective ground-fault current path to the source to remove hazardous voltage from a ground fault by opening the circuit overcurrent protective device [250.4(A)(3) and 250.4(A)(5)]. See Figure 250–50.

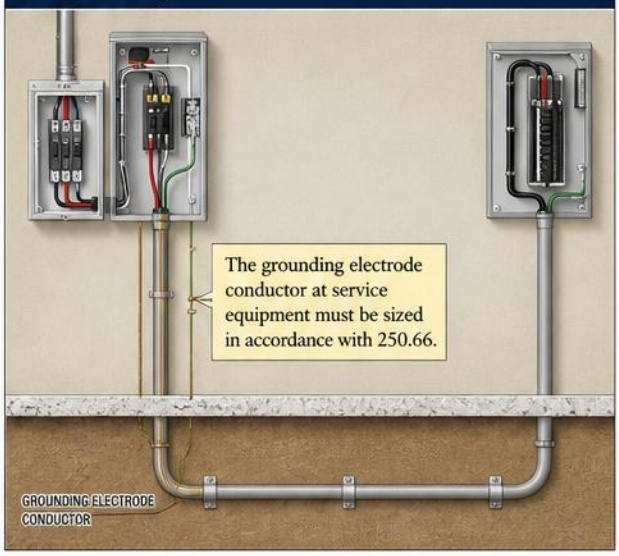
(E) Grounding Electrode Conductor. The grounding electrode conductor at service equipment must be sized in accordance with 250.66. See Figure 250–51.

Figure 250–50 **250.24(D)**
Service Equipment—Neutral Conductor Required **Comment**



The service neutral conductor provides the effective ground-fault current path to the source to remove hazardous voltage from a ground fault by opening the circuit overcurrent protective device.

Figure 250–51 **250.24(E)**
Service Equipment—Grounding Electrode Conductor Sizing



250.25 Grounding of Systems on the Supply Side of the Service Disconnect

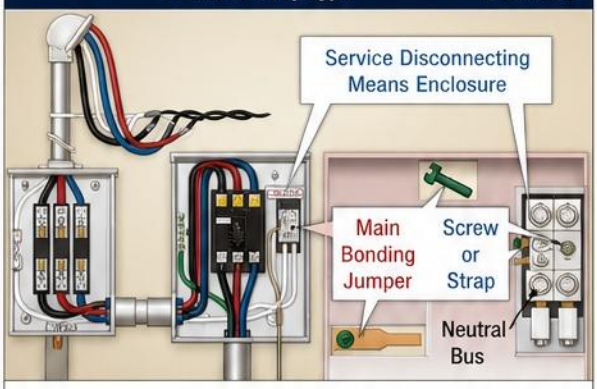
The grounding of systems connected on the supply side of the service disconnect as permitted in 230.82 must be in accordance with 250.24.

250.28 Main Bonding Jumper and System Bonding Jumper

Main bonding jumpers and *system bonding jumpers* must be as follows:

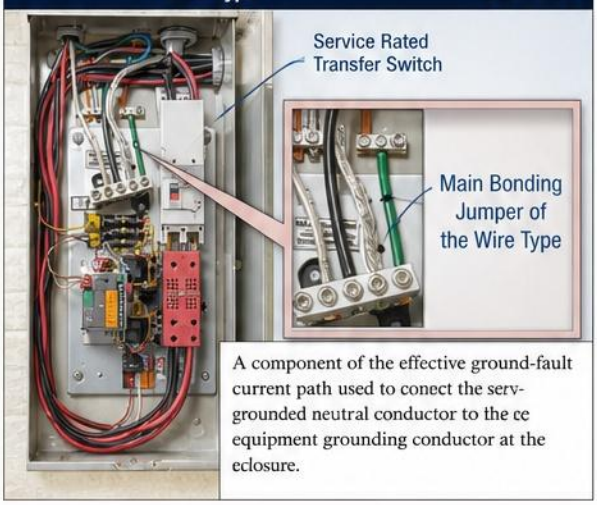
Bonding Jumper, Main Bonding Jumper. A component of the effective ground-fault current path used to connect the service grounded neutral conductor to the equipment grounding conductor, supply-side bonding conductor, or both at the service equipment enclosure. **Figure 250–52**, **Figure 250–53**, and **Figure 250–54**.

Figure 250–52 Main Bonding Jumper Screw or Strap Type *Article 100 Definition*



A component of the effective ground-fault current path used to connect the service grounded neutral conductor to the equipment grounding conductor at the service equipment enclosure.

Figure 250–53 Main Bonding Jumper Wire-Type *Article 100 Definition*



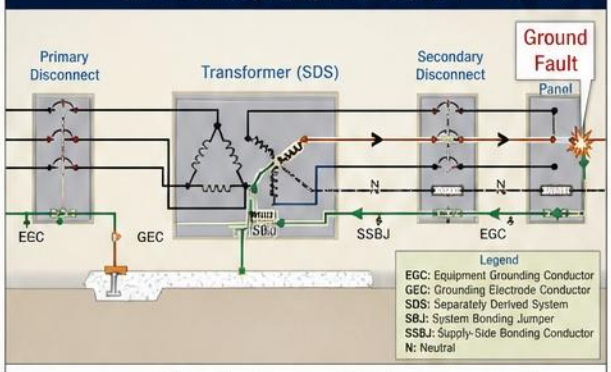
A component of the effective ground-fault current path used to conect the serv- grounded neutral conductor to the ce equipment grounding conductor at the eclosure.

Bonding Jumper, System Bonding Jumper. A component of the effective ground-fault current path that is the connection between the grounded neutral conductor or grounded-phase conductor and the supply-side bonding conductor, equipment grounding conductor, or both at a separately derived system. **Figure 250–55** and **Figure 250–56**

Figure 250–54 Main Bonding Jumper Busbar Type *Article 100 Definition*

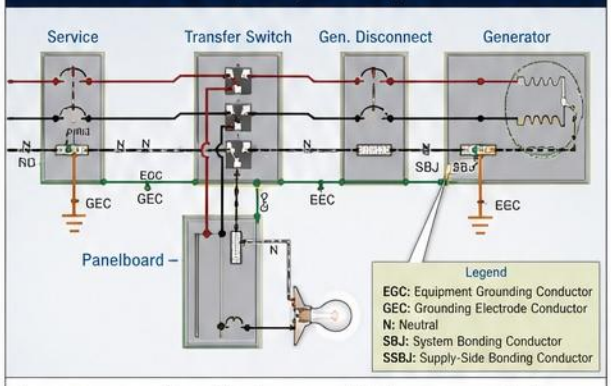
A component of the effective ground-fault current path used to connect the service grounded neutral conductor to the equipment grounding conductor at the service equipment enclosure.

Figure 250–55 System Bonding Jumper Transformer Separately Derived System *Article 100 Definition*



A component of the effective ground-fault current path that is the connection between the grounded neutral conductor and the equipment grounding conductor at a separately derived system.

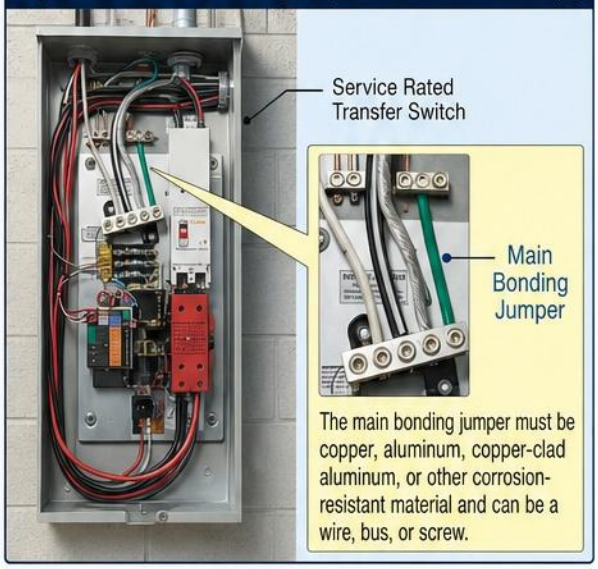
Figure 250–56 System Bonding Jumper Generator Separately Derived System *Article 100 Definition*



A component of the effective ground-fault current path that is the connection between the grounded neutral conductor and the equipment grounding conductor at a separately derived system.

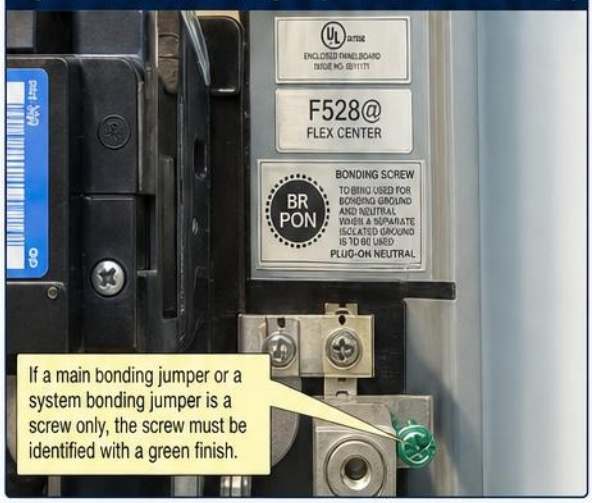
(A) Material. The bonding jumper must be copper, aluminum, copper-clad aluminum, or another corrosion-resistant material and can be a screw, bus, or wire. See ▶Figure 250–57

Figure 250–57 – Main Bonding Jumper Material **250.28(A)**



(B) Construction. If a main bonding jumper or a system bonding jumper is a screw only, the screw must be identified with a green finish. See ▶Figure 250–58

Figure 250–58 – Main Bonding Jumper Construction **250.28(B)**



(D) Size.

(1) Main and system wire-type bonding jumpers must not be sized smaller than specified in Table 250.102(C)(1). See ▶Figure 250–59 and ▶Figure 250–60

Figure 250–59 – Main Bonding Jumper Wire-Type Sizing **250.28(D)(1)**

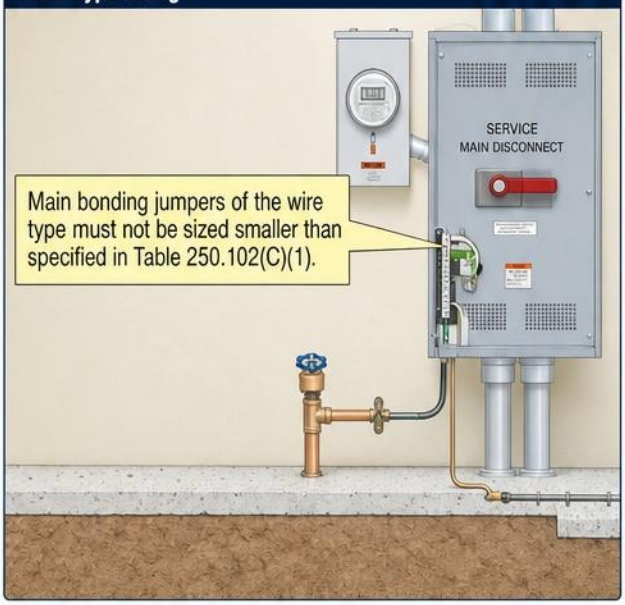
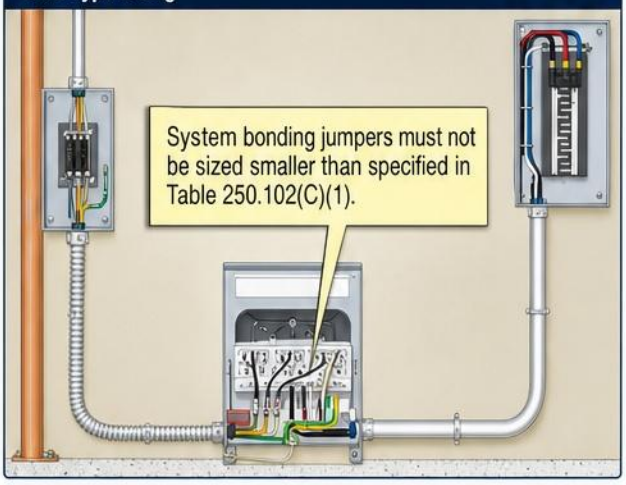


Figure 250–60 – System Bonding Jumper Wire-Type Sizing **250.28(D)(1)**

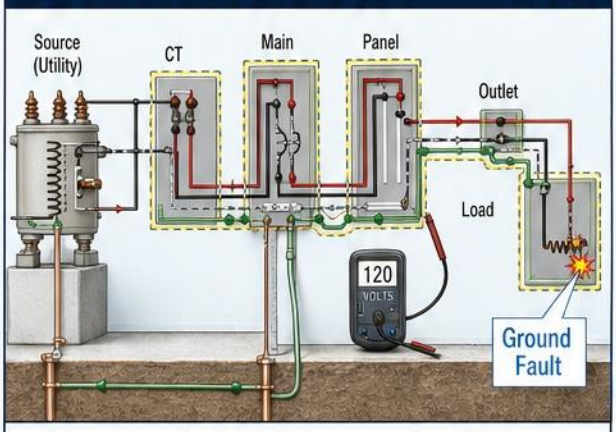


Author's Comment:

- The primary purpose of the main and system bonding jumpers is to create a path for fault current to flow from a fault to the source to open the circuit overcurrent protective device.

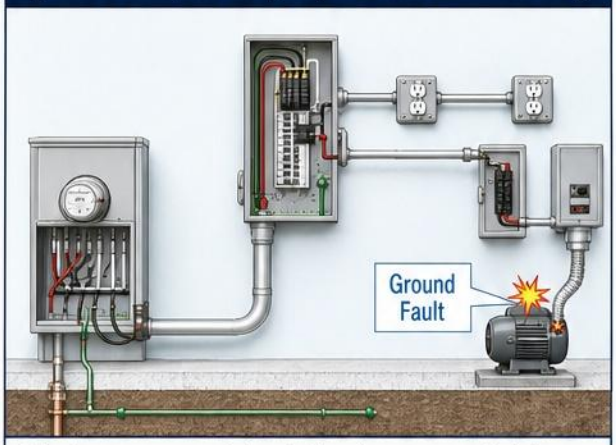
DANGER: Metal parts of electrical equipment, as well as metal piping and structural steel, will become and remain energized with dangerous voltage from a ground fault if a main bonding jumper or system bonding jumper is not installed. A missing main or system bonding jumper causes an opening in the effective ground-fault current path back to the source and creates a condition where overcurrent protective devices will not open during a ground-fault condition.
See ▶Figure 250–61 and ▶Figure 250–62

Figure 250–61 *Main Bonding Jumper Not Installed* *250.28 Danger*



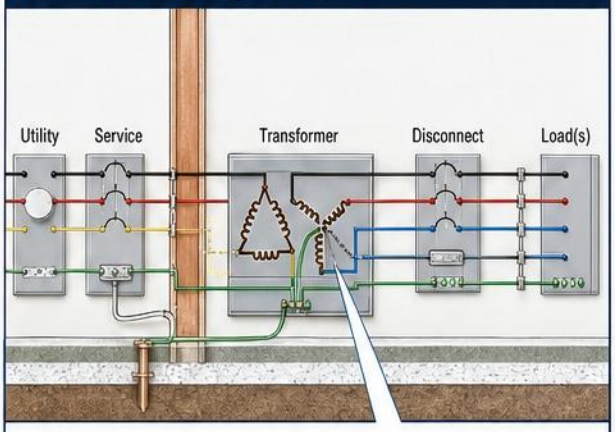
Metal components of electrical equipment, metal piping, and structural steel will become energized and remain energized with dangerous voltage from a ground fault if a main bonding jumper is not installed.

Figure 250–62 *System Bonding Jumper Not Installed* *250.28 Danger*



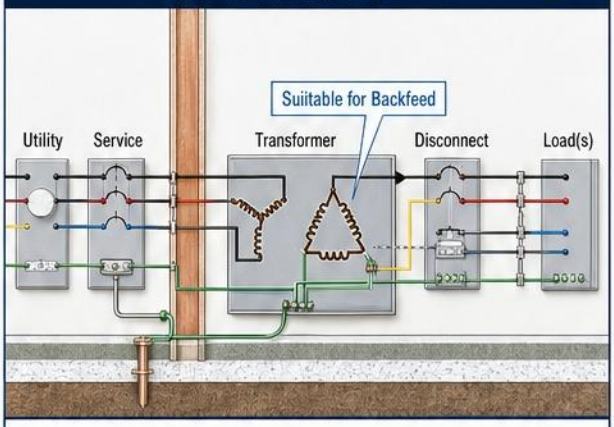
Metal components of electrical equipment, metal piping, and structural steel will become energized and remain energized with dangerous voltage from a ground fault if a system bonding jumper is not installed.

Figure 250–63 *Separately Derived Systems* *Article 100 Definition*



A power supply output having no connection(s) to the circuit conductors of any other electrical source other than through the grounding and bonding connections.

Figure 250–64 *Separately Derived Systems Corner-Grounded Transformer* *Article 100 Definition*



A power supply output having no connection(s) to the circuit conductors of any other electrical source other than through the grounding and bonding connections.

250.30 Transformer Separately Derived Systems

(A) Grounded Systems. Transformer *separately derived systems* must be bonded and grounded in accordance with 250.30(A)(1) through (A)(8). The secondary neutral conductor cannot be connected to metal parts of equipment, equipment grounding conductors, or reconnected to ground on the load side of the system bonding jumper.

> ***Separately Derived System.*** A power supply output having no connections to the circuit conductors of any other electrical source other than grounding and bonding connections.
> Figure 250–63 and Figure 250–64

Author's Comment:

- Other than autotransformers, transformers are separately derived because the primary conductors have no direct electrical connection from the circuit conductors of one system to the circuit conductors of another system.

(1) System Bonding Jumper. A system bonding jumper must be installed at the secondary neutral point or secondary disconnect neutral terminal, but not at both locations in accordance with 25.0.30(A)(1)(a) or (1)(b). Figure 250–65

(a) System Bonding Jumper at Source. The system bonding jumper connects the secondary neutral conductor to the metal enclosure of the transformer separately derived system. Figure 250–66

Figure 250-65 *250.30(A)(1)*

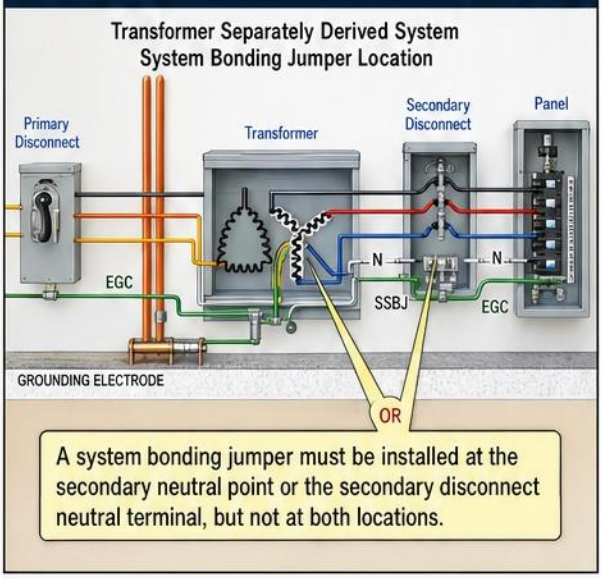
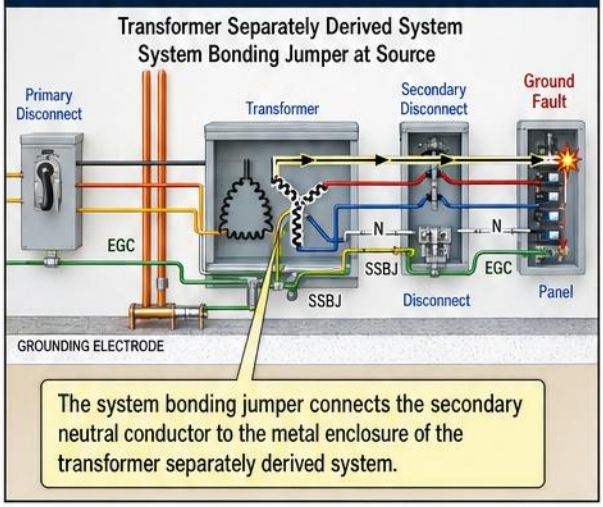


Figure 250-66 *250.30(A)(1)(a)*



(b) System Bonding Jumper at First Disconnecting Means. The system bonding jumper connects the secondary neutral conductor to the transformer secondary disconnect metal enclosure. Figure 250-67

CAUTION: Potentially dangerous objectionable neutral current will flow on conductive metal parts of electrical equipment, metal piping, and structural steel if the system bonding jumper is installed at both the secondary neutral point and secondary disconnect neutral terminal in violation of 250.6(A). Figure 250-68 and Figure 250-69

Figure 250-67 *250.30(A)(1)(b)*

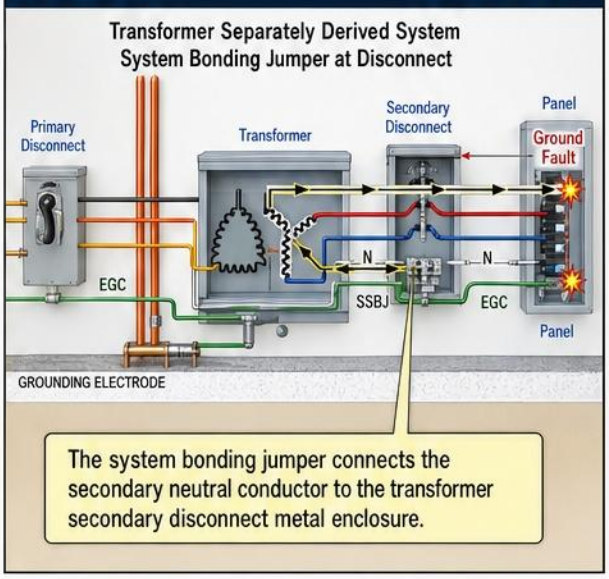


Figure 250-68 *250.30(A)(1) Caution*

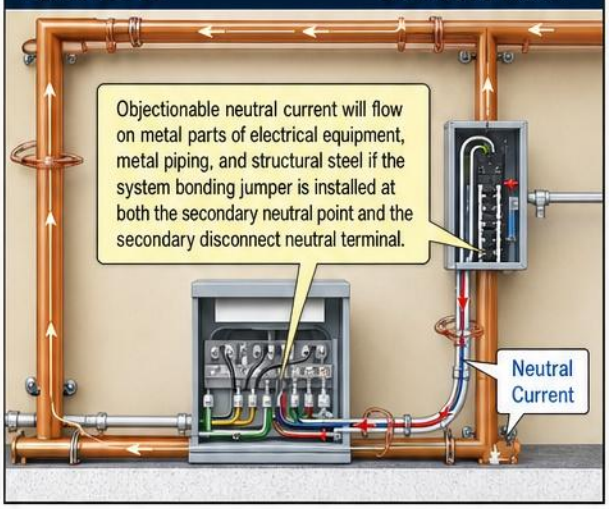
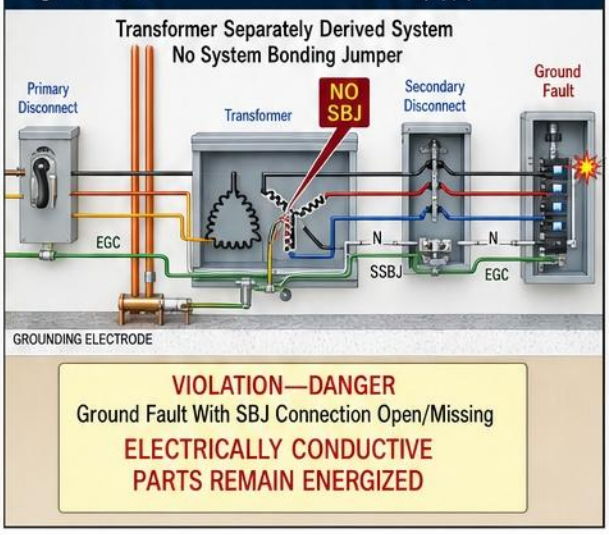


Figure 250-69 *250.30(A)(1) Comment*

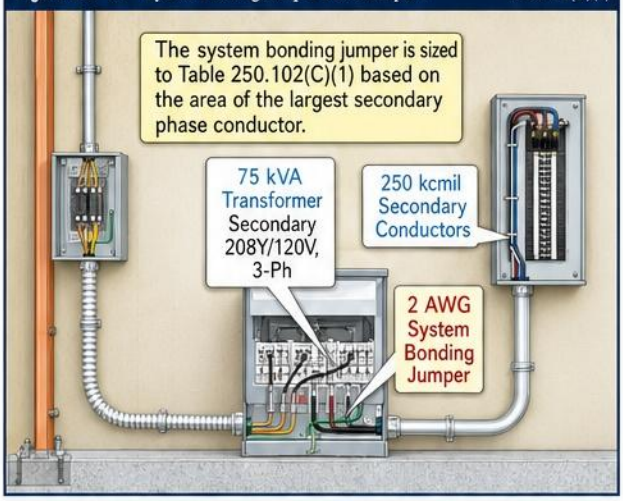


▶ System Bonding Jumper Size [250.30(A)(1)] Example 1

Question: *What size system bonding jumper is needed for a 75 kVA, three-phase, 480V to 208Y/120V transformer when the secondary conductors are sized at 250 kcmil copper?* ▶Figure 250–70

(a) 6 AWG *(b) 4 AWG* *(c) 3 AWG* *(d) 2 AWG*

Figure 250–70 System Bonding Jumper Size Example 1 250.102(C)(1)



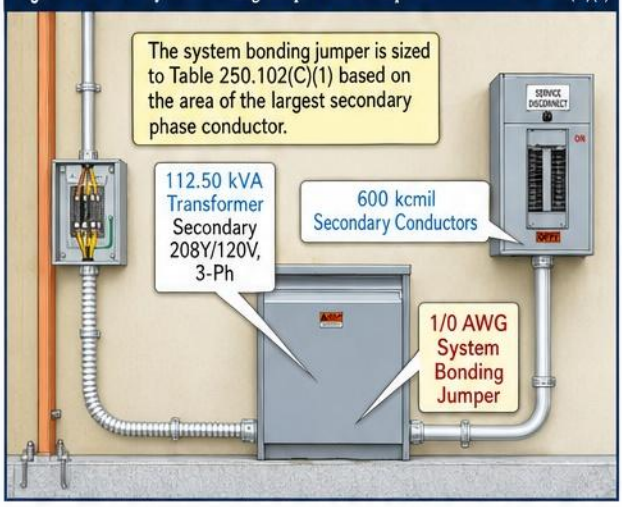
The system bonding jumper is sized to Table 250.102(C)(1) based on the area of the largest secondary phase conductor.

▶ System Bonding Jumper Size [250.30(A)(1)] Example 2

Question: *What size system bonding jumper is needed for a 112.50 kVA, three-phase, 480V to 208Y/120V transformer when the secondary conductors are sized at 600 kcmil copper?* ▶Figure 250–71

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

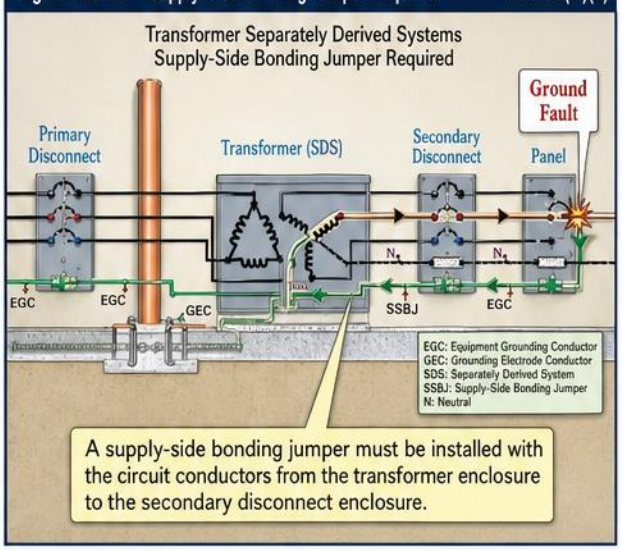
Figure 250–71 System Bonding Jumper Size Example 2 250.102(C)(1)



The system bonding jumper is sized to Table 250.102(C)(1) based on the area of the largest secondary phase conductor.

(2) Supply-Side Bonding Jumper. A supply-side bonding jumper must be installed with the circuit conductors from the transformer enclosure to the secondary disconnect enclosure. ▶Figure 250–72

Figure 250–72 Supply-Side Bonding Jumper Required 250.30(A)(2)



The supply-side bonding jumper is not required to be larger than the secondary phase conductors. The following can be used as a supply-side bonding jumper:

Bonding Jumper, Supply-Side Bonding Jumper. A component of the effective ground-fault current path that is the bonding conductor installed on the supply side of a service, within the service equipment enclosure, or a separately derived system that ensures conductivity between metal parts. ▶Figure 250–73 and ▶Figure 250–74

Figure 250–73 Supply-Side Bonding Jumper *Article 100 Definition*

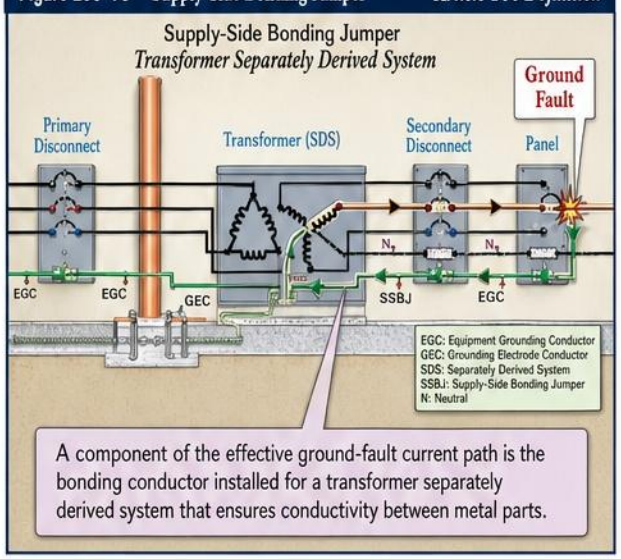
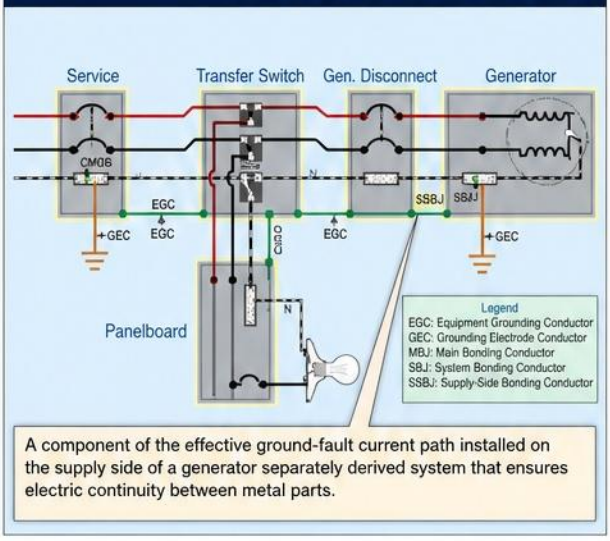


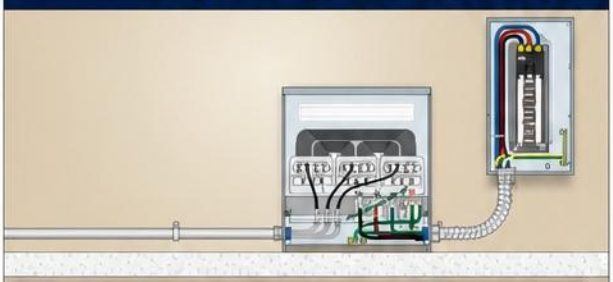
Figure 250–74 Supply-Side Bonding Jumper Generator Separately Derived System *Article 100*



A component of the effective ground-fault current path installed on the supply side of a generator separately derived system that ensures electric continuity between metal parts.

Supply-Side Bonding Jumper of the Wire-Type. A wire-type supply-side bonding jumper sized in accordance with 250.102(C) can be used between the transformer enclosure grounding terminal and the secondary disconnect enclosure grounding terminal. Figure 250–75

Figure 250–75 Transformer Separately Derived System Supply-Side Bonding Jumper, Wire-Type 250.30(A)(2)



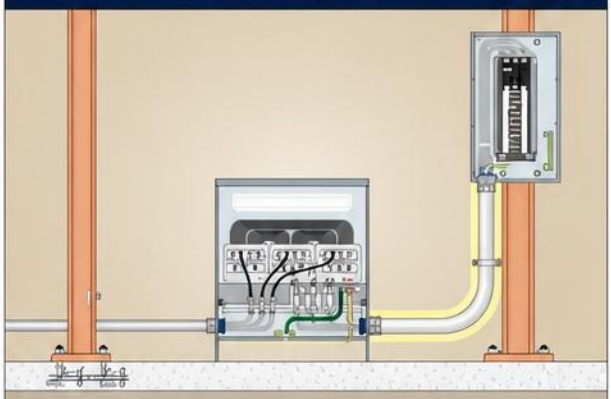
A wire-type supply-side bonding jumper sized in accordance with 250.102(C) can be used between the transformer enclosure grounding terminal and the secondary disconnect enclosure grounding terminal.

Nonflexible Metal Raceway. A nonflexible metal raceway from the transformer enclosure to the secondary disconnect enclosure can be used as a supply-side bonding jumper. Figure 250–76

Author's Comment:

- The supply-side bonding jumper can be RMC, IMC, or EMT run between the transformer separately derived system enclosure and the secondary system disconnect enclosure. A nonmetallic or flexible raceway must have a supply-side bonding jumper of the wire-type.

Figure 250–76 Transformer Separately Derived System Supply-Side Bonding Jumper Nonflexible Metal Raceway 250.30(A)(2)



A nonflexible metal raceway from the transformer enclosure to the secondary disconnect enclosure can be used as a supply-side bonding jumper.

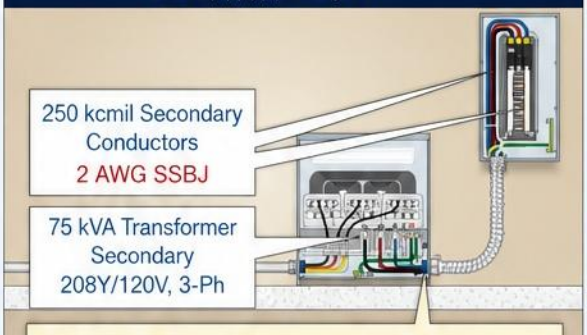
(1) A supply-side bonding jumper of the wire-type must be sized in accordance with 250.102(C) based on the size or area of the secondary phase conductors in the raceway or cable

▶ Supply-Side Bonding Jumper Size [250.30(A)(2)(1)] Example 1

Question: *What size supply-side bonding jumper is required for a 75 kVA, three-phase, 480V to 208Y/120V transformer when containing a flexible metal conduit with 250 kcmil copper secondary conductors?* Figure 250–77

(a) 4 AWG *(b) 3 AWG* *(c) 2 AWG* *(d) 1 AWG*

Figure 250–77 Transformer Separately Derived System Supply-Side Bonding Jumper, Sizing 250.30(A)(2)(1) Example 1



An SSBJ of the wire type must be sized not smaller than specified in Table 250.102(C)(1), based on the size/area of the secondary phase conductor.

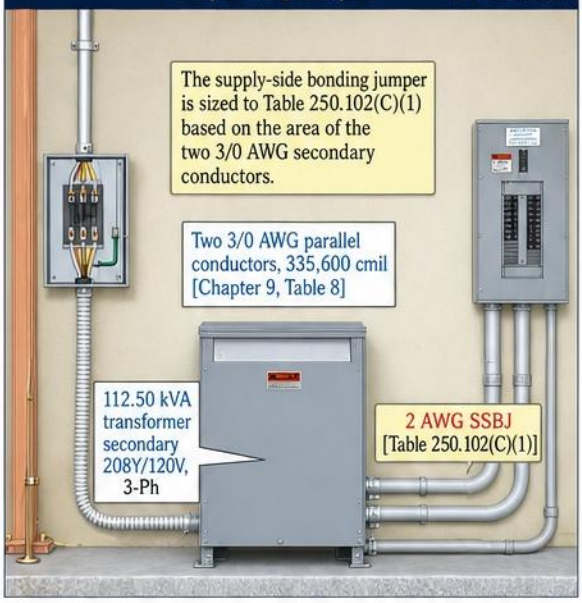
Answer: *(c) 2 AWG [Table 250.102(C)(1)]*

▶ Supply-Side Bonding Jumper Size [250.30(A)(2)(1)] Example 2

Question: *What size supply-side bonding jumper is required for a 112.50 kVA, three-phase, 480V to 208Y/120V transformer when containing a PVC conduit with two sets of 3/0 AWG copper secondary conductors in parallel?*

(a) 6 AWG (b) 8 AWG (c) 3 AWG (d) 2 AWG

Figure 250–78 Supply-Side Bonding Jumper Sizing Example 2 250.30(A)(2)(1)



The supply-side bonding jumper is determined using the area of the two 3/0 AWG secondary conductors in parallel.

Solution:

3/0 AWG conductor circular mil area = 167,800 cmil [Chapter 9, Table 8]

Circular mil area of two parallel conductors = 167,000 cmil × 2

Circular mil area of two parallel conductors = 335,600 cmil

335,600 cmil is 2 AWG [Table 250.102(C)(1)].

Answer: *(d) 2 AWG*

(3) Neutral Conductor Size. If the system bonding jumper is installed at the secondary disconnect neutral terminal (instead of the transformer separately derived system neutral point), the neutral conductor between the transformer separately derived system and the secondary system disconnect is not required to be larger than the phase conductors. The conductor must be sized in accordance with 250.30(A)(3)(a) and (b).

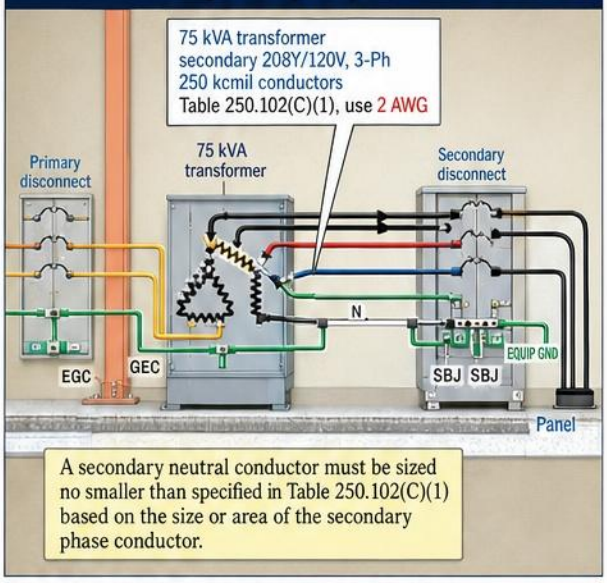
(a) Single Raceway. A secondary neutral conductor must be run from the transformer separately derived system to the secondary disconnect neutral terminal. The secondary neutral conductor must be sized in accordance with Table 250.102(C)(1) based on the size or area of the secondary phase conductor.

▶ Secondary Neutral Conductor Size—Single Raceway [250.30(A)(3)(a)] Example

Question: *What size secondary neutral conductor is required for a 75 kVA, three-phase, 480 to 208Y/120V transformer with 250 kcmil copper secondary conductors?* Figure 250–79

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

Figure 250–79 Secondary Neutral Conductor Size—Single Raceway Example 250.30(A)(3)(a)

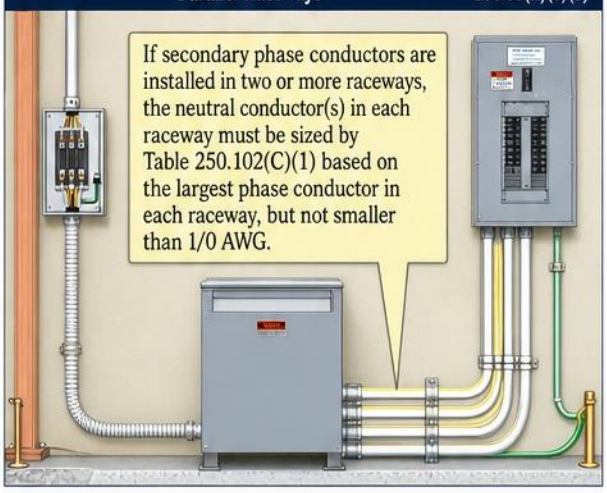


Determine secondary neutral conductor size using the largest phase conductor.

Answer: *(a) 2 AWG [Table 250.102(C)(1)]*

(b) Paralleled in Two or More Raceways or Cables. If the secondary phase conductors are installed in parallel in two or more raceways or cables, the neutral conductor(s) in each raceway or cable connected in parallel must be sized based on the largest phase conductor in each raceway or cable in accordance with Table 250.102(C)(1)—but not smaller than 1/0 AWG. Figure 250–80

Figure 250–80 Neutral Conductor Sizing—Parallel Raceways 250.30(A)(3)(b)

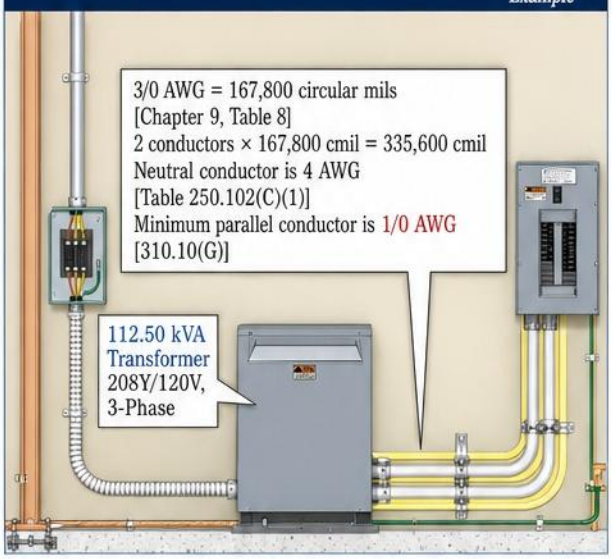


▶ Secondary Neutral Conductor Size–Parallel Raceways [250.30(A)(3)(b)] Example

Question: *The minimum secondary neutral conductor size for a 11250 kVA, three-phase, 480 to 208Y/120V transformer is in each raceway if the secondary paralleled phase conductors are 3/0 AWG copper.*

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

Figure 250–81: Transformer Separately Derived Systems Neutral Conductor Sizing, Parallel Raceways 250.30(A)(3)(b) *Example*



Two secondary phase conductors in parallel with a neutral conductor in a separate raceway.

Solution:

Step 1: *Determine the equivalent area for two 3/0 AWG conductors from Chapter 9, Table 8.*

3/0 AWG = 167,800 circular mils

2 conductors × 167,800 cmil = 335,600 cmil [Table 250.102(C)(1)]

Step 2: *Size the neutral conductor in each raceway to Table 250.102(C)(1) based on 3/0 AWG phase conductors per raceway, which is 4 AWG.*

Step 3: *The minimum parallel conductor is 1/0 AWG in accordance with 310.10(G).*

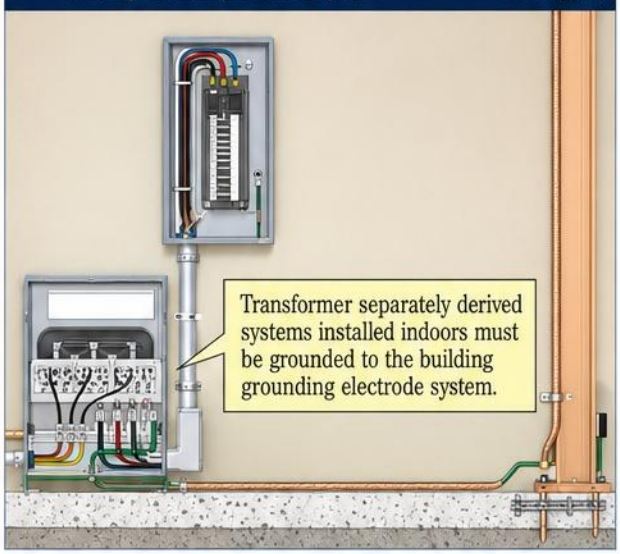
Answer: *(c) 1/0 AWG in each raceway*

(4) Grounding Electrode. Transformer separately derived systems installed indoors must be grounded to the building grounding electrode system. (See Figure 250–82.)

Transformer separately derived systems located outdoors must be grounded in accordance with 250.30(C).

(5) Grounding Electrode Conductor. The grounding electrode conductor must be sized in accordance with 250.66.

Figure 250–82: Transformer Separately Derived System Building Grounding Electrode System 250.30(A)(4)



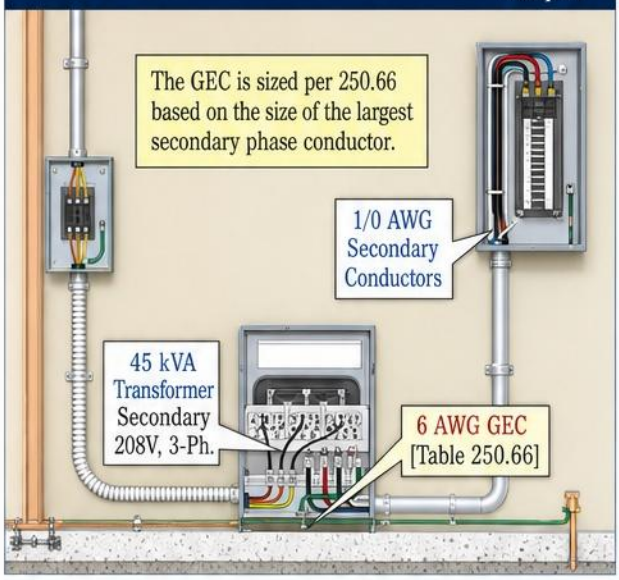
A separately derived transformer system indoors bonded to the building grounding electrode system.

▶ Grounding Electrode Conductor Size [250.30(A)(5)] Example 1

Question: *What size grounding electrode conductor is required for a 45 kVA, three-phase, 480V to 120/208V transformer where the secondary conductors are sized at 1/0 AWG copper?*

(a) 6 AWG (b) 4 AWG (c) 3 AWG (d) 2 AWG

Figure 250–83: Transformer Separately Derived System Grounding Electrode Conductor Sizing 250.30(A)(5) *Example 1*



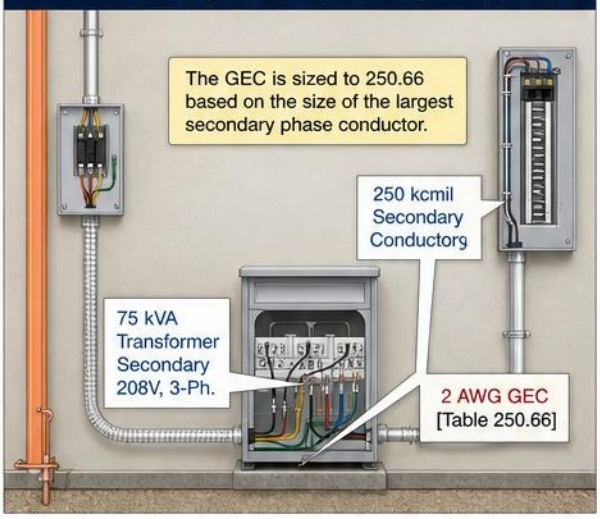
GEC sizing based on the largest secondary phase conductor (1/0 AWG copper).

Answer: *(a) 6 AWG [Table 250.66]*

▶ Grounding Electrode Conductor Size [250.30(A)(5)] Example 2

Question: What size grounding electrode conductor is required for a 75 kVA, three-phase, 480V to 120/208V transformer where the secondary conductors are sized at 250 kcmil copper? *(a) 6 AWG (b) 4 AWG (c) 3 AWG (d) 2 AWG*

Figure 250-84 Transformer Separately Derived System Grounding Electrode Conductor Sizing 250.30(A)(5)



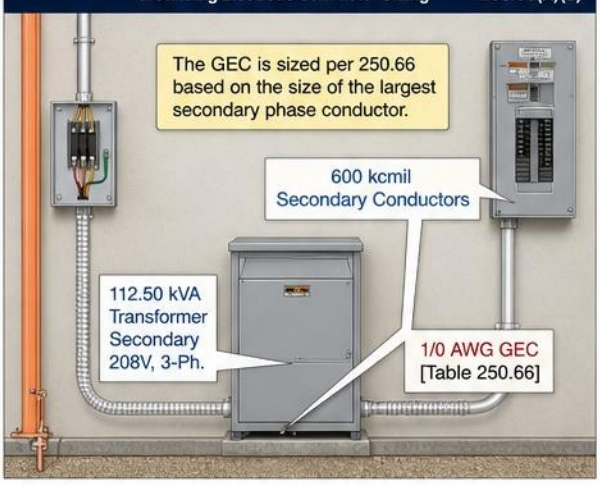
The grounding electrode conductor is determined from Table 250.66 based on the largest secondary phase conductor.

Answer: *(d) 2 AWG [Table 250.66]*

▶ Grounding Electrode Conductor Size [250.30(A)(5)] Example 3

Question: What size grounding electrode conductor is required for a 112.50 kVA, three-phase, 480V to 120/208V transformer where the secondary conductors are sized at 600 kcmil copper? *(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG*

Figure 250-85 Transformer Separately Derived System Grounding Electrode Conductor Sizing 250.30(A)(5)

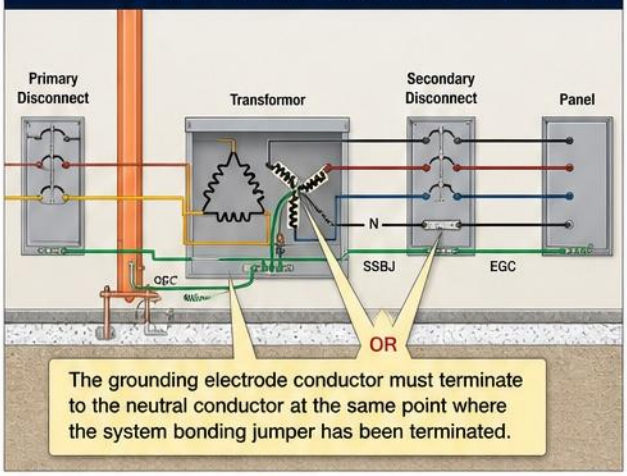


The grounding electrode conductor is selected from Table 250.66 using the largest secondary phase conductor size.

Answer: *(a) 1/0 AWG*

The grounding electrode conductor must terminate to the neutral conductor at the same point where the system bonding jumper has been terminated.

Figure 250-86 Transformer Separately Derived System Grounding Electrode Conductor Termination 250.30(A)(5)



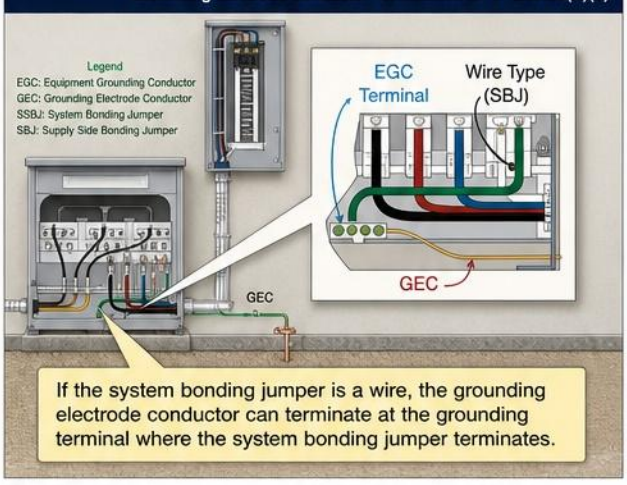
The grounding electrode conductor must connect to the neutral conductor at the exact location where the system bonding jumper is connected.

Author's Comment:

To prevent objectionable neutral current from flowing onto metal parts [250.6], the grounding electrode conductor must originate at the same point on the transformer separately derived system as where the system bonding jumper is connected [250.30(A)(1)].

Ex 1: *If the system bonding jumper is a wire or busbar [250.30(A)(1)], the grounding electrode conductor can terminate at the grounding terminal, bar, or bus where the system bonding jumper terminates, instead of on the neutral terminal.*

Figure 250-87 Transformer Separately Derived System Grounding Electrode Conductor Termination Ex 1 250.30(A)(5)

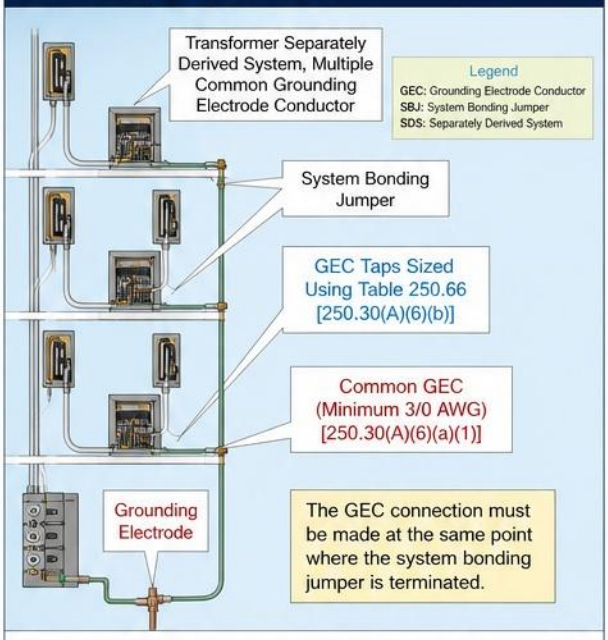


When the system bonding jumper is a wire, the grounding electrode conductor may be connected at the grounding terminal where the system bonding jumper is also connected.

(6) Common Grounding Electrode Conductor, Multiple Separately Derived Transformer Systems. When multiple separately derived transformer systems are used, a grounding electrode conductor may be run from each system to a single common grounding electrode conductor.

This connection must be made at the same point on the transformer separately derived system secondary where the system bonding jumper is terminated [250.30(A)(1)].

Figure 250–88 Multiple Separately Derived Transformer Systems—Common GEC 250.30(A)(6)



Each separately derived system secondary is connected to a common grounding electrode conductor at the point where the system bonding jumper is terminated.

(a) Common Grounding Electrode Conductor. The common grounding electrode conductor can be any of the following:

(1) An unspliced conductor not smaller than 3/0 AWG copper or 250 kcmil aluminum

(2) Interior metal water pipe not more than 5 ft from the point of entrance to the building [250.68(C)(1)]

(3) Metal frame of the building in accordance with 250.68(C)(2) or connected to the grounding electrode system by a conductor not smaller than 3/0 AWG copper or 250 kcmil aluminum

(b) Tap Conductor Size. Grounding electrode conductor taps must be sized in accordance with Table 250.66, based on the area of the largest secondary phase conductor.

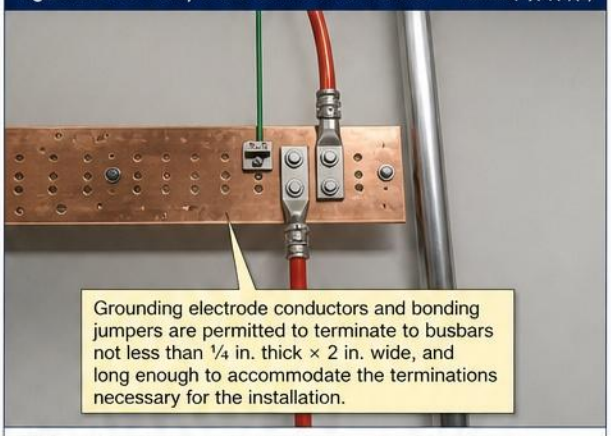
Example: *If the only electrodes present are ground rods [250.66(A)], concrete-encased electrodes [250.66(B)], or ground rings [250.66(C)], the size of the common grounding electrode conductor is not required to be larger than the largest conductor required by 250.66(A), (B), or (C) for the type of electrode that is present.*

(c) Connections. Tap connections to the common grounding electrode conductor must be made at an accessible location by any of the following methods:

(1) Connector listed as "bonding and grounding equipment"

(2) Listed connections to aluminum or copper busbars not less than ¼ in. thick × 2 in. wide, and long enough to accommodate the terminations necessary for the installation

Figure 250–89 Multiple GEC Connections to Busbar 250.30(A)(6)(c)(2)



GECs and bonding jumpers terminate to a copper busbar that meets the size and thickness requirements.

(3) The exothermic welding process

Tap grounding electrode conductors must remain without a splice or joint.

(7) Installation. The grounding electrode conductor must comply with 250.64(A), (B), (C), and (E).

Author's Comment:

- The grounding electrode conductor must be copper within 18 in. of the surface of the earth [250.64(A)], securely fastened to the surface on which it is carried [250.64(B)(1)], and adequately protected if exposed to physical damage [250.64(B)(2) and (3)] in accordance with 250.64. In addition, ferrous metal enclosures enclosing a grounding electrode conductor must be made electrically continuous from the point of attachment to cabinets or equipment to the grounding electrode [250.64(C)].

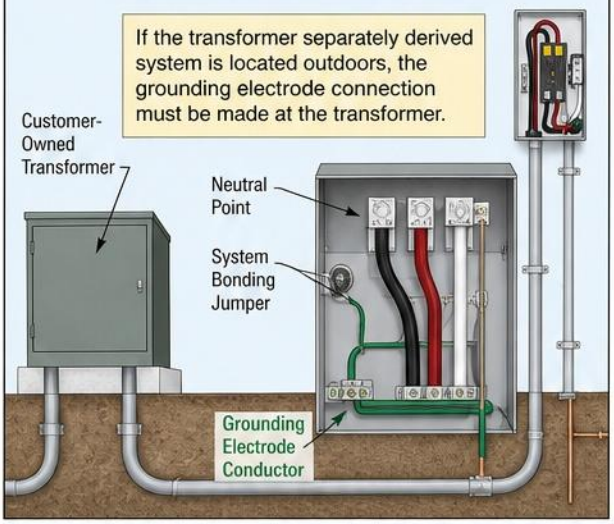
(C) Customer-Owned Outdoor Installation. If the customer-owned transformer separately derived system is located outdoors, the grounding electrode connection must be made at the transformer.

Figure 250–90 Outdoor Installation—GEC Connection at Transformer 250.30(C)

For outdoor customer-owned SDS transformers, the grounding electrode conductor is connected at the transformer.

Figure 250–90 250.30(C)

Transformer Separately Derived System Customer Owned, Located Outdoors



The grounding electrode connection is required at the transformer when the separately derived system is outdoors.

Figure 250–92 250.32(A) Ex

Building Supplied by a Branch Circuit Grounding Electrode System and Conductor

A grounding electrode conductor is not required for a building supplied by a single branch circuit or multiwire branch circuit.

250.32 Buildings Supplied by a Feeder

(A) Grounding Electrode System and Conductor. Buildings supplied by feeders or branch circuits must have a grounding electrode system and a grounding electrode conductor in accordance with Article 250, Part III. Figure 250–91

Figure 250–91 250.32(A)

Buildings Supplied by a Feeder Grounding Electrode System and Conductor

Buildings supplied by feeders must have a grounding electrode system and a grounding electrode conductor in accordance with Article 250, Part III.

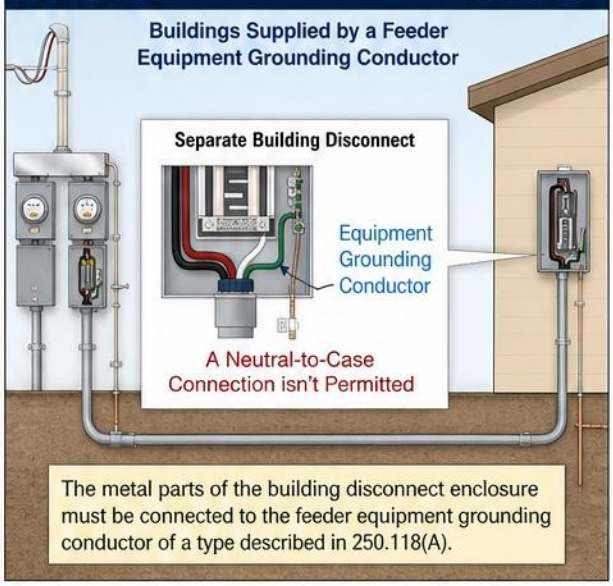
Example: A grounding electrode system and grounding electrode conductor are not required for a building supplied by a single branch circuit or multiwire branch circuit. Figure 250–92

(B) Equipment Grounding Conductor.

(1) Metal parts of the building disconnect enclosure must be connected to the feeder equipment grounding conductor of a type described in 250.118(A). Figure 250–93

Figure 250–93 250.32(B)(1)

Buildings Supplied by a Feeder Equipment Grounding Conductor



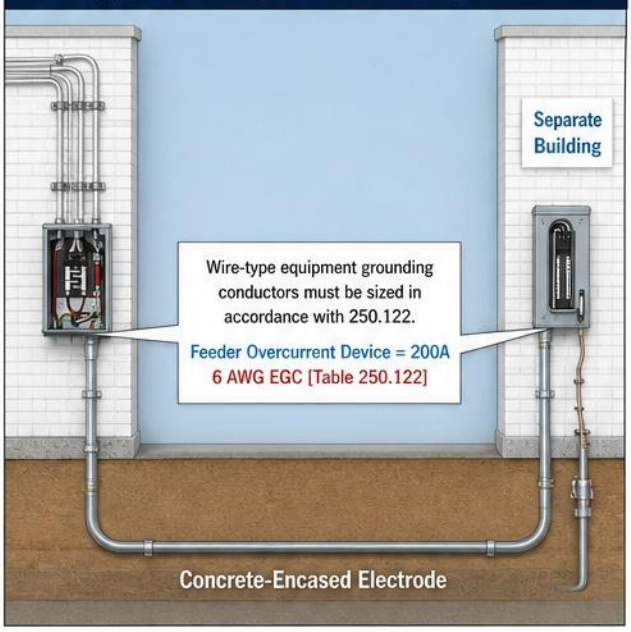
Where the circuit equipment grounding conductor is of the wire-type, it must be sized in accordance with 250.122.

▶ Remote Building Equipment Grounding Conductor Size [250.32(B)(1)] Example

Question: *What size equipment grounding conductor is required for a feeder building disconnect containing a 200A overcurrent protective device?* **Figure 250–94**

(a) 6 AWG *(b) 4 AWG* *(c) 2 AWG* *(d) 1 AWG*

Figure 250–94 **250.32(B)(1)**
Feeder Equipment Grounding Conductor Size Example

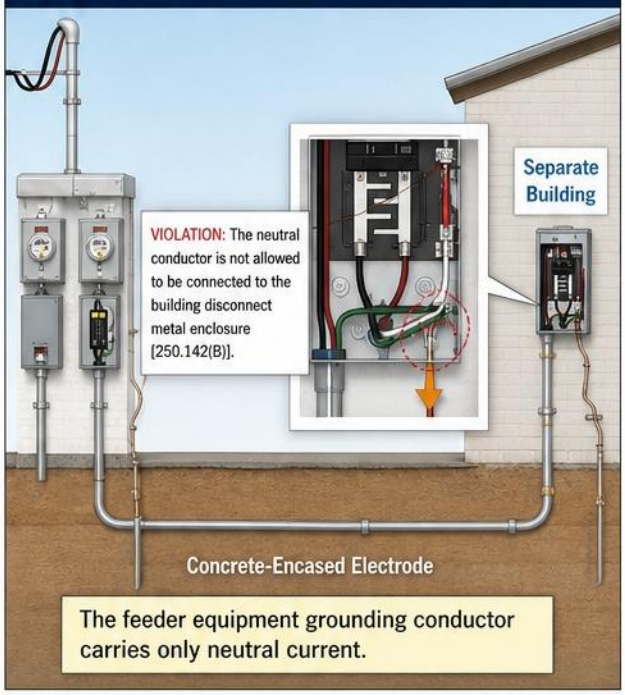


The equipment grounding conductors that supply the building disconnect are not permitted to serve as the equipment grounding conductors for the building.

> **CAUTION:** To prevent hazardous objectionable neutral current from flowing on metal parts [250.6(A)], the neutral conductor is not allowed to be connected to the disconnect metal enclosure of buildings supplied by feeders. See 250.142(B). **Figure 250–95**

(E) **Grounding Electrode Conductor Size.** The grounding electrode conductor must terminate at the equipment grounding terminal of the building disconnect and be sized in accordance with 250.66, based on the size of the largest phase conductor.

Figure 250–95 **250.32(B)(1)**
Improper Neutral-to-Case Connection

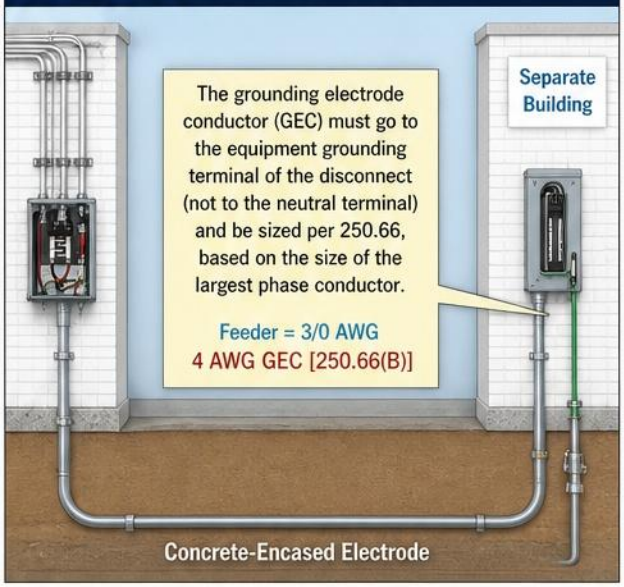


▶ Remote Building Grounding Electrode Conductor Size [250.32(E)] Example

Question: *What size grounding electrode conductor is required for a building disconnect supplied with a 3/0 AWG feeder with a concrete-encased electrode?* **Figure 250–96**

(a) 4 AWG *(b) 3 AWG* *(c) 2 AWG* *(d) 1 AWG*

Figure 250–96 **250.32(E)**
Grounding Electrode Conductor Size Example



Answer: *(a) 4 AWG*

250.34 PORTABLE AND VEHICLE- OR TRAILER-MOUNTED GENERATORS

(A) Portable Generators. A grounding electrode is not required for a portable generator where:

(1) It only provides equipment and/or receptacles mounted on the generator
Figure 250–97 | Figure 250–98

Figure 250–97 Portable Generator, Grounding Not Required 250.34(A)(1)

A grounding electrode is not required for a portable generator that only supplies equipment and/or receptacles mounted on the generator.

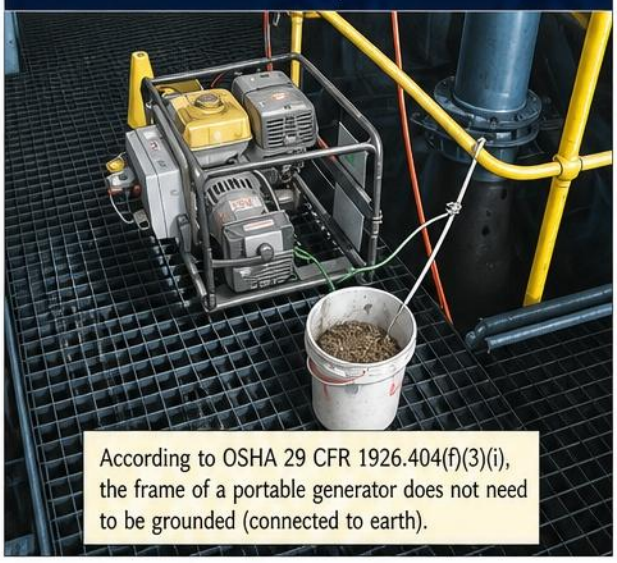
Figure 250–98 Portable Generator, Grounding Not Required 250.34(A)(1)

A grounding electrode is not required for a portable generator that only supplies equipment and/or receptacles mounted on the generator.

Author's Comment:

- According to OSHA 29 CFR 1926.404(f)(3)(i) the frame of a portable generator does not need to be grounded (connected to earth). Figure 250–99

Figure 250–99 Portable Generator, Grounding Not Required 250.34(A)(1) Comment



According to OSHA 29 CFR 1926.404(f)(3)(i), the frame of a portable generator does not need to be grounded (connected to earth).

(B) Vehicle- or Trailer-Mounted Generators. A grounding electrode is not required for a vehicle- or trailer-mounted generator where all the following conditions are met:

(1) Generator frame is bonded to the vehicle or trailer frame

(2) Generator only supplies equipment or receptacles mounted on the vehicle, trailer, or generator | Figure 250–100

Figure 250–100 Vehicle- or Trailer-Mounted Generator, Grounding Not Required 250.34(B)(2)

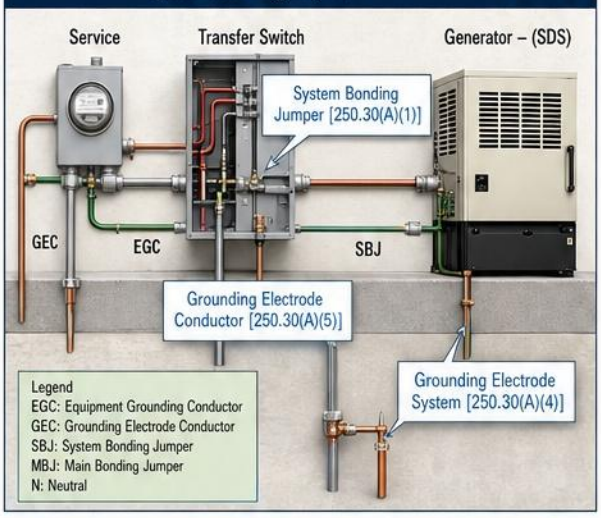
Vehicle-mounted and trailer-mounted generators that only supply receptacles are not required to be grounded.

(3) Normally noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are connected to the generator frame

250.35 PERMANENTLY INSTALLED GENERATORS

(A) Separately Derived System. When a generator is the source of a separately derived system, the requirements of 250.30 apply.

Figure 250–101: Generator Separately Derived System System Grounding Required **250.35(A)**

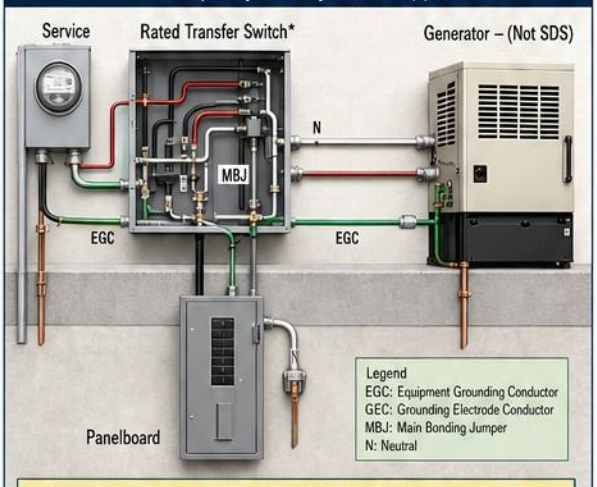


When a generator is the source of a separately derived system, the requirements of 250.30 apply.

Author's Comment:

- Regarding 250.30 Note 1, a generator with a transfer switch that does not open the neutral is not required to be bonded or grounded in accordance with 250.30. This is because the neutral from the generator has a direct connection with the service neutral conductor. Figure 250–102

Figure 250–102: Permanently Installed Generators Nonseparately Derived System, 250.35(A) Comment **Not SDS**



A generator with a transfer switch that does not open the neutral (not separately derived system) is not required to be bonded or grounded in accordance with 250.30 Note 1.

Grounded Systems. A generator separately derived system that includes a built-in disconnect supplyinga switched-neutral transfer switch must be bonded and grounded in accordance with the following:

(1) System Bonding Jumper. A system bonding jumper must be installed to connect the generator neutral point to the metal enclosure of the generator.

(4) Grounding Electrode. A separately derived generator system installed indoors must be grounded to the building grounding electrode system. Separately derived generator systems located outdoors must have the grounding electrode connection made at the generator separately derived system in accordance with 250.30(C).

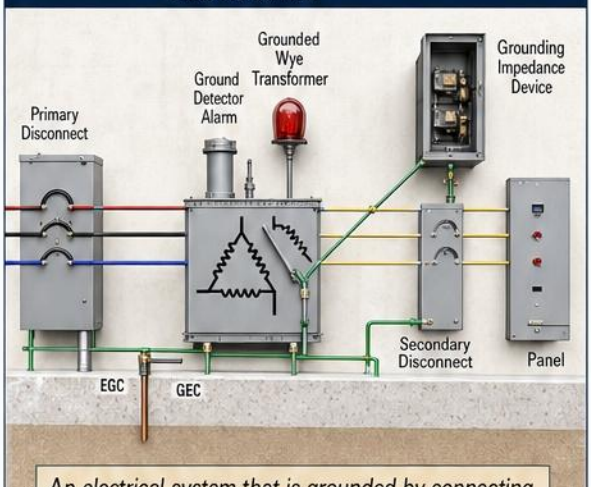
(5) Grounding Electrode Conductor. The grounding electrode conductor must terminate to the neutral terminal of the generator where the system bonding jumper is installed.

Ex 1: If the system bonding jumper is a wire or busbar, the grounding electrode conductor can terminate at the generator equipment grounding terminal.

250.36 IMPEDANCE GROUNDED SYSTEMS—480V TO 1000V

Grounded System, Impedance Grounded System. An electrical system that is grounded by connecting the system neutral point to the metal parts of the enclosure through an impedance device. Figure 250–103

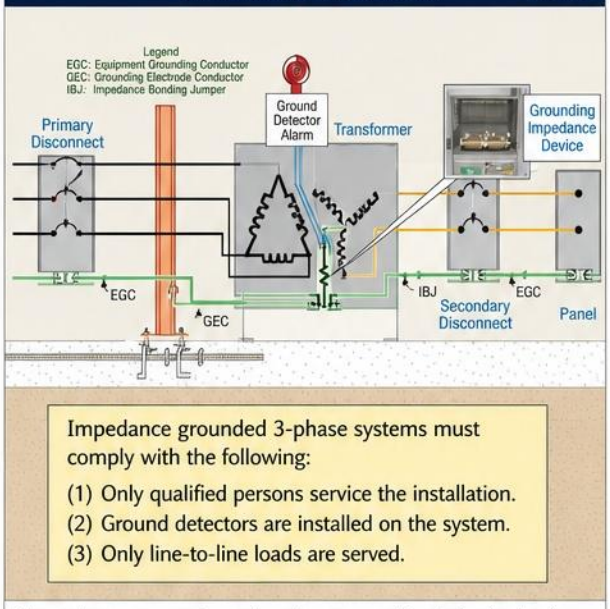
Figure 250–103: Impedance Grounded System *Article 100 Definition*



An electrical system that is grounded by connecting the system neutral point to the metal parts of the enclosure through an impedance device.

To limit ground-fault current to a low value, an *impedance grounded* system with a grounding impedance device (typically a resistor) is permitted to be installed on three-phase systems of 480V up to 1000V where all the following conditions are met: ▸Figure 250–104

Figure 250–104 Impedance Grounded Systems Three-Phase 480V to 1000V 250.36



Three-phase system using an impedance grounding device (resistor) to limit ground-fault current per 250.36.

(1) Conditions of maintenance and supervision ensure that only qualified persons service the installation

(2) Ground detectors are installed on the system

(3) Only line-to-line loads are served

Note: Impedance grounding is an effective tool for reducing arc-flash hazards. See Annex O of *NFPA 70E, Standard for Electrical Safety in the Workplace.* ▸Figure 250–105

Figure 250–105 Impedance Grounded Systems Reduces Arc-Flash Hazards 250.36 Note

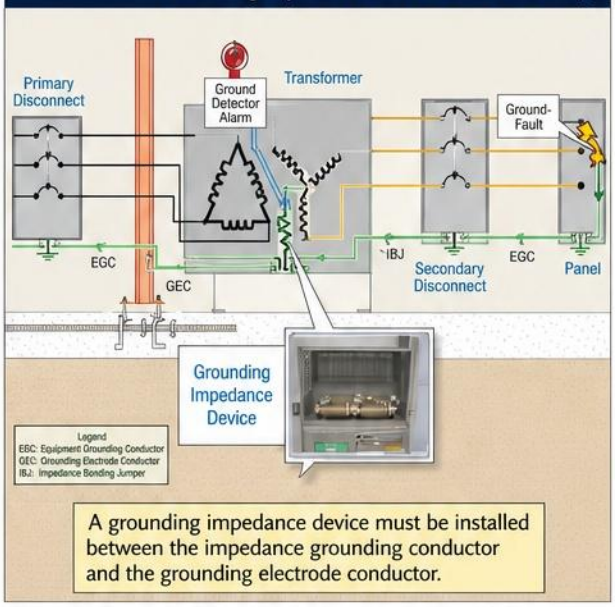
Photo of impedance grounded system equipment illustrating arc-flash hazard reduction benefits.

AUTHOR'S COMMENT

- Impedance grounded systems are generally referred to as "high-resistance grounded systems" in the industry. These systems are generally used where sudden interruption of power will create increased hazards so a reduction of incident energy is needed for worker safety.
- High-resistance grounding will insert an impedance in the ground return path. It will typically limit the fault current to 10A or less, leaving insufficient fault energy—thereby reducing the arc-flash hazard level. High-resistance grounding will not affect arc-flash energy for line-to-line faults. See *NFPA 70E, Standard for Electrical Safety in the Workplace.*

(A) Grounding Impedance Device Location. A grounding impedance device must be installed between the impedance grounding conductor and the grounding electrode conductor. ▸Figure 250–106

Figure 250–106 Impedance Grounded Systems Grounding Impedance Device Location 250.36(A)



Grounding impedance device installed in the grounding path between the impedance grounding conductor and the grounding electrode conductor.

Part III. Grounding Electrode System and Grounding Electrode Conductor

250.50 Grounding Electrode System

A grounding electrode system is comprised of bonding together the grounding electrodes described in 250.52(A)(1) through (A)(7) that are present at a building as determined by the AHJ. ▸Figure 250–107

Grounding Electrode. A conducting object used to make a connection to the earth [250.50 through 250.70]. ▸Figure 250–108

Figure 250–107 250.50

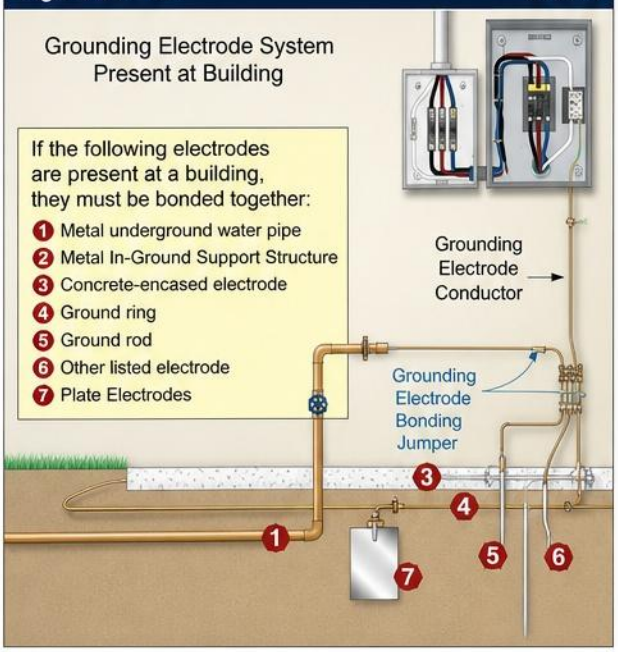


Figure 250–108 Article 100 Definition

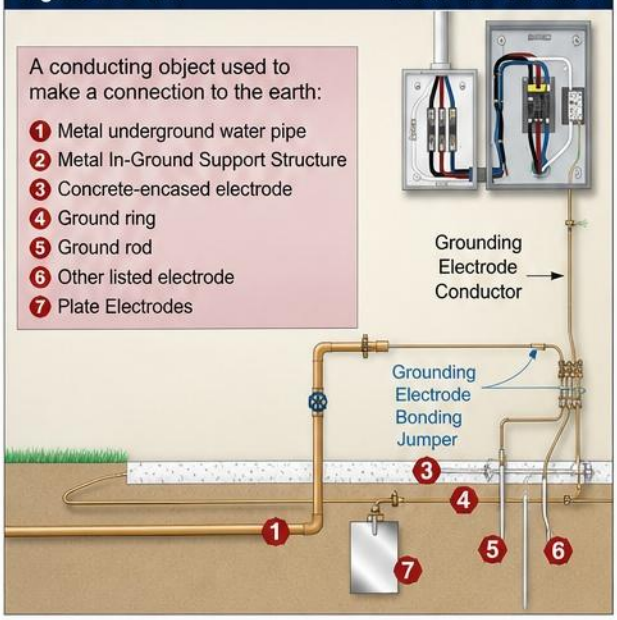
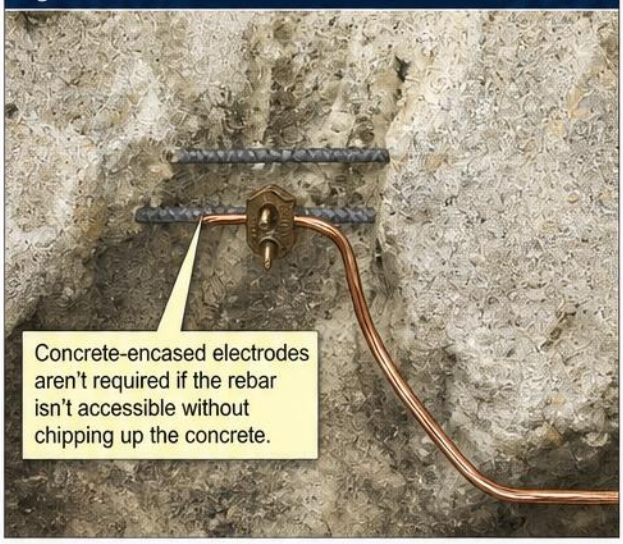
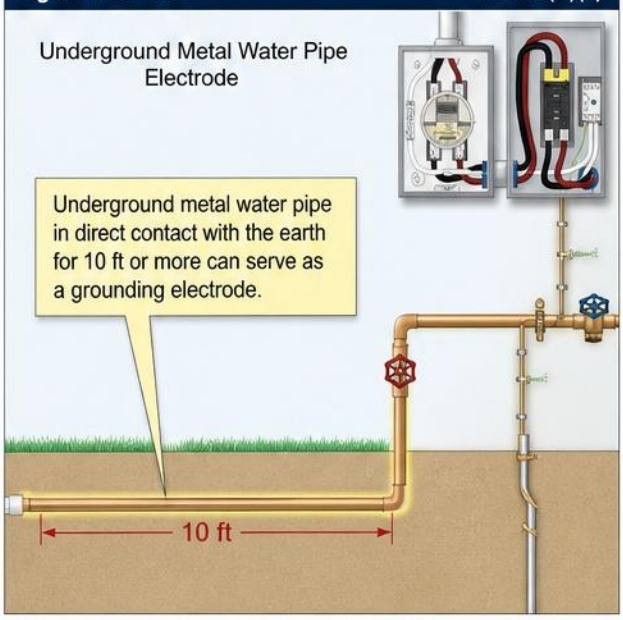


Figure 250–109 250.50 Ex



Example: Concrete-encased electrodes are not required to be installed at an existing building if the rebar is not accessible without chipping up the concrete.

Figure 250–110 250.52(A)(1)



250.52 Grounding Electrode Types

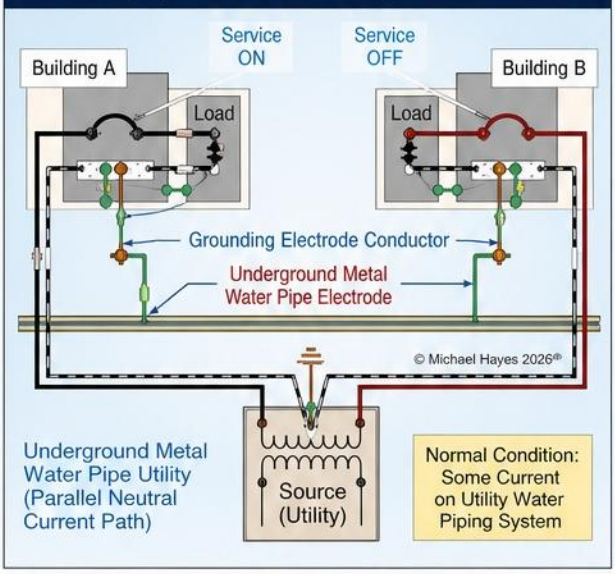
(A) Electrodes Permitted.

(1) Underground Metal Water Pipe Electrode. An underground metal water pipe in direct contact with the earth for 10 ft or more can serve as a grounding electrode. **Figure 250–110**

Author's Comment:

Controversy about using metal underground water piping as a grounding electrode has existed since the early 1900s. The water industry believes that neutral current flowing on water piping corrodes the metal. For more information, contact the American Water Works Association about their report, *Effects of Electrical Grounding on Pipe Integrity and Shock Hazard*, Catalog No. 90702; 1.800.926.7337. **Figure 250–111**

Figure 250–111 Neutral Current Flow on Underground Metal Water Pipe (Parallel Neutral Current Path) 250.52(A)(1) Comment



In normal operation, a portion of the neutral current can flow on the utility's underground metal water pipe, creating a parallel neutral current path.

Author's Comment:

- It is common for the service neutral to be left open while the underground water piping system remains in place. This can result in symptoms often associated with an open service neutral. Such a condition can pose a hazard to workers who open the underground water pipe while it is carrying service neutral current.
- Underground sprinkler metal piping cannot be used as a grounding electrode. See *NFPA 13, Standard for Installation of Sprinkler Systems*, section 6.6.

(2) Metal In-Ground Support Structure(s). Metal in-ground support structure(s) in direct contact with the earth vertically for 10 ft or more can serve as a grounding electrode. Figure 250–112

Note: Metal in-ground support structures include (but are not limited to) pilings, casings, and other structural metal.

(3) Concrete-Encased Electrodes. The following can serve as a concrete-encased electrode:

(1) Rebar. One or more pieces of conductive rebar of not less than ½ in. diameter that are connected by steel tie wires to create a 20 ft or greater length can serve as a grounding electrode. Figure 250–113

(2) Conductor. A bare copper conductor not smaller than 4 AWG and 20 ft or greater in length can serve as a grounding electrode. Figure 250–114

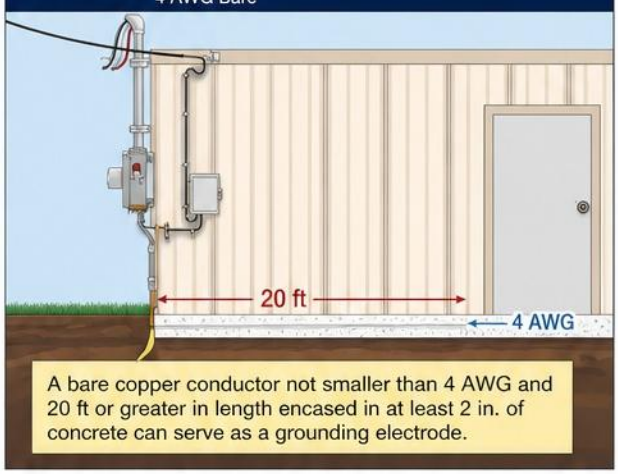
Figure 250–112 Metal In-Ground Support Structure Electrode 250.52(A)(2)

Steel building columns or other metal support structures that are in direct contact with the earth for 10 ft or more may be used as a grounding electrode.

Figure 250–113 Concrete-Encased Electrode, Rebar 250.52(A)(3)(1)

Reinforcing steel that is tied together and embedded in concrete to form a continuous length of 20 ft or more can function as a grounding electrode.

Figure 250–114 Concrete-Encased Electrode, 4 AWG Bare 250.52(A)(3)(2)



A bare copper conductor sized 4 AWG or larger and run for 20 ft or more within at least 2 in. of concrete can be used as a grounding electrode.

Rebar or Conductor. The rebar or hare copper conductor used as part of the concrete-encased electrode must be encased by at least 2 in. of concrete and can be horizontal or vertical within a concrete foundation or footing that is in direct contact with the earth.

Note: Direct contact with the earth is hindered by insulation, vapor barriers, films, or similar items that separate the concrete from the earth.

Figure 250–115 Concrete-Encased Electrode, Earth Contact 250.52(A)(3) Note

Author's Comment:

A concrete-encased grounding electrode is also called "Ufer Ground." The Ufer is named after Herbert G. Ufer, a consultant for the U.S. Army during World War II who worked on a series of bomb storage vaults near Flagstaff, Arizona. The technique was necessary because the site had no underground water table and little rainfall.

(4) Ground Ring. A bare copper conductor in direct contact with the earth, not smaller than 2 AWG, encircling a building can serve as a grounding electrode.

▶250.52(A)(4)

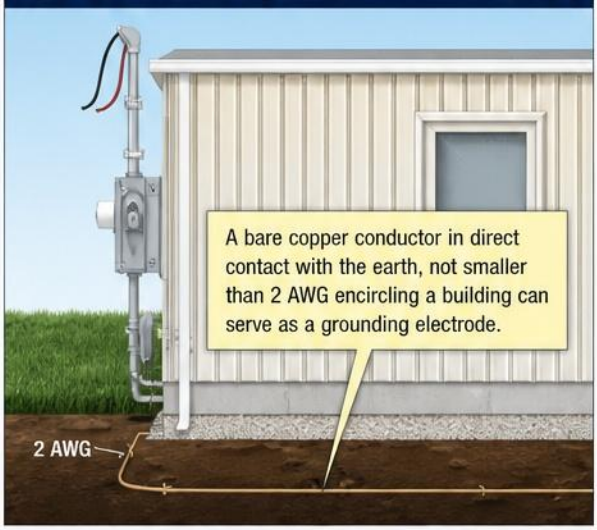
Author's Comment:

A ground ring encircling a building must not be installed less than 30 in. below the surface of the earth [250.53(F)].

(5) Ground Rod. Ground rods at least 8 ft in length can serve as a grounding electrode.

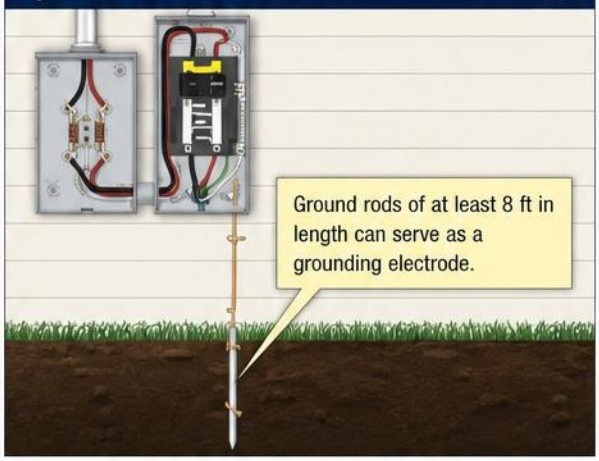
▶250.52(A)(5)

Figure 250–116 Ground Ring Electrode 250.52(A)(4)



A continuous bare copper conductor not smaller than 2 AWG that encircles the building and is in direct contact with the earth is permitted to be used as a grounding electrode.

Figure 250–117 Ground Rod Electrode 250.52(A)(5)



A ground rod at least 8 ft long installed in the earth can serve as a grounding electrode.

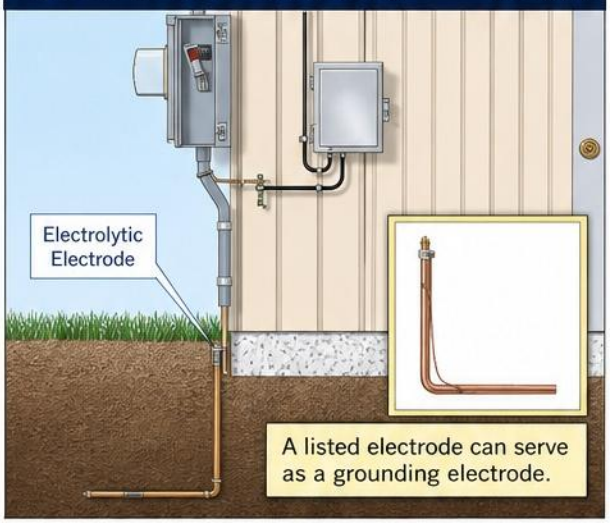
Author's Comment:

The diameter of a ground rod has an insignificant effect on the contact resistance of a rod to the earth. However, larger diameter rods (¾ in. and 1 in.) are sometimes installed where mechanical strength is desired or is needed to compensate for the loss of the electrode's metal due to corrosion.

(6) Listed Electrode. Other listed electrodes can serve as a grounding electrode.

▶250.52(A)(6)

Figure 250–118 Listed Grounding Electrode 250.52(A)(6)



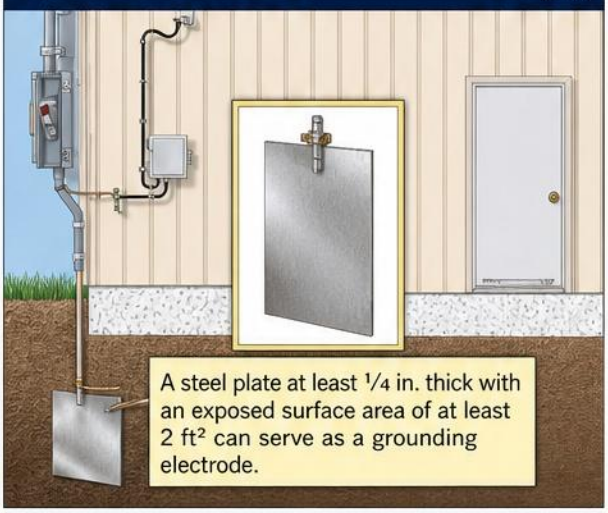
An approved electrode is acceptable for use as a grounding electrode.

Author's Comment:

- Additional listed electrodes include electrolytic electrodes, which are placed in an enlarged borehole and surrounded by a conductive material. This setup prevents corrosion and enhances conductivity by ensuring solid contact between the electrode and the surrounding soil.

(7) Plate Electrode. A steel plate that is at least ¼ in. thick and has a surface area exposed to the soil of no less than 2 ft² can be used as a grounding electrode. Figure 250–119

Figure 250–119 Plate Electrode 250.52(A)(7)



Author's Comment:

- A 1 ft × 1 ft plate electrode with two sides exposed meets the minimum 2 ft² surface area requirement.

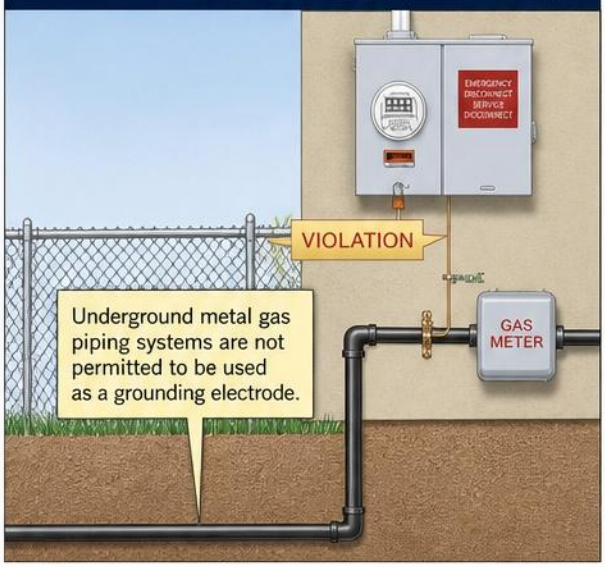
(8) Metal Underground Systems. Metal underground piping and metal well casings that are not linked to a metal water pipe can function as a grounding electrode. Figure 250–120

Figure 250–120 Metal Underground System Electrode 250.52(A)(8)

(B) Not Permitted to Serve as a Grounding Electrode.

(1) Underground metal gas piping systems Figure 250–121

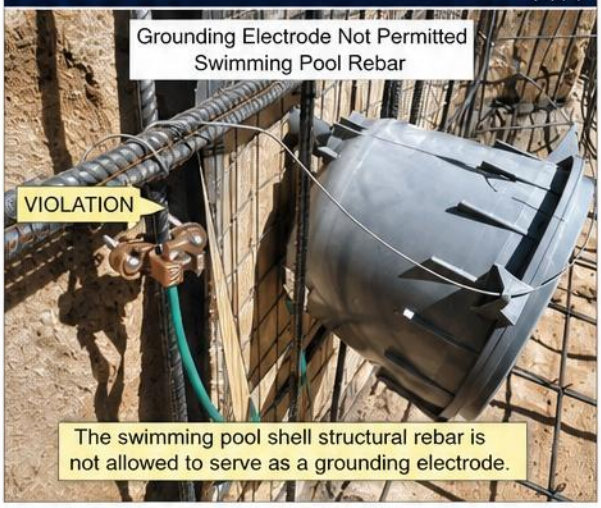
Figure 250–121 Grounding Electrode Not Permitted Underground Gas Piping 250.52(B)(1)



(2) Aluminum

(3) Swimming pool shell structural rebar Figure 250–122

FIGURE 250–122 250.52(B)(3)



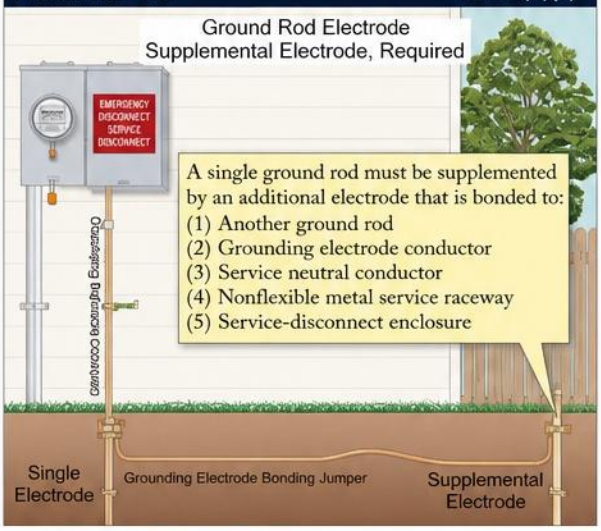
Example: A single ground rod or plate electrode having a contact resistance to the earth of 25 ohms or less is not required to have a supplemental electrode.

250.53 GROUNDING ELECTRODE INSTALLATION

(A) Ground Rods. Ground rods, pipes, and plate electrodes must be free from nonconductive coatings such as paint or enamel.

(2) Supplemental Electrode. A single ground rod or plate electrode must be supplemented by an additional electrode that is bonded to:
Figure 250–123.

FIGURE 250–123 250.53(A)(2)



(1) Another ground rod

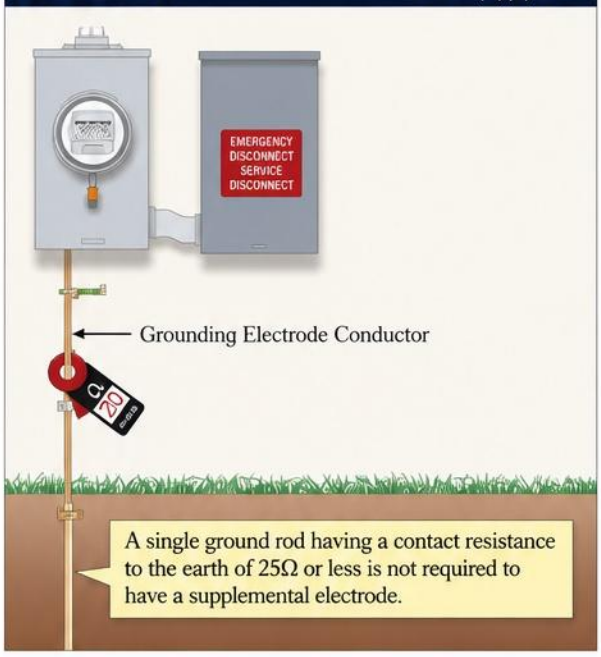
(2) Grounding electrode conductor

(3) Service neutral conductor

(4) Nonflexible metal service raceway

(5) Service-disconnect enclosure

FIGURE 250–124 250.53(A)(2) Ex



Example: A single ground rod or plate electrode having a contact resistance to the earth of 25 ohms or less is not required to have a supplemental electrode.

Measuring Contact Resistance of Electrodes to Earth

Soil Resistivity. The contact resistance of an electrode to the earth is influenced by soil resistivity, which can change widely around the world. Soil resistivity is affected by electrolytes—namely moisture, minerals, and dissolved salts. Since soil resistivity varies with moisture content, the contact resistance of a grounding system to earth will also change with the seasons. A ground resistance clamp meter or a three-point fall-of-potential ground resistance meter can be used to determine the contact resistance of a grounding electrode to the earth.

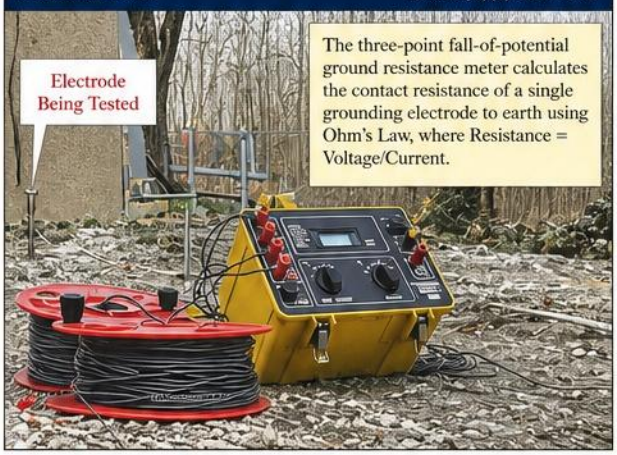
Ground Resistance Clamp Meter. A ground resistance clamp meter measures the contact resistance of the grounding electrode system to earth by injecting a high-frequency signal through the service neutral conductor to the serving electric utility's grounding system, then measuring the strength of the return signal through the earth back to the grounding electrode being tested. Figure 250–125.

Figure 250–125 Measuring Contact Resistance of Electrodes to Earth Using Ground Resistance Clamp Meter *250.53(A)(2) Comment*

The clamp meter determines the contact resistance of the grounding electrode system to earth by applying a high-frequency signal to the utility grounding and then measuring the strength of the return signal.

Fall-of-Potential Ground Resistance Meter. The three-point fall-of-potential ground resistance meter establishes the contact resistance between a single grounding electrode and earth in accordance with Ohm's Law, where Resistance = Voltage/Current (R = E/I). **Figure 250–126**

Figure 250–126 Measuring Contact Resistance of Electrodes to Earth Using Fall-of-Potential Ground Resistance Meter 250.53(A)(2) Comment



This test meter determines ground resistance by dividing the voltage between the electrode under test and the potential (P) stake by the current flowing between the electrode and the current (C) stake. Both test stakes are typically ¾-inch diameter steel rods, 24 inches long, driven to roughly two-thirds of their length into the soil. The placement and alignment of these stakes are essential for accurate results. For an 8-foot ground rod, standard practice is to drive the current stake (C) about 80 feet from the electrode. The potential stake (P) is positioned in line between them—approximately 62% of the total distance, or about 50 feet from the electrode. The three-point fall-of-potential test measures only one electrode at a time, and that electrode must be isolated from the electrical system. If two electrodes are connected together, they must be separated prior to testing. When two electrodes are spaced far enough apart that their resistance areas do not overlap, their combined resistance can be treated as two resistors in parallel.

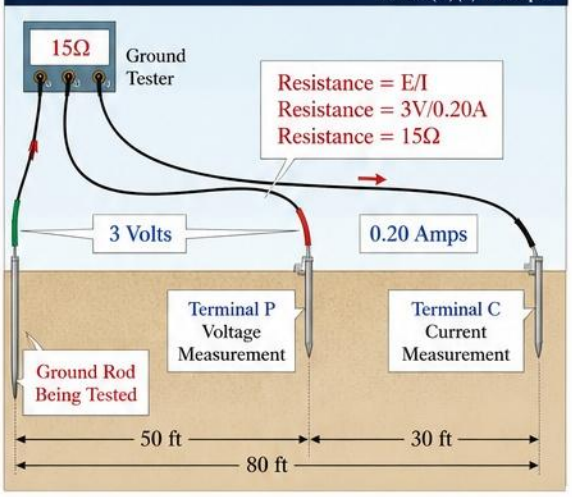
The fall-of-potential test evaluates only one electrode at a time, and that electrode must be isolated from the electrical system. If two electrodes are connected together, they must be separated before testing. When two electrodes are spaced far enough apart that their resistance areas do not overlap, their combined resistance can be treated as two resistors in parallel.

3-Point Fall-of-Potential Method Example

Question: *If the voltage between the ground rod and the voltage test stake (P) is 3V, and the current between the ground rod and the current test stake (C) is 0.20A, what will be the Earth contact resistance of the electrode to the Earth?* **Figure 250–127**

(a) 5 ohms *(b) 10 ohms* *(c) 15 ohms* *(d) 20 ohms*

Figure 250–127 Measuring Contact Resistance of Electrodes to Earth—3-Point Fall Potential Method Example 250.53(A)(2) Example



Solution:

Resistance = Voltage/Current

Voltage = 3V

Current = 0.20A

Resistance = 3V/0.20A
Resistance = 15 ohms

Answer: *(c) 15 ohms*

(3) Supplemental Ground Rod, Spacing. A ground rod serving as a supplemental electrode must be at least 6 ft apart from the other ground rod. **Figure 250–128**

Figure 250–128 Ground Rod Electrode Supplemental Electrode, Spacing 250.53(A)(3)

Supplemental ground rods must be separated by a minimum of 6 ft.

Note: The paralleling efficiency of rods is increased by spacing them twice the length of the longest rod.

(4) Rod Electrodes. Rod electrodes must be installed in accordance with the following:

(a) Ground rods must be driven to a depth of not less than 8 ft in contact with the soil.

(b) The ground rod must be driven vertically to a depth not less than 8 ft.

Ex 1: Where rock bottom is encountered, the ground rod can be driven at an angle not to exceed 45 degrees.

Ex 2: Where rock bottom is encountered at an angle of 45 degrees, the ground rod can be placed in a trench that is at least 30 in. deep. 250–129

Figure 250–129 Ground Rod Electrode 8 Ft of Earth Contact 250.53(A)(4)

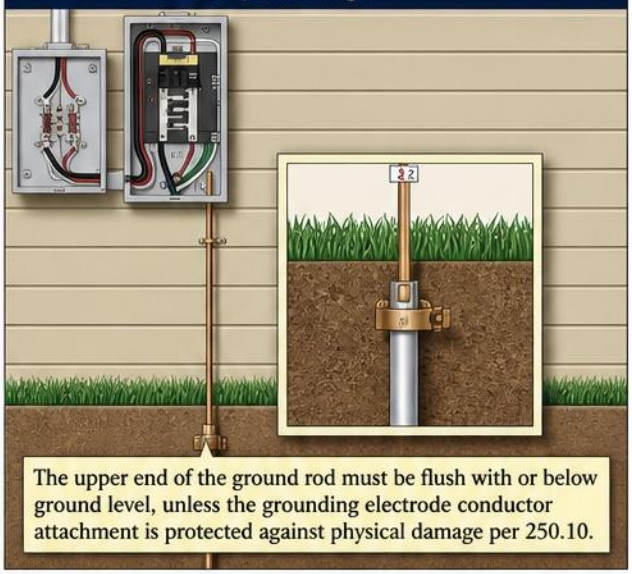
A The ground rod must be driven vertically to a depth not less than 8 ft in contact with the soil [250.53(A)(4)(a) and (b)].

B Where rock bottom is encountered, the ground rod can be driven at an angle not to exceed 45 degrees [250.53(A)(4)(b) Ex 1].

C Where rock bottom is encountered at an angle of 45 degrees, the ground rod can be placed in a trench that is at least 30 in. deep [250.53(A)(4)(b) Ex 2].

(c) The upper end of the ground rod must be flush with or below ground level, unless the grounding electrode conductor attachment is protected against physical damage as determined to the AHJ as specified in 250.10 250–130

Figure 250–130 Ground Rod Electrode Protection from Physical Damage 250.53(A)(4)(c)

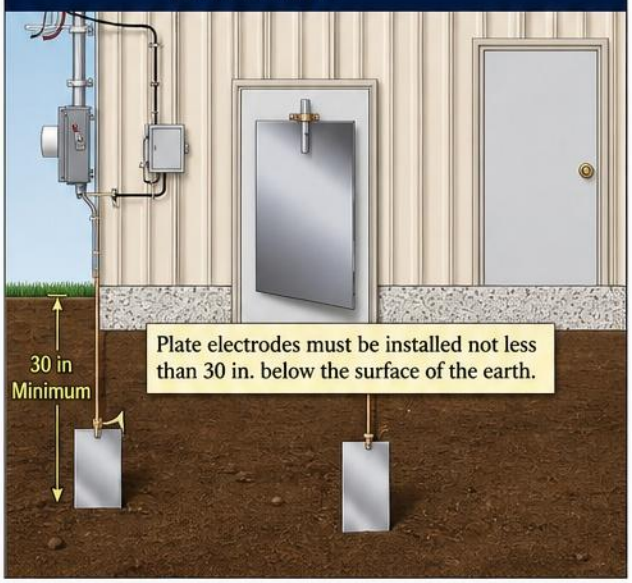


Author's Comment:

- When the grounding electrode attachment fitting is underground (below ground level), it must be listed for direct soil burial [250.70(A)].

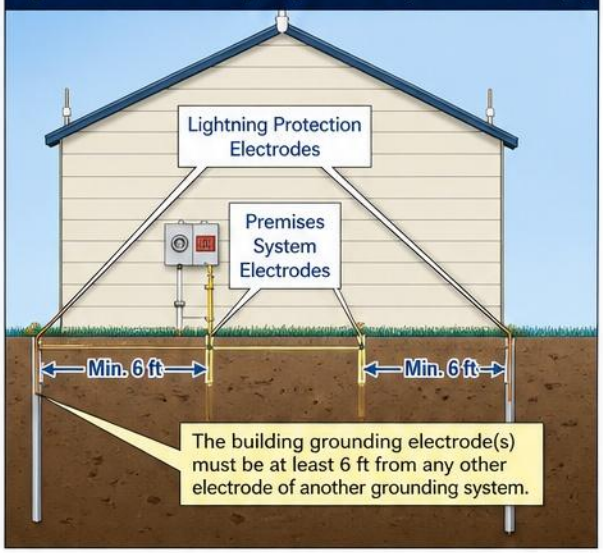
(5) Plate Electrode. Plate electrodes must be installed not less than 30 in. below the surface of the earth. 250–131

Figure 250–131 Plate Electrode 30 in. Below Earth 250.53(A)(5)



(B) Electrode Spacing. The building grounding electrode(s) must be at least 6 ft from any other electrode of another grounding system. Figure 250–132

Figure 250–132 Electrode Spacing from Other Systems 250.53(B)



Building grounding electrodes are spaced not less than 6 ft from any other electrode of a different grounding system.

(C) Grounding Electrode Bonding Jumper.

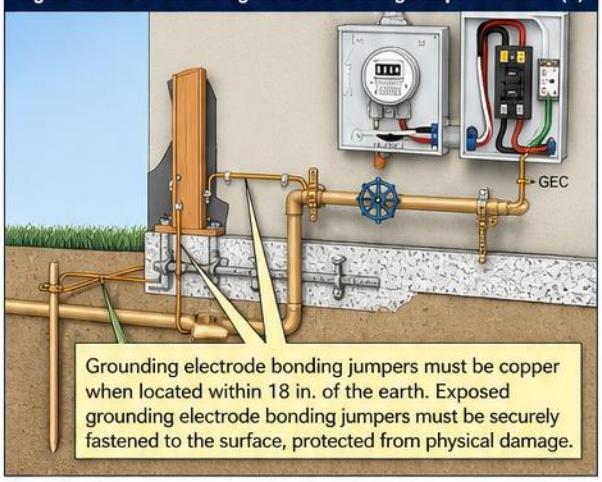
Copper. Grounding electrode bonding jumpers must be copper when located within 18 in. of the earth [250.64(A)].

Physical Damage. Exposed grounding electrode bonding jumpers must be securely fastened to the surface and protected from physical damage [250.64(B)].

Bonding. Grounding electrode bonding jumpers installed in metal raceways must be bonded at both ends [250.64(C)].

Sizing. Grounding electrode bonding jumpers must be sized in accordance with 250.66. Figure 250–133

Figure 250–133 Grounding Electrode Bonding Jumper 250.53(C)



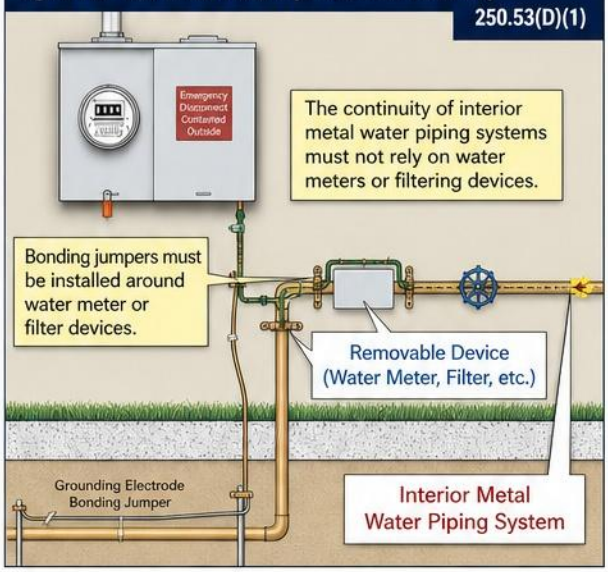
Copper bonding jumpers near the earth, secured and protected from physical damage.

Concrete or Direct Buried. When the grounding electrode bonding jumper termination is encased in concrete of direct buried, the termination fittings must be listed for this purpose [250.70(A)].

(D) Underground Metal Water Pipe Electrode.

(1) Continuity. The continuity of interior metal water piping systems must not rely on water meters or filtering devices. Figure 250–134

Figure 250–134 Metal Water Pipe Electrode Continuity 250.53(D)(1)



Bonding jumpers around meters or filters maintain continuity of interior metal water piping.

(2) Water Pipe Supplemental Electrode. When an underground metal water pipe grounding electrode is present, it must be supplemented by one of the following electrodes:

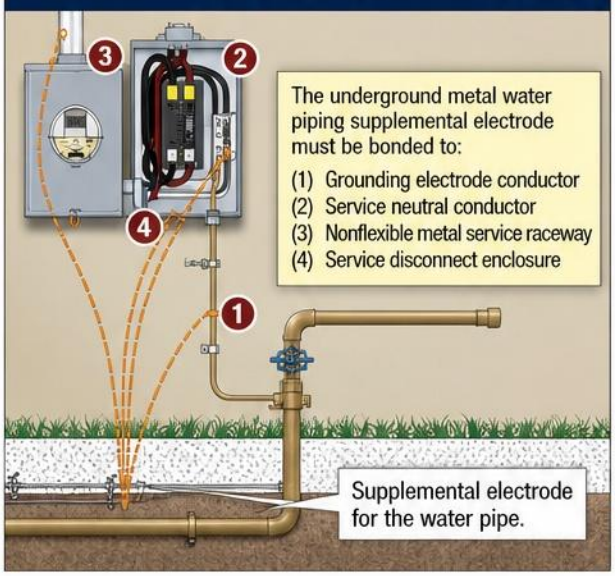
- Metal frame of the building electrode [250.52(A)(2)]
- Concrete-encased electrode [250.52(A)(3)]
- Rod electrode [250.52(A)(5)]
- Other type of listed electrode [250.52(A)(6)]
- Metal underground piping electrode [250.52(A)(8)]

The grounding electrode conductor for the underground metal water piping supplemental electrode must be bonded to: Figure 250–135

(1) Grounding electrode conductor
(2) Service neutral conductor
(3) Nonflexible metal service raceway
(4) Service-disconnect enclosure

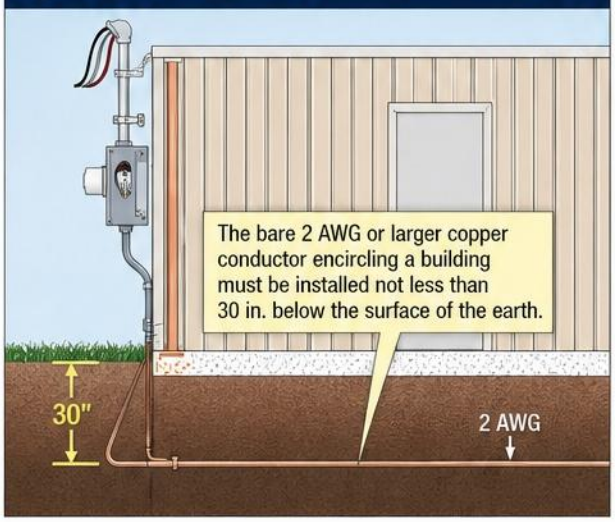
(E) Supplemental Ground Rod Bonding Jumper Size. The grounding electrode bonding jumper to a ground rod that serves as an underground metal water pipe supplemental electrode is not required to be larger than 6 AWG copper.

Figure 250–135 Supplemental Electrode for the Water Pipe. 250.53(D)(2)



(F) Ground Ring. A bare 2 AWG or larger copper conductor that encircles a building [250.52(A)(4)] must be installed no less than 30 in. below the earth's surface. This conductor serves as the ground ring. 250–136

Figure 250–136 Ground Ring Electrode 250.53(F)



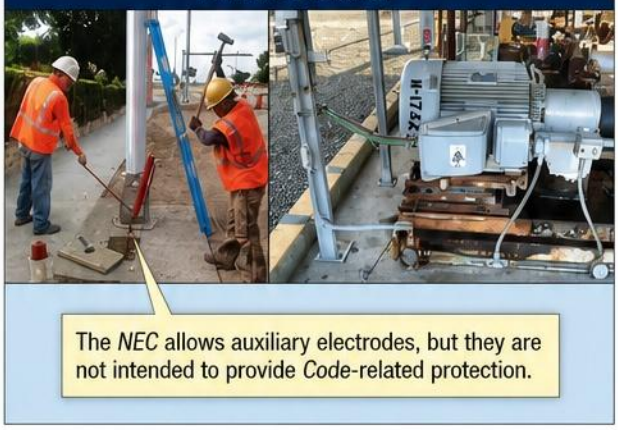
250.54 Auxiliary Grounding Electrodes

Grounding electrodes may be connected to metal parts of electrical equipment. They are not required to meet the electrode bonding requirements of 250.50 or 250.53(C) or the resistance requirements of 250.53(A)(2) Ex.

AUTHOR'S COMMENT:

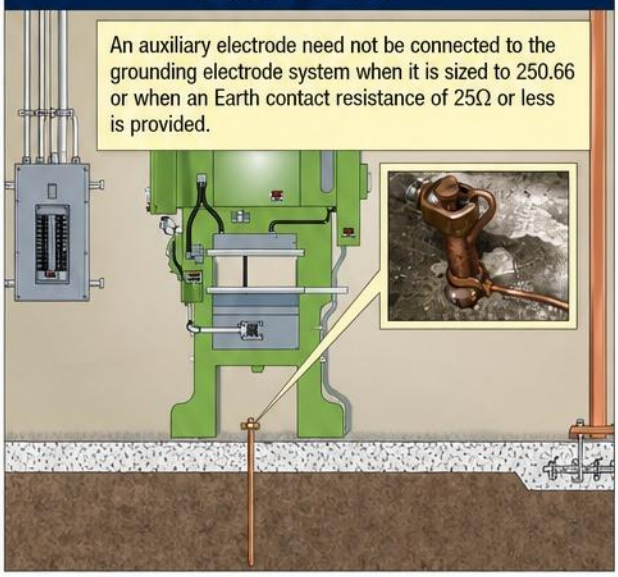
- Grounding electrodes that are not required by the NEC are known as "auxiliary electrodes" and are connected to equipment grounding conductors. Because they do not serve an electrical safety purpose related to the electrical safety addressed by the Code, they have no NEC requirements. 250–137

Figure 250–137 Auxiliary Grounding Electrodes *Author's Comment*



- When an auxiliary electrode is present, it is not necessary to connect it to the building grounding electrode system. However, if the grounded conductor is sized to 250.66 or complies with the 25 ohm single ground rod requirement of 250.53(A)(2) Ex, it is permitted to be connected. 250–138

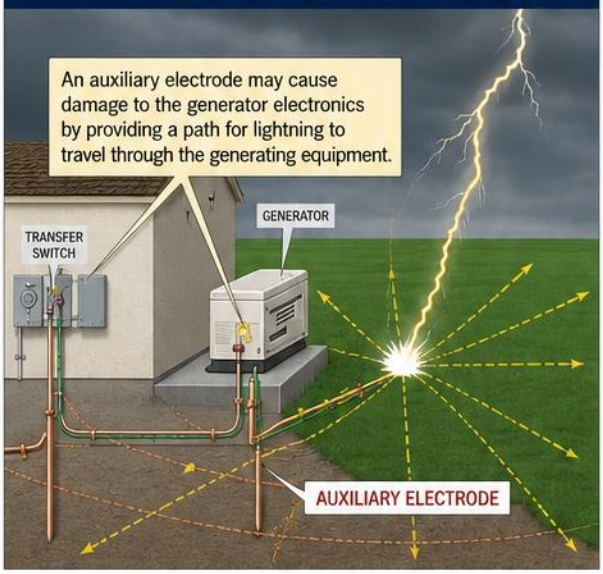
Figure 250–138 Auxiliary Grounding Electrodes *Author's Comment*



CAUTION: An auxiliary electrode may cause damage to the generator electronics or CNC machines by providing a path for lightning to travel through the equipment.

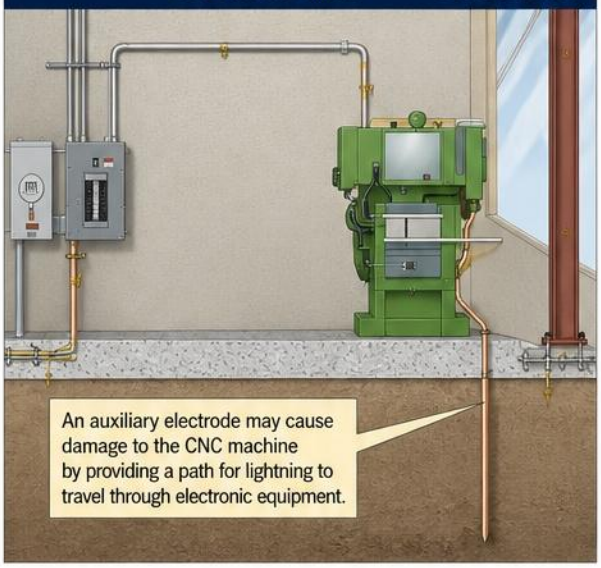
See Figure 250–139 and Figure 250–140.

Figure 250–139 Auxiliary Grounding Electrodes Generator Failure 250.54 Caution



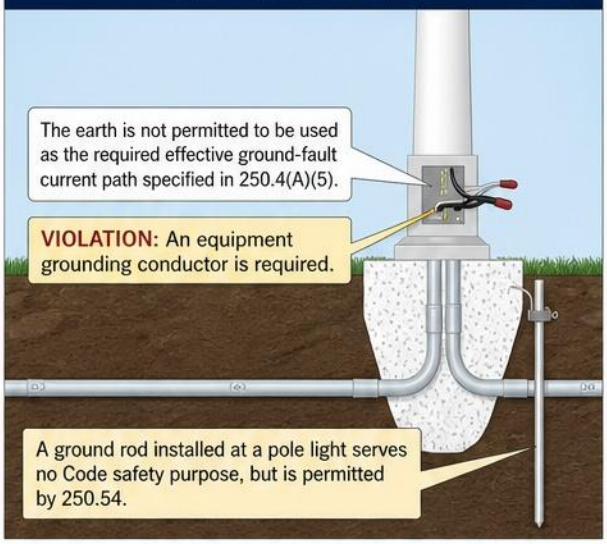
An auxiliary electrode can introduce lightning energy into the generator system through the grounding path, which may damage sensitive electronics.

Figure 250–140 Auxiliary Grounding Electrodes CNC Machine Failure 250.54 Caution



An auxiliary electrode can allow lightning energy to travel into CNC machinery through the grounding system, which may damage electronic components.

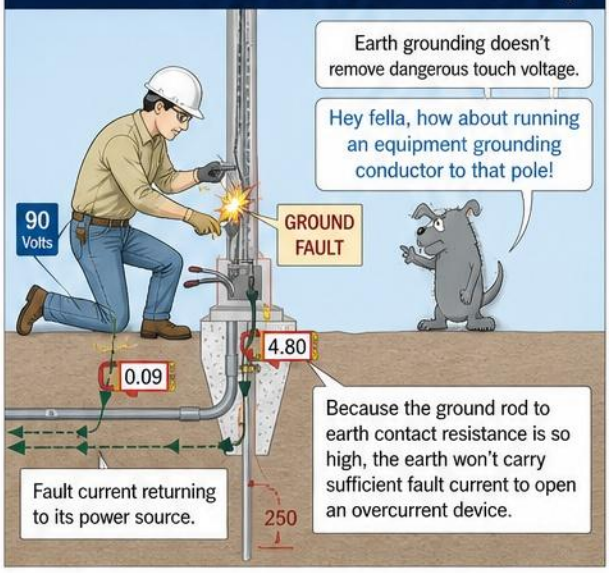
Figure 250–141 Auxiliary Grounding Electrode Earth Not Suitable as EGFCP 250.54



The soil cannot be relied upon as the effective ground-fault current path required by 250.4(A)(5).

DANGER: Because the contact resistance of an electrode to the earth is so great, little fault current returns to the source if the earth is the only fault-current return path. As a result, the circuit overcurrent protective device will not open and clear the ground fault. All metal parts associated with the electrical installation, metal piping, and structural building steel will become and remain energized. See Figure 250–142.

Figure 250–142 Auxiliary Grounding Electrode Earth Not Suitable as EGFCP 250.54 Danger

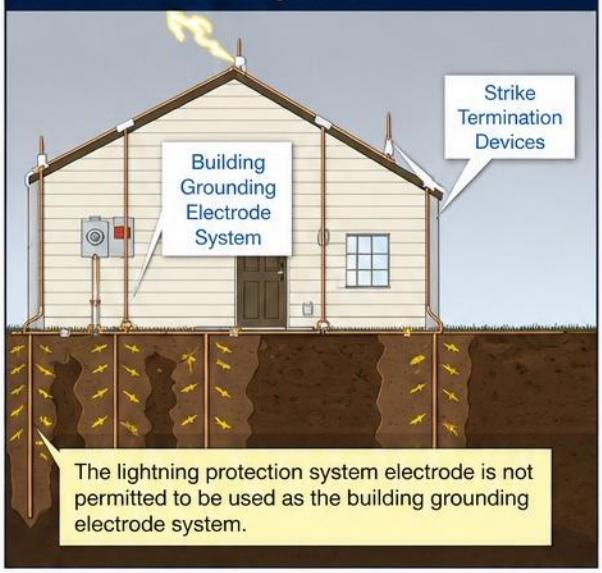


High earth contact resistance prevents enough fault current from returning to trip an overcurrent device.

250.60 Lightning Protection Electrode

The lightning protection system electrode is not allowed to be used for the building grounding electrode required for service equipment [250.24(A)(1)], separately derived systems [250.30], or building feeder disconnect [250.32(A)].

Figure 250–143 250.60
Lightning Protection Electrode
Not Permitted for Grounding Electrode



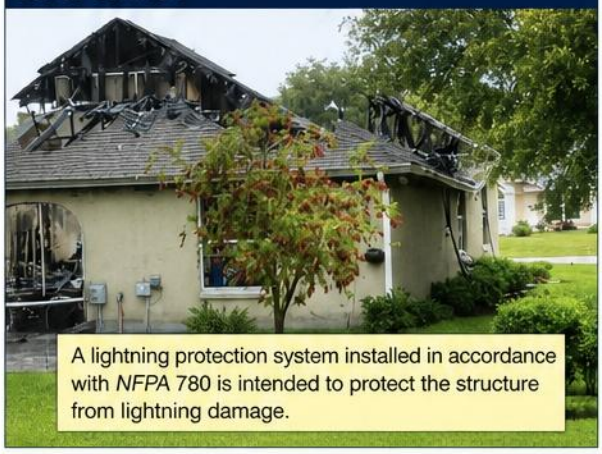
This illustration shows a lightning protection system with down conductors and electrodes. That electrode system cannot be used as the building grounding electrode system.

Note 1: For the bonding requirements of the lightning protection system to the building grounding electrode system, see 250.106.

Author's Comment:

- According to *NFPA 780*, a lightning protection system is intended to protect the structure from lightning damage [Figure 250–144].

Figure 250–144 NFPA 780
Lightning Protection System
250.60 Comment



250.64 Grounding Electrode Conductor Installation

(A) Aluminum or Copper-Clad Aluminum Conductors.

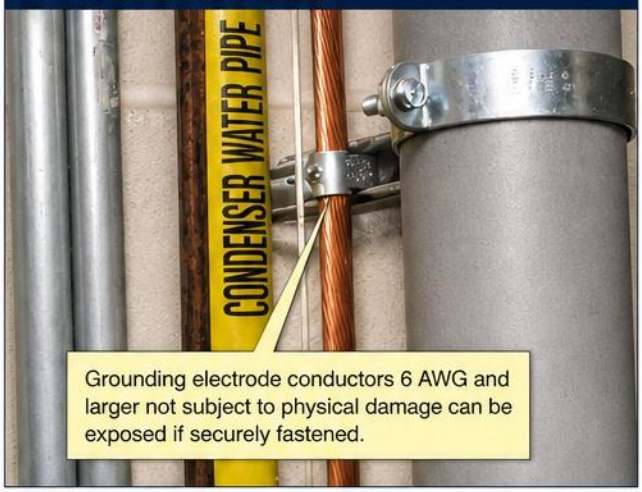
(1) Aluminum or copper-clad aluminum grounding electrode conductors are not permitted where they may be subject to corrosive conditions or to direct contact with concrete.

(3) Aluminum or copper-clad aluminum grounding electrode conductors are not permitted to terminate within 18 in. of the earth.

(B) Conductor Protection. Exposed grounding electrode conductors must be securely fastened to the surface on which they are carried.

(1) Not Exposed to Physical Damage. Grounding electrode conductors 6 AWG and larger that are not subject to physical damage can be exposed if securely fastened [Figure 250–145].

Figure 250–145
Grounding Electrode Conductor
Not Exposed to Physical Damage 250.64(B)(1)



(2) Exposed to Physical Damage. Grounding electrode conductors 6 AWG and larger exposed to physical damage as determined by the AHJ must be installed in rigid metal conduit, intermediate metal conduit, electrical metallic tubing, Schedule 80 polyvinyl chloride conduit, or cable armor [Figure 250–146].

(3) Grounding Electrode Conductors 8 AWG. Grounding electrode conductors 8 AWG and smaller must be installed in rigid metal conduit, intermediate metal conduit, electrical metallic tubing, Schedule 80 polyvinyl chloride conduit, or cable armor.

Author's Comment:

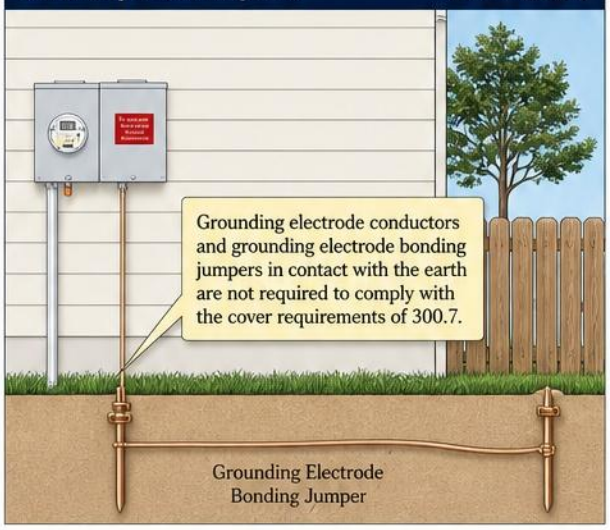
- Where grounding electrode conductors are installed in metal raceways, they must be bonded at both ends of the raceway [250.64(E)].

Figure 250–146 Grounding Electrode Conductor Exposed to Physical Damage 250.64(B)(2)

Grounding electrode conductors 6 AWG and larger exposed to physical damage must be installed in RMC, IMC, EMT, schedule 80 PVC, or cable armor.

(4) Burial Depth Not Required. Grounding electrode conductors and grounding electrode bonding jumpers in contact with the earth are not required to comply with the burial cover requirements of 300.7. **Figure 250–147**

Figure 250–147 Grounding Electrode Conductor Burial Depth Not Required 250.64(B)(4)



(C) Continuous. Grounding electrode conductors must be installed without a splice or joint except as permitted by the following:

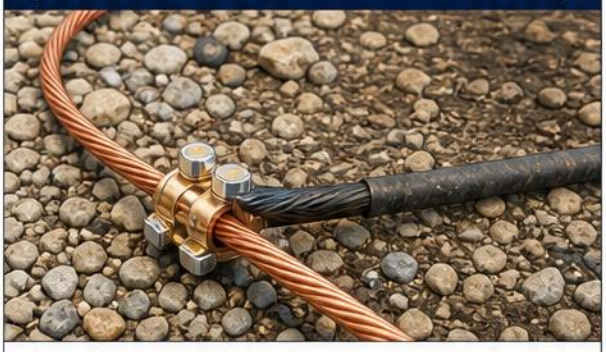
(1) Irreversible compression-type connectors or exothermic welding **Figure 250–148**

(2) Listed grounding and bonding equipment at accessible locations

(3) Busbars connected together

(4) Bolted, riveted, or welded connections to the structural metal frames of buildings

Figure 250–148 Grounding Electrode Conductor Splice or Joint Permitted 250.64(C)(1)



Grounding electrode conductors can be spliced or joined with irreversible compression-type connectors or exothermic welding.

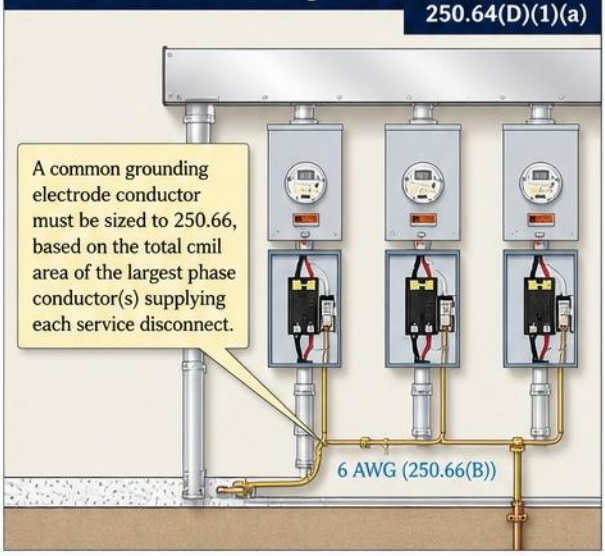
(5) Threaded, welded, brazed, soldered, or bolted-flange connections to metal water piping

(D) Multiple Disconnect Enclosures. If a building contains two or more service disconnects or building feeder disconnects, the grounding electrode connections must comply with 250.64(D)(1), (D)(2), or (D)(3).

(1) Common Grounding Electrode Conductor and Taps. Common grounding electrode conductors and grounding electrode conductor taps are as follows:

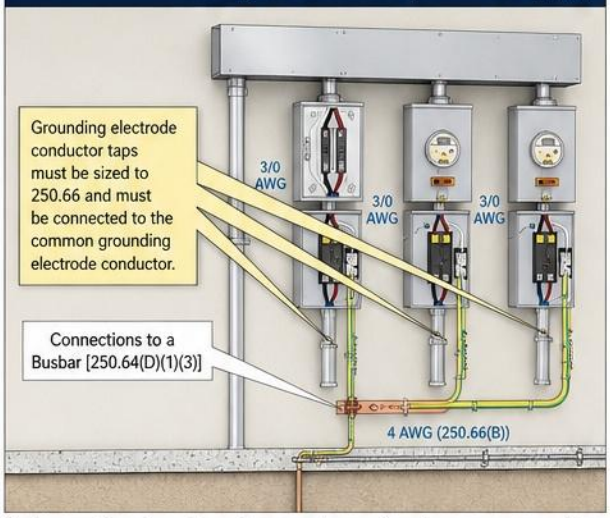
(a) Common Grounding Electrode Conductor. A common grounding electrode conductor must be sized in accordance with 250.66, based on the total cmil area of the largest phase conductor(s) supplying each service disconnect. **Figure 250–149**

Figure 250–149 Grounding Multiple Service Disconnect Enclosures Common Grounding Electrode Conductor 250.64(D)(1)(a)



(b) Grounding Electrode Conductor Taps. The grounding electrode conductor taps from each disconnect enclosure must be sized in accordance with 250.66 and connected to the common grounding electrode conductor.

Figure 250–150 Grounding Multiple Service Disconnect Enclosures Grounding Electrode Conductor Taps 250.64(D)(1)(b)



Each grounding electrode conductor tap is routed to the common grounding electrode conductor via the busbar connection.

Grounding electrode conductor taps must be connected to the common grounding electrode by any of the following methods:

(1) Exothermic welding

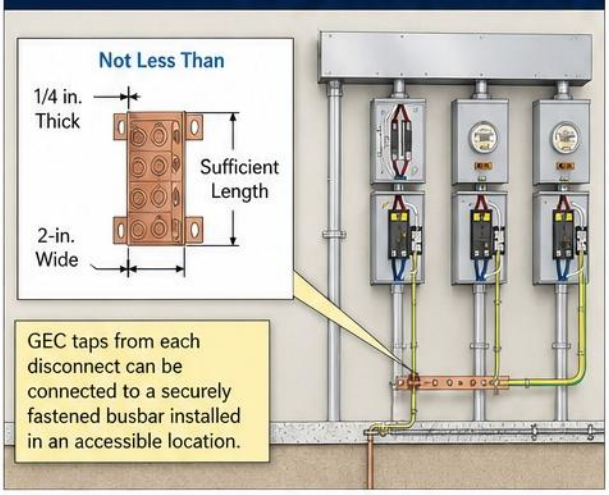
(2) Connectors listed as grounding and bonding equipment

(3) Connections to a busbar are as follows:

a. Busbars must not be less than ¼ in. thick × 2 in. wide

b. Busbars must be securely fastened and installed in an accessible location

Figure 250–151 Grounding Multiple Service Disconnect Enclosures Grounding Electrode Conductor Busbar 250.64(D)(1)(b)(3)(a) and (b)



Busbars must meet the minimum thickness and width and be securely mounted in a location that is readily accessible.

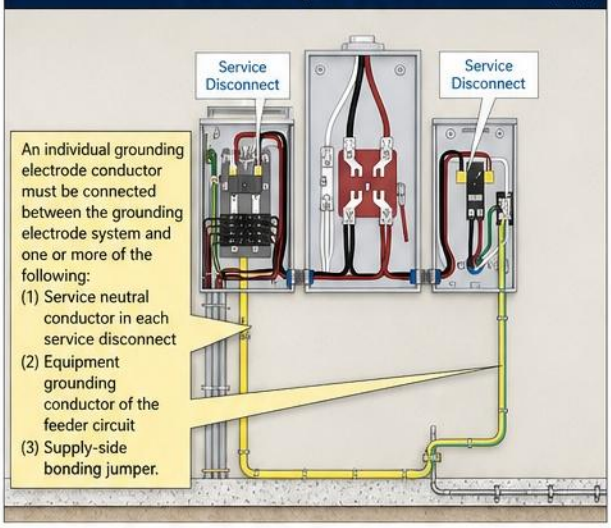
(2) Individual Grounding Electrode Conductors. An individual grounding electrode conductor must be connected between the grounding electrode system and one or more of the following:

(1) Service neutral conductor in each service disconnect

(2) Equipment grounding conductor of the feeder circuit

(3) Supply-side bonding jumper

Figure 250–152 Grounding Multiple Service Disconnect Enclosures Individual Grounding Electrode Conductor 250.64(D)(2)



The individual grounding electrode conductor provides a direct path between the grounding electrode system and the specified connection points.

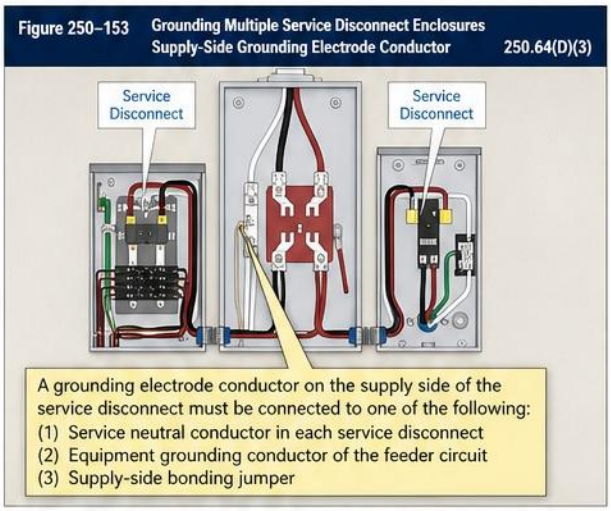
(3) Supply Side of Disconnects. A grounding electrode conductor on the supply side of the service disconnect must be sized in accordance with 250.66 based on the largest phase conductor(s) supplying the service. It must be connected to one of the following:

(1) Service neutral conductor in each service disconnect

(2) Equipment grounding conductor of the feeder circuit

(3) Supply-side bonding jumper

Figure 250–153 Grounding Multiple Service Disconnect Enclosures Supply-Side Grounding Electrode Conductor 250.64(D)(3)



The supply-side grounding electrode conductor must be connected to one of the listed points to ensure proper grounding and bonding of the service equipment.

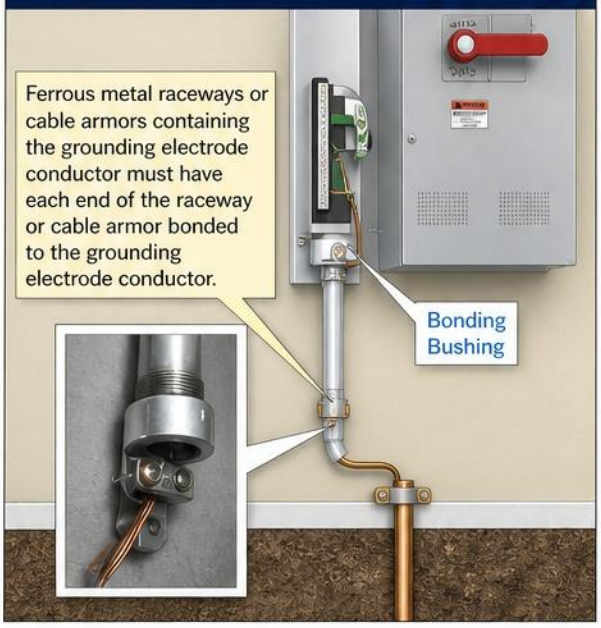
(E) Ferrous Raceway or Cable Armor Containing the Grounding Electrode Conductor

(1) General. Raceways or cable armor that contain grounding electrode conductors must comply with the following:

(a) Ferrous metal raceways or cable armor for grounding electrode conductors must comply with the following:

(3) Ferrous metal raceways or cable armor containing the grounding electrode conductor must have each end of the raceway or cable armor bonded to the grounding electrode conductor. Figure 250–154

Figure 250–154 250.64(E)(1)(a)(3)



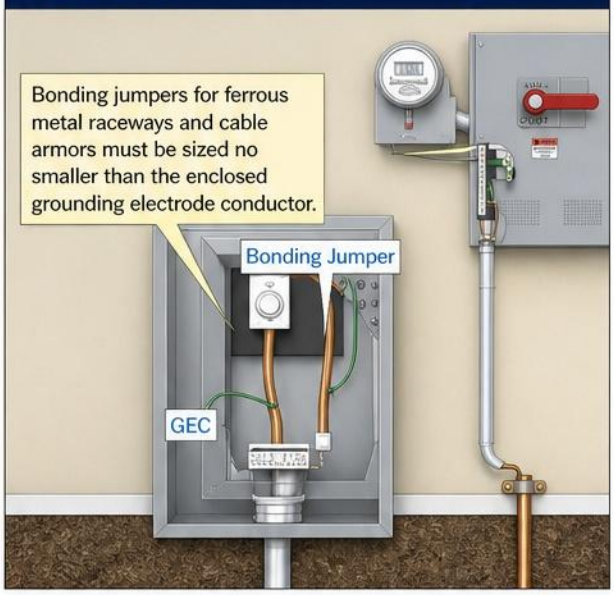
(2) Bonding Methods. Ferrous metal raceways or cable armors must be bonded in accordance with 250.92(B)(2) through (B)(4).

(3) Bonding Jumper Size. Bonding jumpers for ferrous metal raceways and cable armor must be sized no smaller than the enclosed grounding electrode conductor. Figure 250–155

Author's Comment:

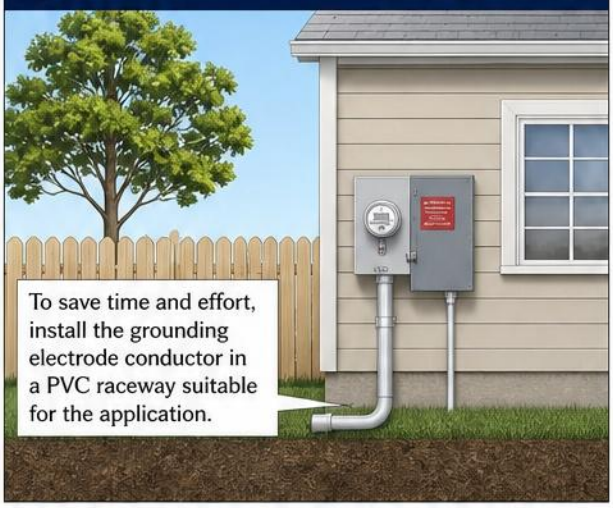
- Nonferrous metal raceways enclosing the grounding electrode conductor, such as aluminum rigid metal conduit, are not required to meet the "bonding each end of the raceway to the grounding electrode conductor" provisions of this section.
- To save time and effort, install the grounding electrode conductor in a PVC raceway suitable for the application. Schedule 40 PVC can be used for exposed work [352.10(G)], but Schedule 80 PVC is required in areas subject to physical damage [250.64(B)(2)(3) and 352.10(K)]. Figure 250–156

Figure 250–155 250.64(E)(3)



Bonding jumpers must be sized at least as large as the enclosed grounding electrode conductor.

Figure 250–156 250.64(E) Comment



Using PVC raceway provides a durable and code-compliant solution for routing the grounding electrode conductor.

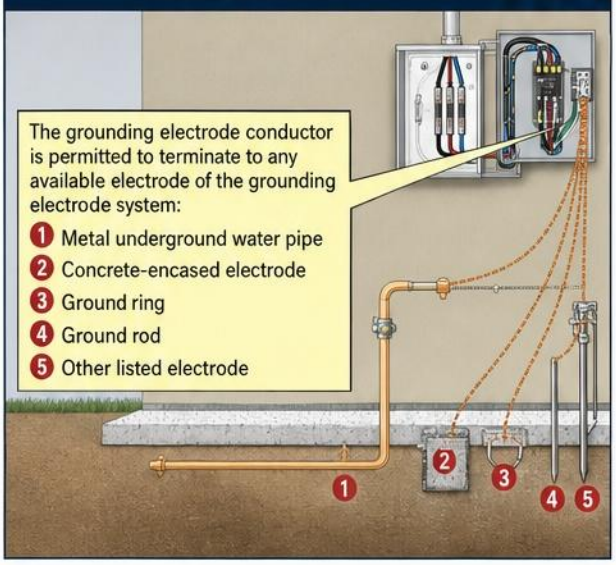
(F) Termination to Grounding Electrode

(1) Single Grounding Electrode Conductor. The single grounding electrode conductor can terminate to any grounding electrode of the grounding electrode system. Figure 250–157

(2) Multiple Grounding Electrode Conductors. Where multiple grounding electrode conductors are installed, each one can terminate to any grounding electrode of the grounding electrode system.

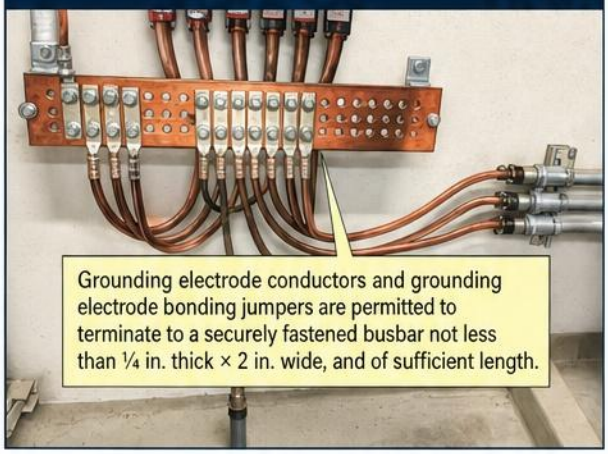
(3) Termination to Busbar. Grounding electrode conductors and grounding electrode bonding jumpers are permitted to terminate to a busbar not less than ¼ in. thick × 2 in. wide and of sufficient length. The busbar must be securely fastened and installed in an accessible location. Figure 250–158

Figure 250–157 Grounding Electrode Conductor Termination 250.64(F)(1)



The grounding electrode conductor may be connected to any accessible electrode that is part of the grounding electrode system, including a metal underground water pipe, concrete-encased electrode, ground ring, ground rod, or other listed electrode.

Figure 250–158 Grounding Electrode Conductor Termination to Busbar 250.64(F)(3)



Grounding electrode conductors and grounding electrode bonding jumpers may be connected to a solidly mounted busbar that is at least ¼ in. thick, 2 in. wide, and long enough to accommodate the connections.

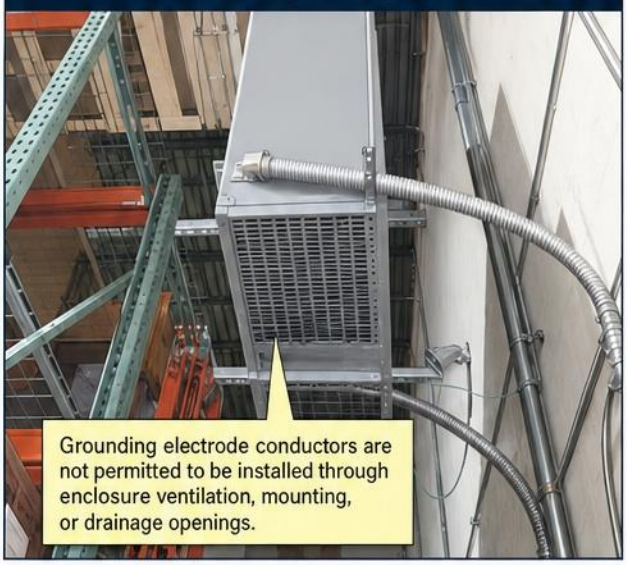
(G) Enclosures with Ventilation, Mounting, or Drainage Openings.

Grounding electrode conductors are not permitted to be installed through enclosure ventilation, mounting, or drainage openings. 250–159

Author's Comment:

- The terminal bar for grounding and bonding conductors within a transformer enclosure must not be installed over any vented portions of the enclosure in accordance with 450.12(A).

Figure 250–159 Grounding Electrode Conductor in Enclosures: Ventilation, Mounting, or Drainage Openings 250.64(G)



Grounding electrode conductors are not allowed to pass through enclosure ventilation holes, mounting slots, or drainage openings.

250.66 Sizing Grounding Electrode Conductors

Except as permitted in 250.66(A) through (C), grounding electrode conductors and grounding electrode bonding jumpers must be sized in accordance with Table 250.66.

▶ Grounding Electrode Conductor Size [Table 250.66] Service Equipment Example 1

Question: *What size grounding electrode conductor is required for a 400A, three-phase, 120/208V service disconnect when the service conductors are sized at 600 kcmil copper?* 250–160

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

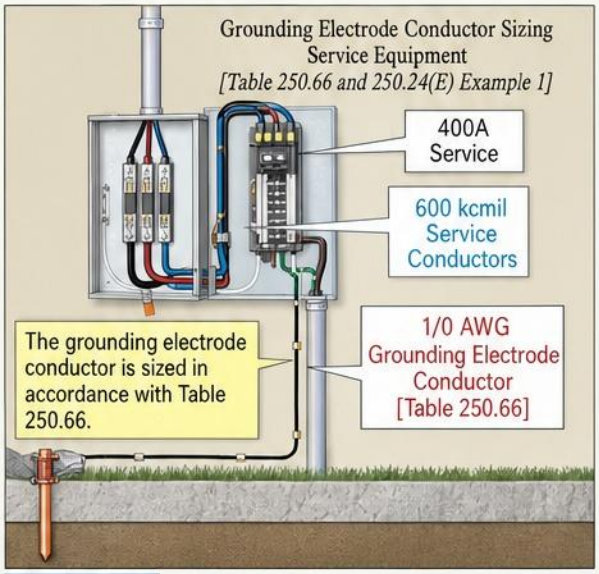


Figure 250–160

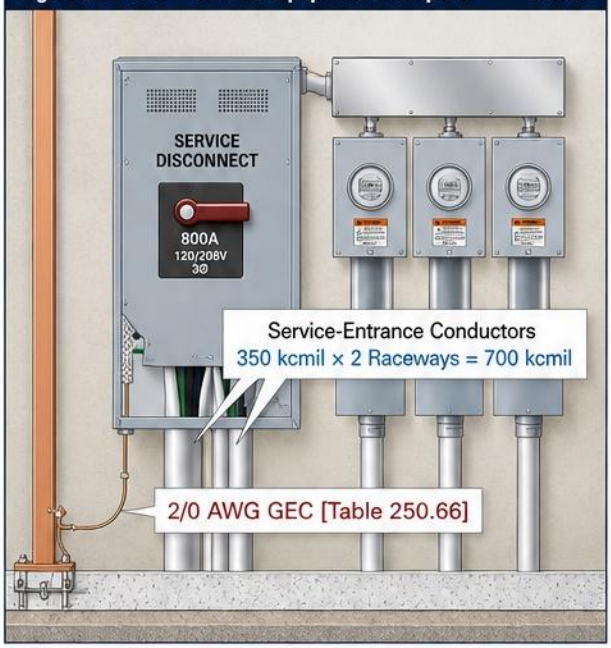
Answer: (a) 1/0 AWG

▶ Grounding Electrode Conductor Size [Table 250.66] Service Equipment Example 2

Question: What size grounding electrode conductor is needed for an 800A, three-phase, 120/208V service disconnect when the service conductors are installed in parallel with 2 sets of 350 kcmil copper? ▶ **Figure 250–161**

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

Figure 250–161 Service Equipment Example 2 250.66



The service conductors total 700 kcmil (350 kcmil × 2 sets), so the required grounding electrode conductor is 2/0 AWG.

Answer: *(b) 2/0 AWG*

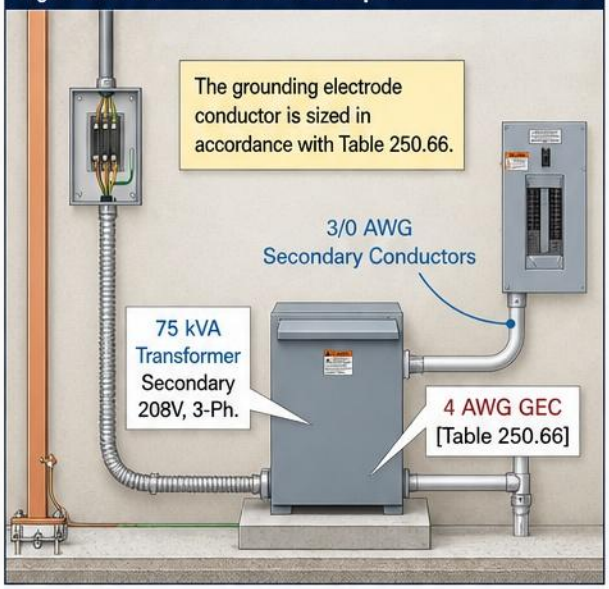
▶ Grounding Electrode Conductor Size [Table 250.66] Transformer Example 1

Question: What size grounding electrode conductor is needed for a 75 kVA, three-phase, 480V to 120/208V transformer when the secondary conductors are sized at 3/0 AWG copper? ▶ **Figure 250–162**

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 3 AWG

Answer: *(c) 4 AWG*

Figure 250–162 Transformer Example 1 250.66



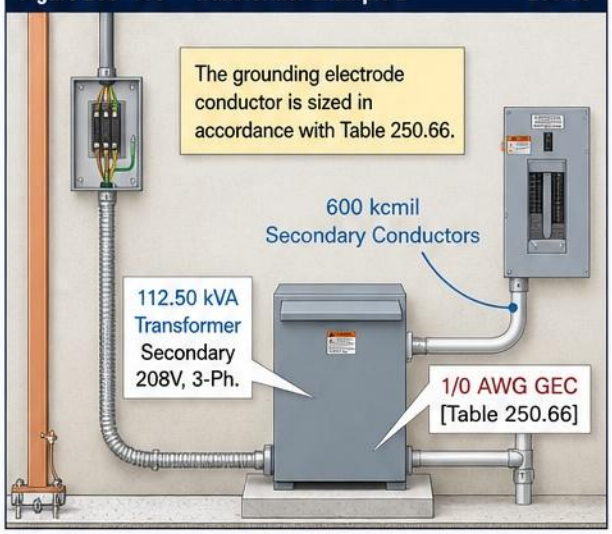
A 75 kVA transformer with secondary conductors of 3/0 AWG requires a 4 AWG grounding electrode conductor per Table 250.66.

▶ Grounding Electrode Conductor Size [Table 250.66] Transformer Example 2

Question: What size grounding electrode conductor is required for a 112.50 kVA, three-phase, 480V to 120/208V transformer when the secondary conductors are sized at 600 kcmil copper? ▶ **Figure 250–163**

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

Figure 250–163 Transformer Example 2 250.66

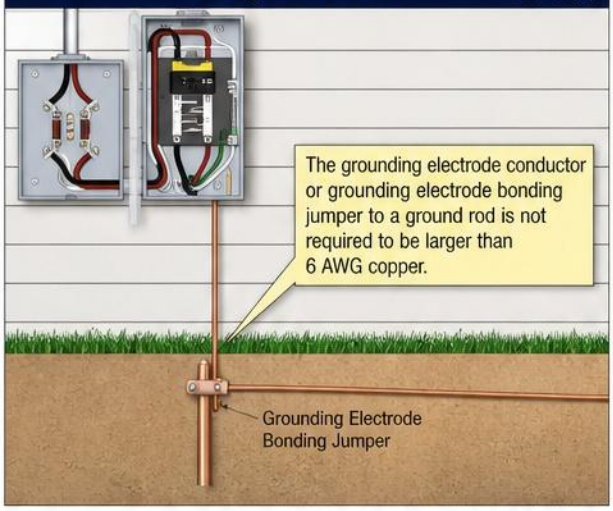


A 112.50 kVA transformer with secondary conductors of 600 kcmil requires a 1/0 AWG grounding electrode conductor per Table 250.66.

Answer: *(a) 1/0 AWG*

(A) Ground Rods. When there is no connection from a ground rod to other types of electrodes, the grounding electrode conductor or grounding electrode bonding jumper to a ground rod is not required to be larger than 6 AWG copper.
▸ Figure 250–164

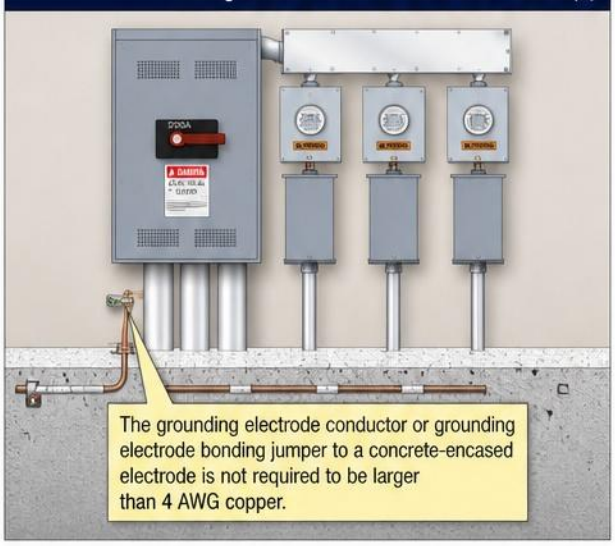
Figure 250–164 Grounding Electrode Conductor, Sizing Ground Rods 250.66(A)



Where no other electrodes are connected to the ground rod, the grounding electrode conductor or bonding jumper to the rod need not exceed 6 AWG copper.

(B) Concrete-Encased Electrodes. When there is no connection from a concrete-encased electrode to other types of electrodes, the grounding electrode conductor or grounding electrode bonding jumper to a concrete-encased electrode is not required to be larger than 4 AWG copper.
▸ Figure 250–165

Figure 250–165 Grounding Electrode Conductor, Sizing Concrete-Encased Electrodes 250.66(B)



In the absence of other electrode connections, the conductor or bonding jumper to a concrete-encased electrode shall not be larger than 4 AWG copper.

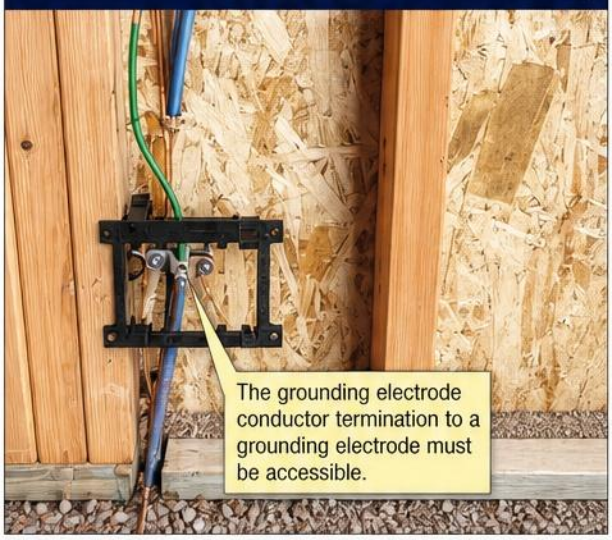
Table 250.66 Grounding Electrode Conductor

AWG or Area of Parallel Copper Conductors	Copper Grounding Electrode Conductor
2 AWG or Smaller 100A or less	8 AWG
1 or 1/0 AWG 125-200A	6 AWG
2/0 or 3/0 AWG 225-300	4 AWG
Over 3/0 through 350 kcmil 350-500A	2 AWG
Over 350 through 600 kcmil 600-800	1/0 AWG
Over 600 through 1100 kcmil 1000	2/0 AWG
Over 1100 kcmil 1200	3/0 AWG

250.68 GROUNDING ELECTRODE CONDUCTOR TERMINATION

(A) Accessibility. The termination of the grounding electrode conductor to a grounding electrode must be accessible.
▸ Figure 250–166

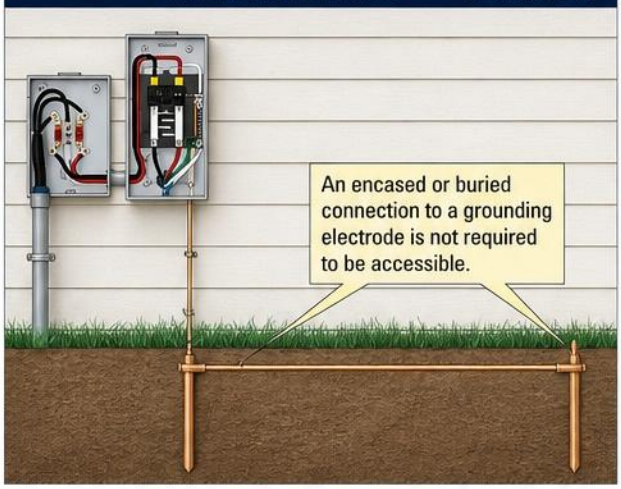
Figure 250–166 Grounding Electrode Conductor Termination Must Be Accessible 250.68(A)



Example: An encased or buried connection to a grounding electrode is not required to be accessible. ▸ Figure 250–167

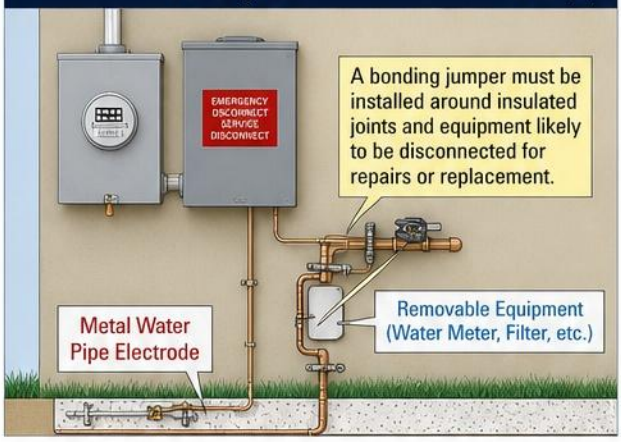
(B) Metal Water Pipe Electrode, Grounding Path. A bonding jumper must be installed around insulated joints and equipment likely to be disconnected for repairs or replacement for an underground water piping system used as a grounding electrode. The bonding jumper must be of sufficient length to allow the removal of such equipment, while retaining the integrity of the grounding path.
▸ Figure 250–168

Figure 250–167 Grounding Electrode Conductor Termination Encased or Buried Electrode 250.68(A) Ex 1



Encased or buried connections to grounding electrodes are not required to be accessible.

Figure 250–168 Metal Water Pipe Electrode Bonding Jumper Grounding Path 250.68(B)



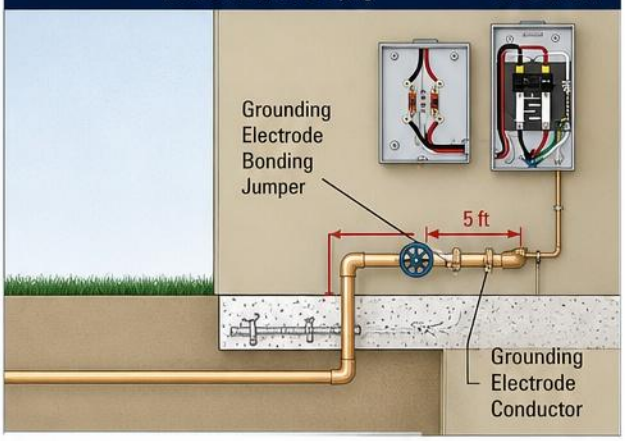
A bonding jumper must be installed around insulated joints and equipment that can be removed for service or replacement.

(C) Grounding Electrode Conductor Extension. Grounding electrode conductors and grounding electrode bonding jumpers are permitted to extend the connection to an electrode at the following locations:

(1) Interior Metal Water Piping. Interior metal water piping that is electrically continuous with an underground metal water pipe electrode and is not more than 5 ft from the point of entrance to the building, as measured along the water piping can be used for the connection of electrodes. ▸ Figure 250–169

(2) Metal Structural Frame. The metal structural frame of a building connected to a grounding electrode can be used for the connection of electrodes. ▸ Figure 250–170 and ▸ Figure 250–171

Figure 250–169 Grounding Electrode Conductor Extension Interior Metal Water Piping 250.68(C)(1)

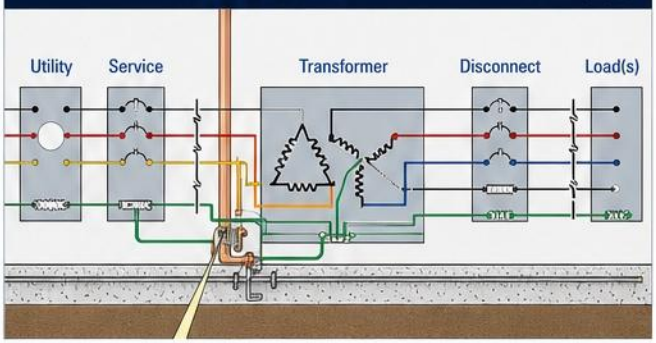


Interior metal water piping that is electrically continuous with an underground metal water pipe electrode and is not more than 5 ft from the point of entrance to the building can be used for the connection of electrodes.

Figure 250–170 Grounding Electrode Conductor Extension Metal Structural Frame 250.68(C)(2)

The metal structural frame of a building connected to a grounding electrode can be used for the interconnection of electrodes.

Figure 250–171 Grounding Electrode Conductor Extension Metal Structural Frame 250.68(C)(2)

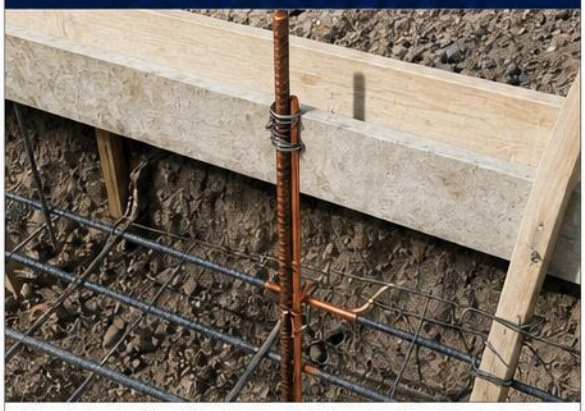


The metal structural frame of a building connected to a grounding electrode can be used for the interconnection of electrodes.

(3) Rebar from Concrete-Encased Electrode. A rebar-type concrete-encased electrode with rebar that is extended to an accessible location above the concrete foundation or footing, where it will not be exposed to corrosion, may be used for the termination of the grounding electrode conductor in the following situations:

(a) The extended rebar is connected to the rebar-type concrete-encased electrode by steel tie wires or other effective means 250.68(C)(3)(a)

Figure 250–172 250.68(C)(3)(a)
Grounding Electrode Conductor Connection
Rebar from Concrete-Encased Electrode



A section of rebar that is extended from a rebar-type concrete-encased electrode can be used to connect the grounding electrode conductor.

(b) The extended rebar from a rebar-type concrete-encased electrode does not make contact with the earth or subject to corrosion 250.68(C)(3)(b)

Figure 250–173 250.68(C)(3)(b)
Grounding Electrode Connection
Rebar Not in Contact with Earth

Rebar from a rebar-type concrete-encased electrode cannot make contact with the earth or be subject to corrosion.

(c) The rebar from a rebar-type concrete-encased electrode is not permitted to be used to interconnect electrodes

250.70 Grounding Electrode Conductor Fittings

(A) Only One Conductor. No more than one conductor can terminate on a single ground clamp or fitting, unless listed for multiple conductors. 250.70(A)

Figure 250–174 250.70(A)
Grounding Electrode Conductor Fittings
One Conductor per Clamp

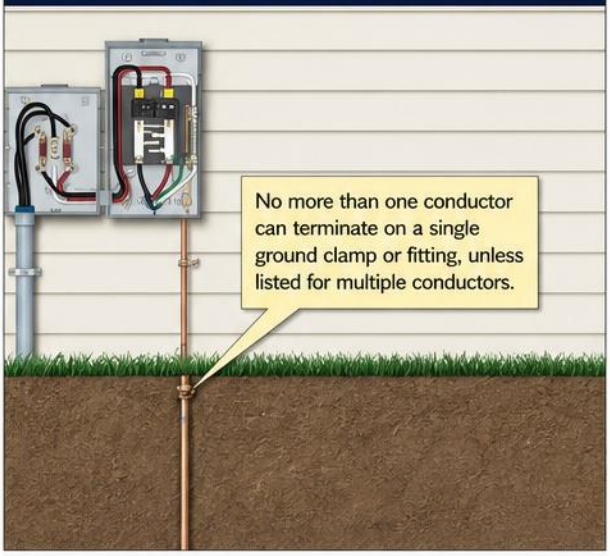
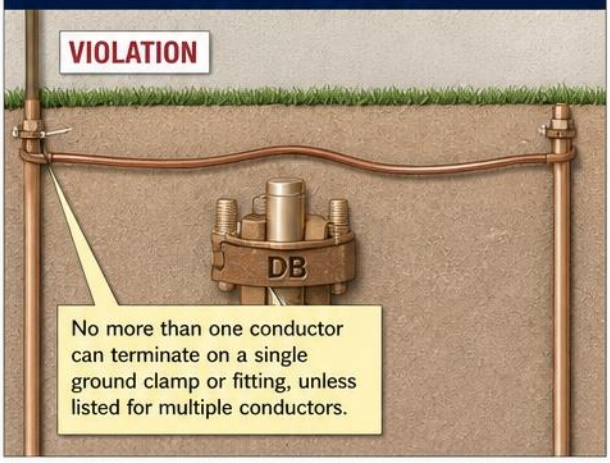


Figure 250–175 250.70(A)
Grounding Electrode Conductor Fittings
One Conductor per Clamp



(1) Termination. The grounding electrode conductor must terminate to the grounding electrode by one of the following methods:

(1) Exothermic welding

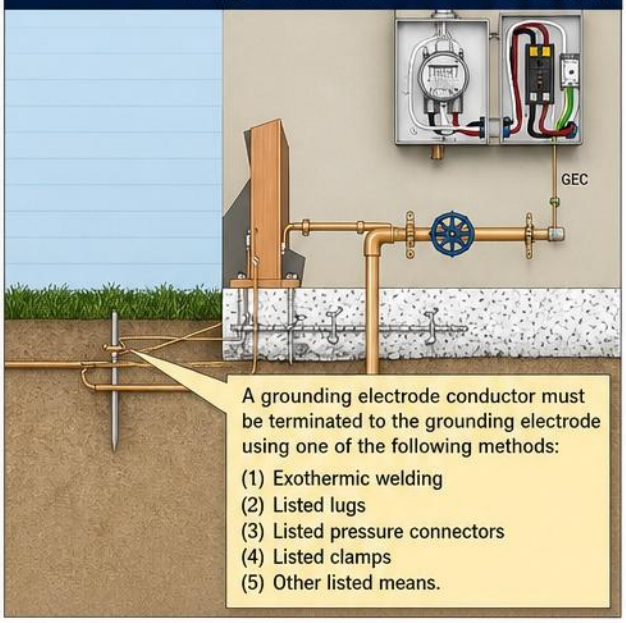
(2) Listed lugs

(3) Listed pressure connectors

(4) Listed clamps

(5) Other listed means 250.70(B)

Figure 250–176 Grounding Electrode Conductor Fittings—Termination 250.70(A)(1)



(2) Concrete Encasement or Direct Burial. When the termination to a grounding electrode is encased in concrete or buried, the termination fitting must be listed for direct soil burial. Figure 250–177

Figure 250–177 Grounding Electrode Conductor Fittings—Concrete Encasement or Direct Burial 250.70(A)(2)

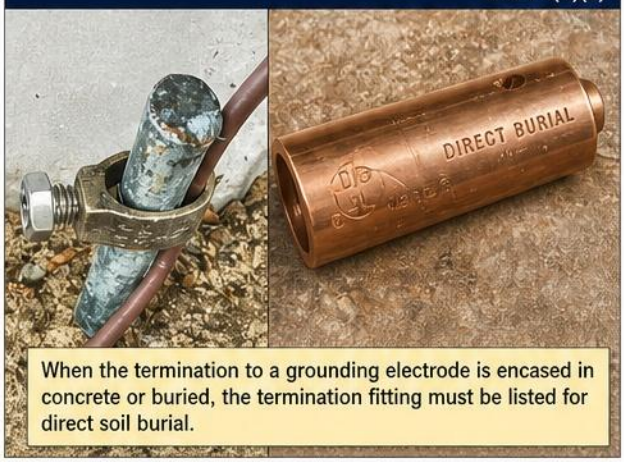
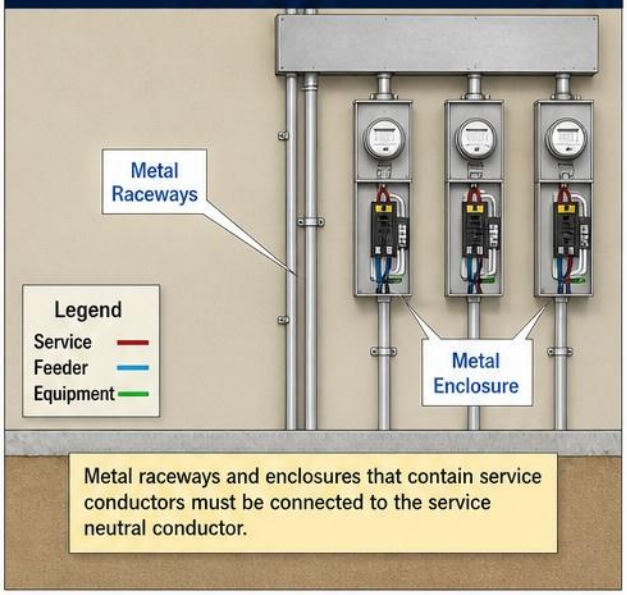


Figure 250–178 Service Metal Enclosures and Raceways—Connection to Service Neutral Conductor 250.80



Ex: Metal elbows in an underground nonmetallic raceway with a minimum cover of 18 in. are not required to be connected to the service neutral conductor, supply-side bonding jumper, or grounding electrode conductor. Figure 250–179

Figure 250–179 Service Underground Nonmetallic Raceways With Metal Elbows 250.80 Ex

Part IV. Enclosure and Raceway

250.80 Service Raceways and Enclosures

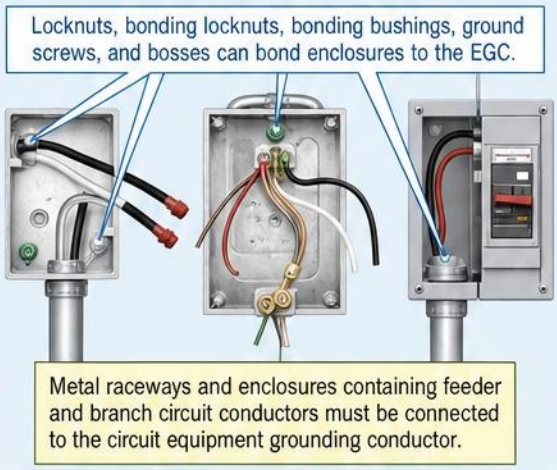
Metal raceways and enclosures that contain service conductors must be connected to the service neutral conductor. Figure 250–178

250.86 Other than Service Enclosures and Raceways

Metal raceways and enclosures that contain feeder and branch-circuit conductors must be connected to the circuit equipment grounding conductor. Figure 250–180

Figure 250–180 250.86

Other Than Service Metal Enclosures and Raceways Connection to Equipment Grounding Conductor

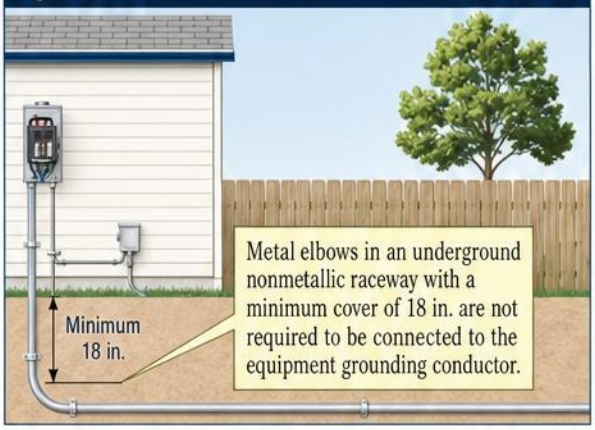


Metal raceways and enclosures that contain feeder or branch-circuit conductors must be connected to the equipment grounding conductor.

Ex 2: Short sections of metal raceways used for the support or physical protection of cables as determined by the AHJ are not required to be connected to the circuit equipment grounding conductor.

Ex 3: *Metal elbows in an underground nonmetallic raceway with a minimum cover of 18 in. are not required to be connected to the equipment grounding conductor.*

Figure 250–181 250.86 Ex 3



Metal elbows in an underground nonmetallic raceway with at least 18 in. of cover depth do not need to be connected to the equipment grounding conductor.

AUTHOR'S COMMENT

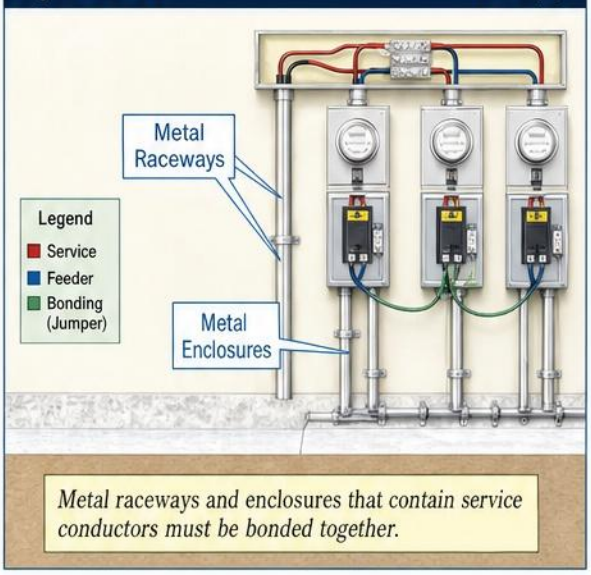
Metal RMC elbows are often installed because PVC elbows can be damaged during conductor installation from the friction caused by pull lines or ropes rubbing against the interior radius of the elbow.

Part V. Bonding

250.92 Bonding Metal Service Raceways and Enclosures

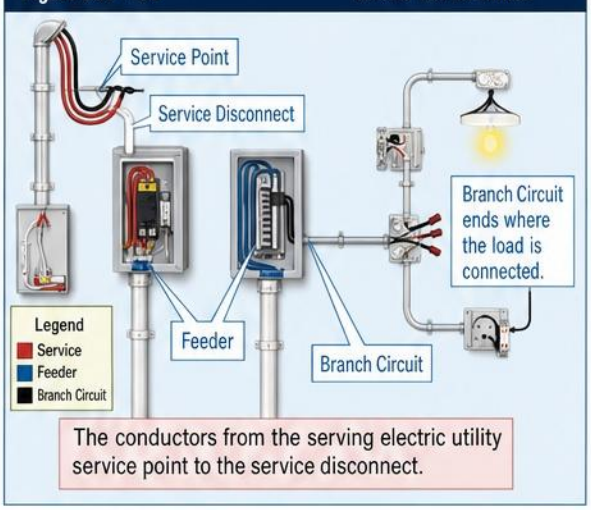
(A) Metal Raceways and Enclosures. Metal raceways and enclosures containing *service conductors* must be bonded together in accordance with 250.92(B).

Figure 250–182 250.92(A)



Service Conductors. The conductors from the serving electric utility service point to the service disconnect.
250.92

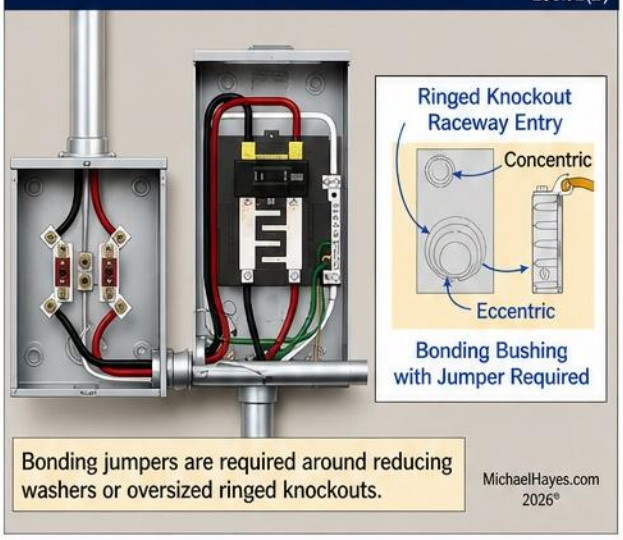
Figure 250–183 Article 100 Definition



(B) Methods of Bonding Raceways and Enclosures.

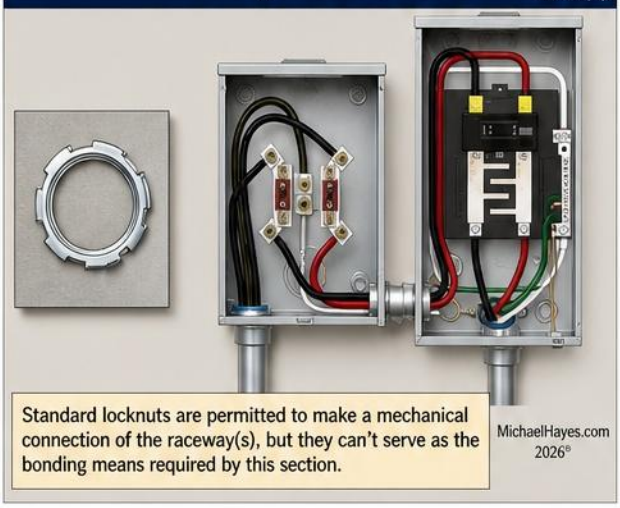
Impaired Connections. Bonding jumpers are required around reducing washers or oversized ringed knockouts. *250.92(B)*

Figure 250–184 Service Metal Raceways and Enclosures Bonding, Impaired Connections 250.92(B)



Locknuts Not Suitable. Standard locknuts are permitted to make a mechanical connection to the raceway(s), but they cannot serve as the bonding means required by this section. Figure 250–185

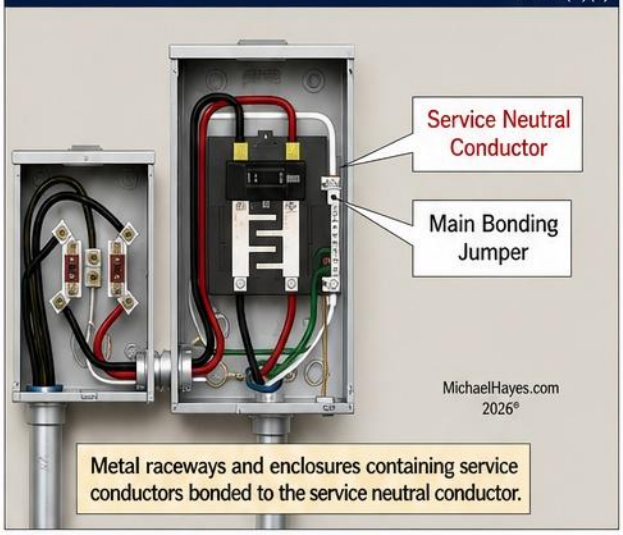
Figure 250–185 Service Metal Raceways and Enclosures Bonding, Locknut Not Suitable 250.92(B)



Other Connections. Metal raceways and enclosures containing service conductors must be bonded to ensure electrical continuity by one of the following methods:

(1) Bonding to Service Neutral. Metal raceways and enclosures containing service conductors can be bonded to the service neutral conductor. Figure 250–186

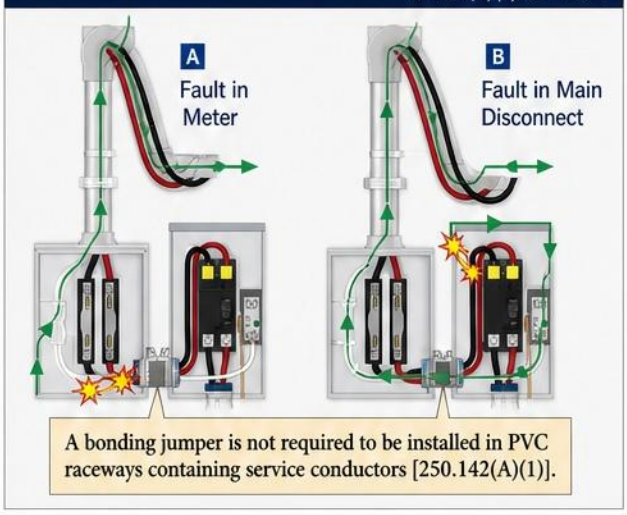
Figure 250–186 Service Metal Raceways and Enclosures Bonding, Service Neutral Conductor 250.92(B)(1)



Author's Comment:

- A main bonding jumper is required to bond the service disconnect to the service neutral conductor [250.24(C) and 250.28].
- A supply-side bonding jumper can be used to bond metal service raceways to the neutral conductor.
- At the service disconnect, the service neutral conductor provides the effective ground-fault current path to the source [250.24(D)].
- A supply-side bonding jumper is not required to be installed in nonmetallic raceways containing service conductors [250.142(A)(1) and 352.60 Ex 2]. Figure 250–187

Figure 250–187 Service Metal Raceways and Enclosures Bonding Not Required, PVC Raceway 250.92(B)(1) Comment



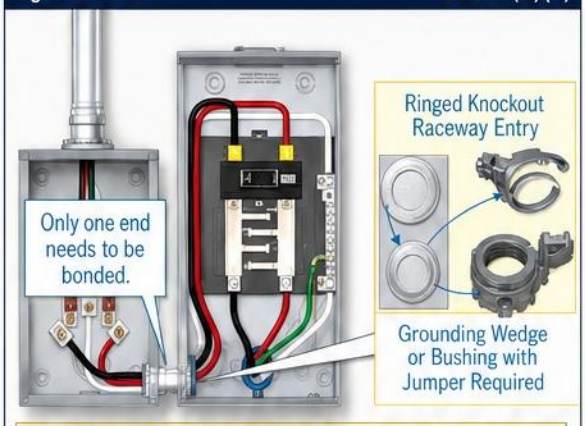
(2) Threaded Fittings. Threaded metal raceways containing service conductors can be bonded with threaded metal fittings.

(3) Threadless Fittings. Threadless metal raceways containing service conductors can be bonded with threadless metal fittings.

(4) Other Listed Fittings. Metal raceways containing service conductors can be bonded to the service neutral conductor with bonding-type locknuts, grounding/bonding wedges, bonding hubs, or grounding/bonding bushings with bonding jumpers as follows:

Ring Knockouts. Metal service raceways that terminate to a metal enclosure with ringed knockouts must have a grounding bushing or grounding wedge with a bonding jumper connected to the service neutral conductor. Figure 250–188

Figure 250–188 250.92(B)(4)



Metal service raceways terminating to ringed knockouts must have a grounding bushing or grounding wedge with a bonding jumper connected to the service neutral conductor.

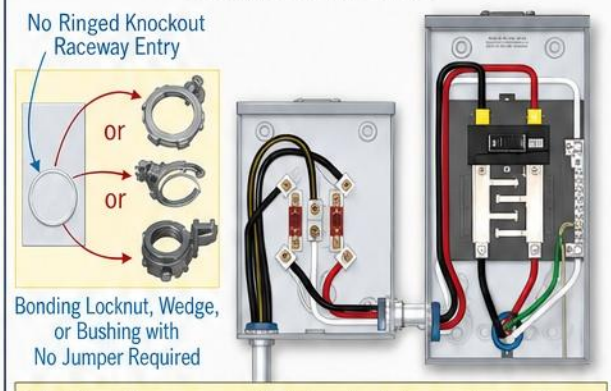
No Ringed Knockout. Metal service raceways that terminate to a metal enclosure without ringed knockouts must have a bonding-type locknut, bonding wedge, bonding hub, or bonding bushing connected to the service neutral. Figure 250–189

Author's Comment:

- A bonding locknut differs from a standard locknut because it contains a bonding screw with a sharp point that drives into the metal enclosure to ensure a solid connection.
- Bonding is only required at one end of a service raceway to the service neutral which provides a low-impedance fault current path to the source required by 250.4(A)(3) and (A)(5). Figure 250–190

Figure 250–189 250.92(B)(4)

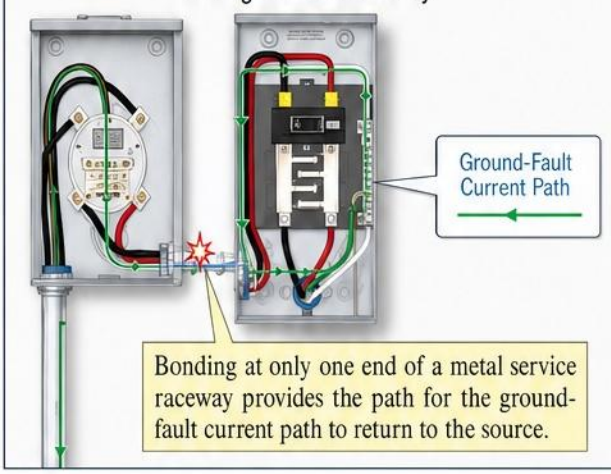
Service Metal Raceways and Enclosures Bonding, No Ring Knockouts



Metal service raceways that terminate to a metal enclosure without ringed knockouts must have a bonding-type locknut, bonding wedge, bonding hub, or bonding bushing connected to the service neutral.

Figure 250–190 250.92(B)(4) Comment

Service Metal Raceways and Enclosures Bonding One End of Raceway

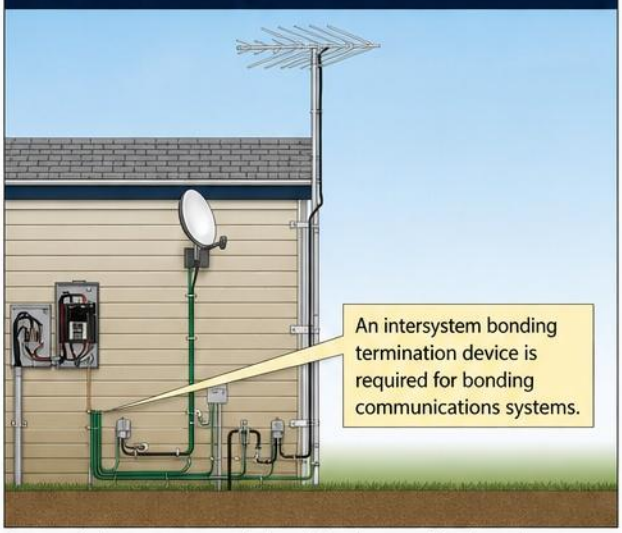


250.94 Intersystem Bonding Termination

An *intersystem bonding termination* device is required for bonding communications systems. Figure 250–191

Intersystem Bonding Termination (IBT). A device that provides a means to connect intersystem bonding conductors for communications systems (such as antennas) to the grounding electrode system. Figure 250–192

Figure 250–191 Bonding Communications Systems 250.94



Communications systems must be bonded to the grounding electrode system using an intersystem bonding termination device.

Figure 250–192 Intersystem Bonding Termination *Article 100 Definition*

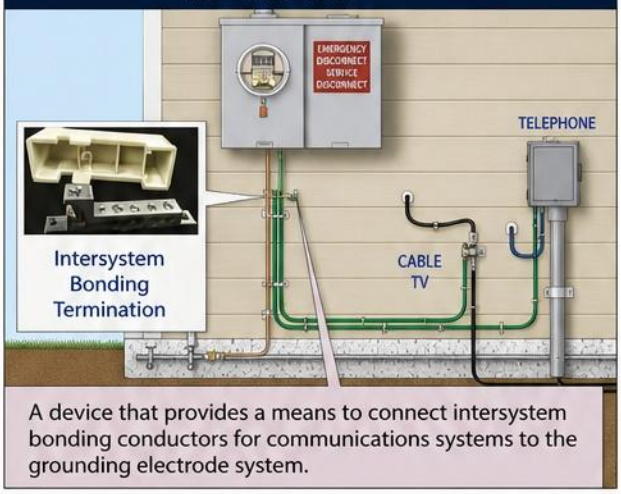
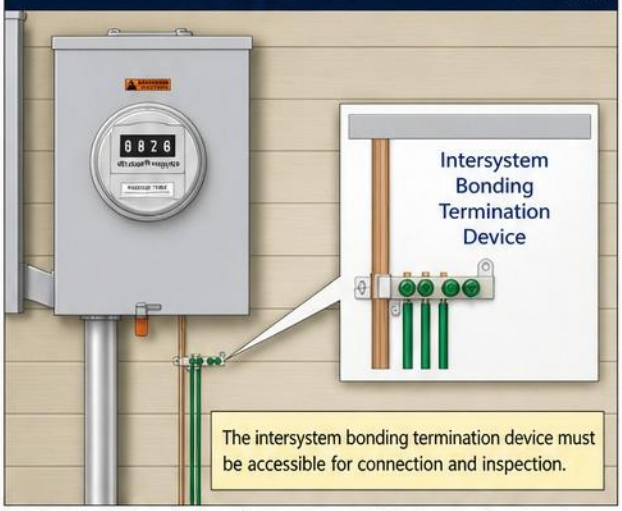
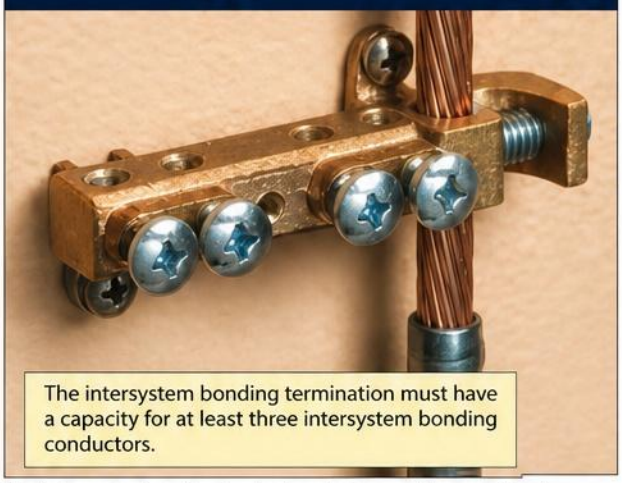


Figure 250–193 Intersystem Bonding Termination Device Accessible Location 250.94(A)(1)



The intersystem bonding termination device shall be installed in a location that is accessible for connection and inspection.

Figure 250–194 Intersystem Bonding Termination Device Capacity 250.94(A)(2)



The intersystem bonding termination device must be capable of accommodating at least three intersystem bonding conductors.

(A) Intersystem Bonding Termination Device (IBT).

Intersystem bonding termination devices must be installed at the service equipment enclosures, meter enclosures, or at the building disconnect enclosures supplied by a feeder and meet all the following requirements:

(1) Be accessible for connection and inspection ▸ Figure 250–193

(2) Have a capacity for at least three intersystem bonding conductors ▸ Figure 250–194

(3) Be installed not to interfere with the opening of any enclosure

(4) The intersystem bonding termination device (IBT) must be:

(a) Securely mounted at the service equipment to the:

(i) Metal service disconnect enclosure

(ii) Metal meter enclosure

(iii) Metal service nonflexible raceway

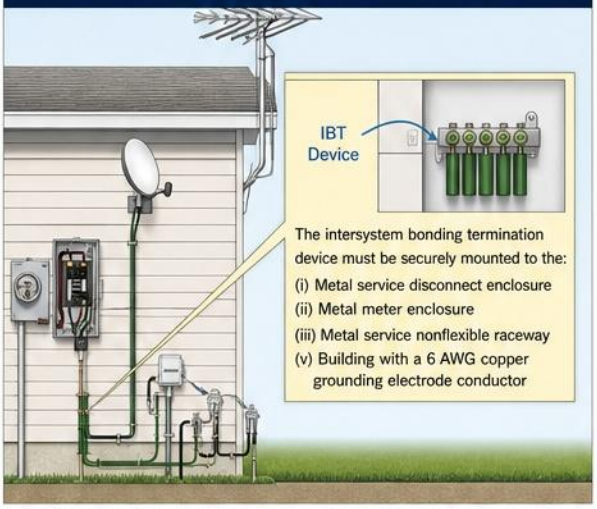
(iv) Building with a 6 AWG copper grounding electrode conductor ▸ Figure 250–195

(b) Securely mounted at the building disconnect supplied by a feeder to the:

(i) Metal feeder disconnect enclosure for the building

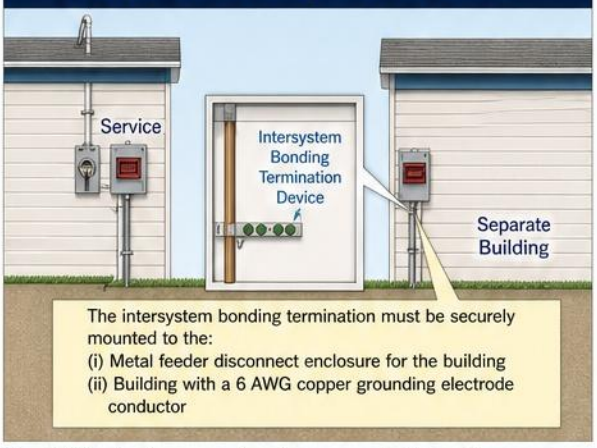
(iii) Building with a 6 AWG copper grounding electrode conductor ▸ Figure 250–196

Figure 250–195 **250.94(A)(4)(a)**
Intersystem Bonding Termination Device Securely Mounted to Service Equipment Enclosure



The IBT device is mounted to the service equipment enclosure and connected to the grounding electrode system.

Figure 250–196 **250.94(A)(4)(b)**
Intersystem Bonding Termination Device Securely Mounted to Building Disconnect Enclosure



The IBT device is mounted to the separate building disconnect enclosure and connected with a 6 AWG copper grounding electrode conductor.

(5) Listed as grounding and bonding equipment or as communications grounding and bonding equipment

Example: An intersystem bonding termination device is not required where communications systems are not likely to be used.

Note: For intersystem bonding and grounding requirements for limited-energy systems, see 750.66.

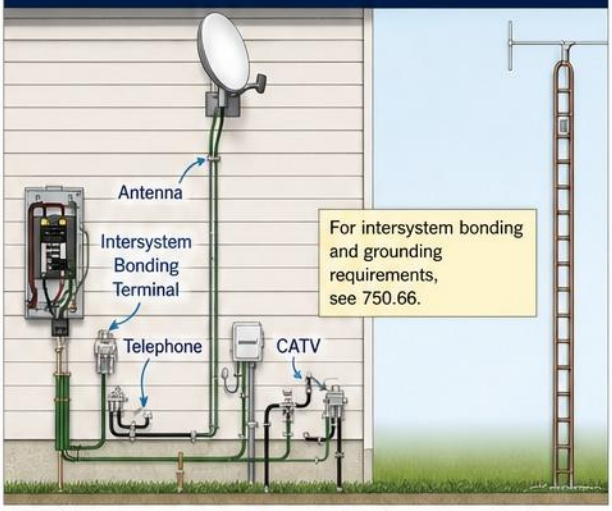
▸ **Figure 250–197**

250.96 Bonding Metal Parts

(A) General. Metal parts that serve as the equipment grounding conductor must be bonded together to ensure electrical continuity and the capacity to conduct fault current likely to be imposed on them.

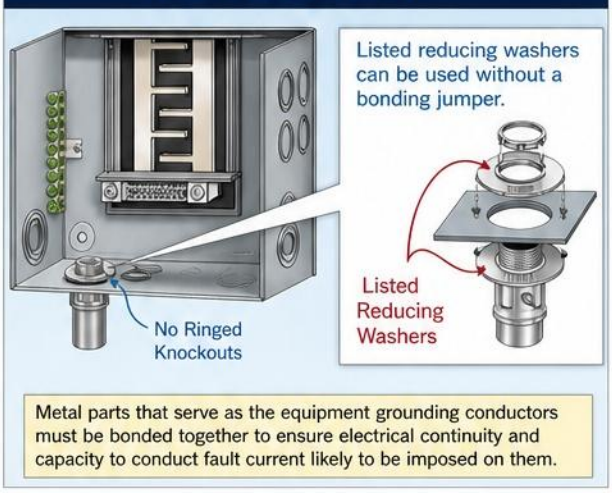
▸ **Figure 250–198**

Figure 250–197 **250.94(A) Note**
Intersystem Bonding Termination Device Communication Systems



The IBT for communications systems bonds antenna, telephone, and CATV systems in accordance with 250.94(A).

Figure 250–198 **250.96(A)**
Bonding Metal Parts Feeders and Branch Circuits



Author's Comment:

- In accordance with *UL Guide Listing QCRV*, metal reducing washers are suitable for bonding in enclosures containing other than service conductors after all the concentric and eccentric rings have been removed.

▸ **Figure 250–199**

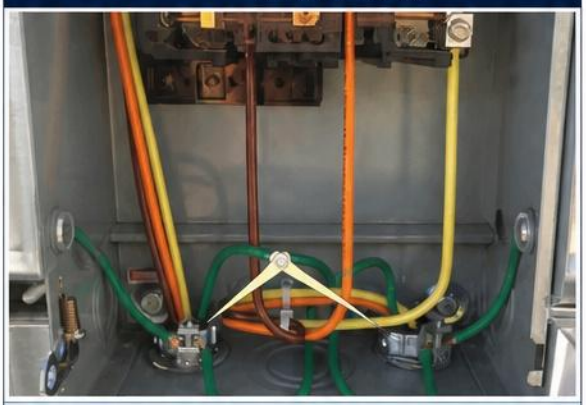
Figure 250–199 Bonding Metal Parts Reducing Washers — 250.96(A) *Comment*

Reducing washers listed in accordance with UL Guide Listing QCRV are appropriate for bonding in enclosures that contain service conductors other than after the concentric and eccentric rings have been removed.

250.97 Bonding Metal Raceways and Metal Cables Containing 480Y/277V Circuits

Metal raceways and metal cables that include feeder or branch-circuit conductors operating at 277V or 480V and terminating at ringed knockouts must be bonded with a bonding fitting and bonding jumper in accordance with 250.92(B)(4). ▶ Figure 250–200

Figure 250–200 Bonding Metal Raceways and Cables 480Y/277V Circuits — 250.97

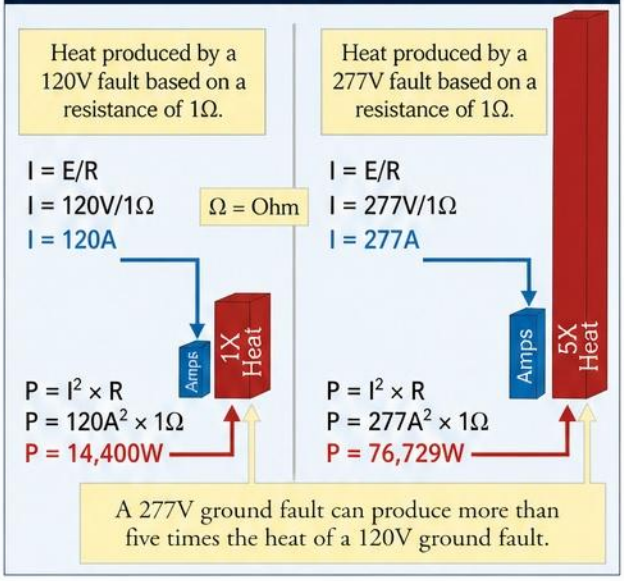


Metal raceways and metal cables with conductors operating at 277V or 480V and terminating at ringed knockouts must be bonded using a bonding fitting and a bonding jumper.

Author's Comment:

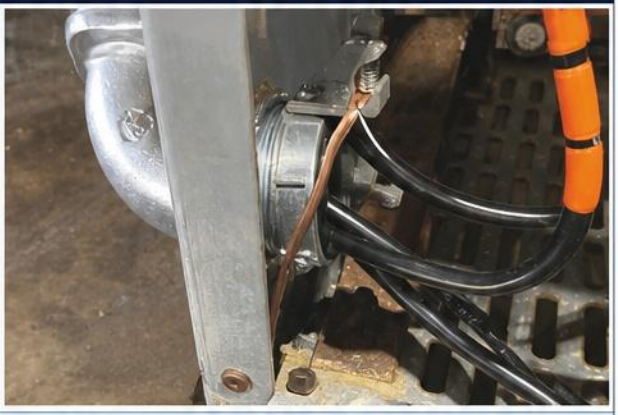
- Bonding jumpers for raceways and cables containing 277V or 480V circuits are required at ringed knockout terminations to ensure the ground-fault current path has the capacity to safely conduct the maximum ground-fault current likely to be imposed [250.4(A)(5)].
- Ringed knockouts are not listed to withstand the heat generated by a 277V ground fault, which can produce five times as much heat as a 120V ground fault. ▶ Figure 250–201

Figure 250–201 Bonding Metal Raceways and Cables 480Y/277V Circuits — 250.97 *Comment*



Ex: A bonding fitting and bonding jumper for metal raceways or metal cable terminations is not required if a ringed knockout is not encountered. ▶ Figure 250–202

Figure 250–202 Bonding Metal Raceways and Cables 480Y/277V Circuits — 250.97 Ex



A bonding fitting and bonding jumper or metal raceways or metal cable terminations is not required when a ringed knockout is not encountered.

250.98 Bonding Loosely Jointed Metal Raceways

Metal raceways that use expansion fittings, expansion-deflection fittings, deflection fittings, or telescoping sections must be installed to provide electrical continuity by utilizing equipment bonding jumpers or other methods.

Figure 250–203 250.98
Bonding Loosely Jointed Metal Raceways

Metal raceways that use expansion fittings, expansion-deflection fittings, deflection fittings, or telescoping sections must be installed to provide electrical continuity by utilizing equipment bonding jumpers or other methods.

Author's Comment:

- A listed expansion fitting with an internal bonding jumper does not require any additional bonding.

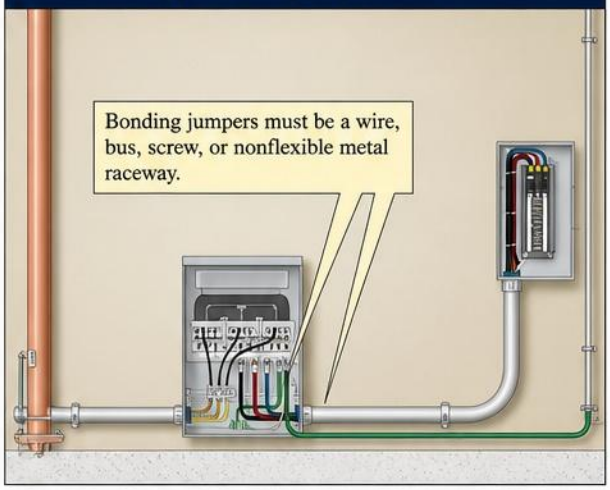
Figure 250–204 250.98 Comment
Bonding Loosely Jointed Metal Raceways

A listed expansion fitting with an internal bonding jumper does not require any additional bonding.

250.102 Bonding Jumper Sizing

(A) Material. Bonding jumpers must be a wire, bus, screw, or nonflexible metal raceway.

Figure 250–205 250.102(A)
Type of Bonding Jumper Material

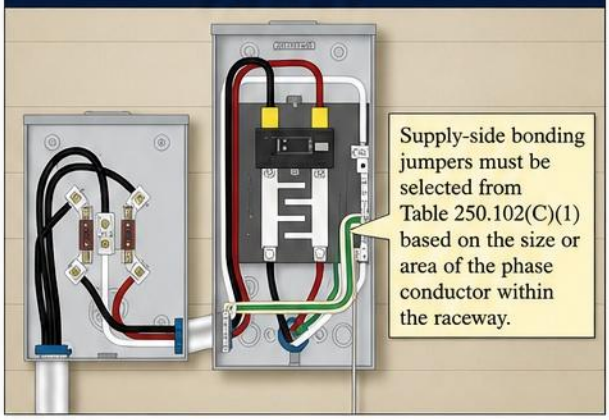


Bonding jumpers must be a wire, bus, screw, or nonflexible metal raceway.

(C) Supply-Side Bonding Jumper Sizing.

(1) Conductors in Single Raceway or Cable. Bonding jumpers on the supply side of the service disconnect and separately derived system secondary (transformer) disconnect must be selected from Table 250.102(C)(1), based on the size or area of the phase conductor within the raceway or cable.

Figure 250–206 250.102(C)(1)
Supply-Side Bonding Jumper Sizing, Single Raceway



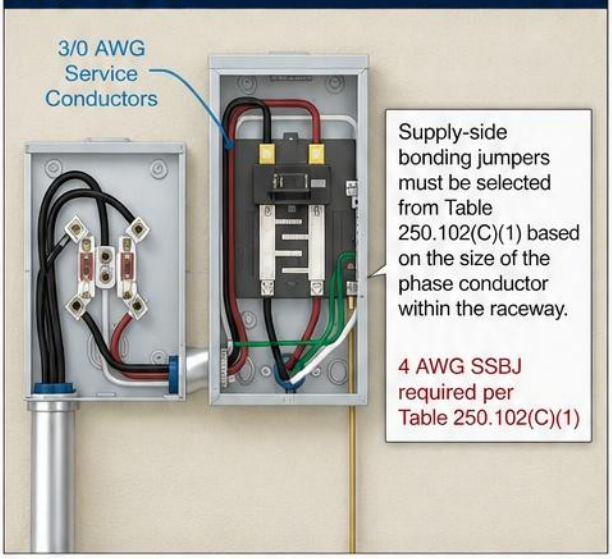
Supply-side bonding jumpers must be selected from Table 250.102(C)(1) based on the size or area of the phase conductor within the raceway or cable.

▶ Supply-Side Bonding Jumper Size—Single Raceway [250.102(C)(1)] Example

Question: *What size copper single supply-side bonding jumper is required for a metal raceway containing 3/0 AWG copper service conductors?* ▶Figure 250–207

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

Figure 250–207
Supply-Side Bonding Jumper, Sizing Single Raceway
250.102(C)(1) Example



You must size the bonding jumper from Table 250.102(C)(1) according to the largest phase conductor in the raceway.

(2) Parallel Conductors in Multiple Raceways or Cables. If the phase conductors are connected in parallel in multiple raceways or cables, the bonding jumper on the supply side of the service disconnect and separately derived system secondary (transformer) disconnect must be sized in accordance with either of the following:

(1) Individual Bonding Jumper for Each Raceway. An individual bonding jumper for each raceway or cable must be selected from Table 250.102(C)(1)—based on the size of the largest phase conductors in each raceway or cable. ▶Figure 250–208

Figure 250–208
Supply-Side Bonding Jumper, Sizing Parallel Raceways, Individual Jumpers
250.102(C)(2)(1) Example

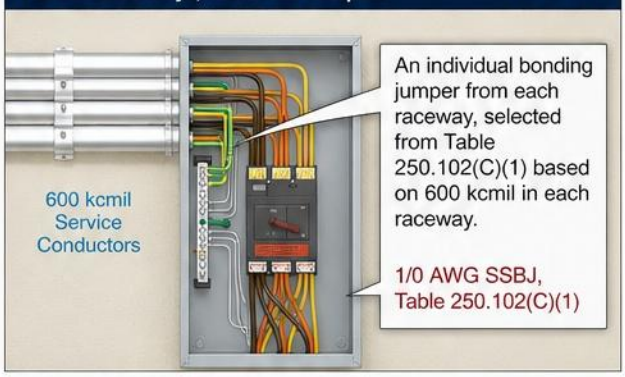
Each raceway that contains phase conductors requires its own supply-side bonding jumper sized using Table 250.102(C)(1) and the largest phase conductor in that raceway.

▶ Supply-Side Bonding Jumper Size—Parallel Raceway [250.102(C)(2)(1)] Example

Question: *What size individual copper supply-side bonding jumper is required for each of three metal raceways—if each raceway contains 600 kcmil copper service conductors in parallel?* ▶Figure 250–209

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

Figure 250–209
Supply-Side Bonding Jumper, Sizing Parallel Raceways, Individual Jumpers
250.102(C)(2)(1) Example



Size a bonding jumper from each raceway using Table 250.102(C)(1) for the largest phase conductor—600 kcmil in this example.

Solution:
An individual supply-side bonding jumper is permitted for each raceway where multiple raceways are installed, based on the area of the 600 kcmil phase conductors in each raceway.

Answer: *(c) 1/0 AWG*

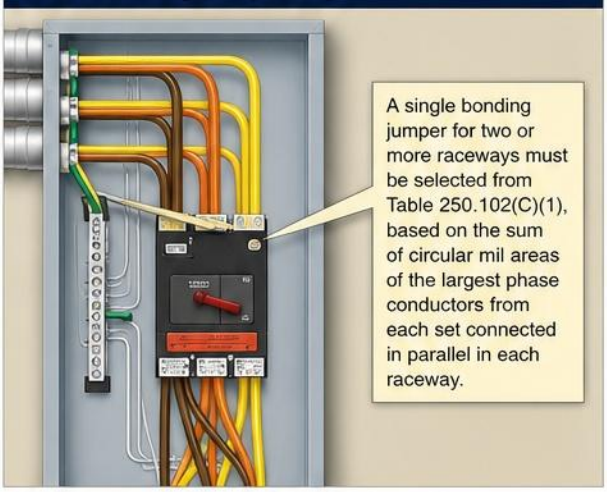
TABLE 250.102(C)(1)
NEUTRAL CONDUCTOR, MAIN BONDING JUMPER, SYSTEM BONDING JUMPER, AND SUPPLY-SIDE BONDING JUMPER

Size of Largest Phase Conductor Per Raceway or Equivalent Area for Parallel Conductors	Size of Bonding Jumper or Neutral Conductor	
Copper	Aluminum or Copper-Clad Aluminum	Copper-Aluminum
2 or smaller	1/0 or smaller	8 CU–6 AL
1 or 1/0	2/0 or 3/0	6 CU–4 AL
2/0 or 3/0	Over 3/0 250 kcmil	4 CU–2 AL
Over 3/0–350 kcmil	Over 250–500 kcmil	2 CU–1/0 AL
Over 350–600 kcmil	Over 500–900 kcmil	1/0 CU–3/0 AL
Over 600–1100 kcmil	Over 900–1750 kcmil	2/0 CU–4/0 AL
Over 1100 kcmil	Over 1750 kcmil	See Note 1

Note 1: *If the total area of the parallel phase conductors exceeds 1100 kcmil, then the size of the single bonding jumper is not permitted to be sized less than 125 percent of the total area of the parallel phase conductors.*

(2) Single Bonding Jumper for All Raceways. A single bonding jumper for two or more raceways or cables containing parallel conductors must be selected from Table 250.102(C)(1)—based on the sum of the circular mil areas of all parallel phase conductors from each set **connected** in parallel in each raceway or cable. Figure 250–210

Figure 250–210 250.102(C)(2)(2)
Supply-Side Bonding Jumper, Sizing Parallel Raceways, Single Jumper



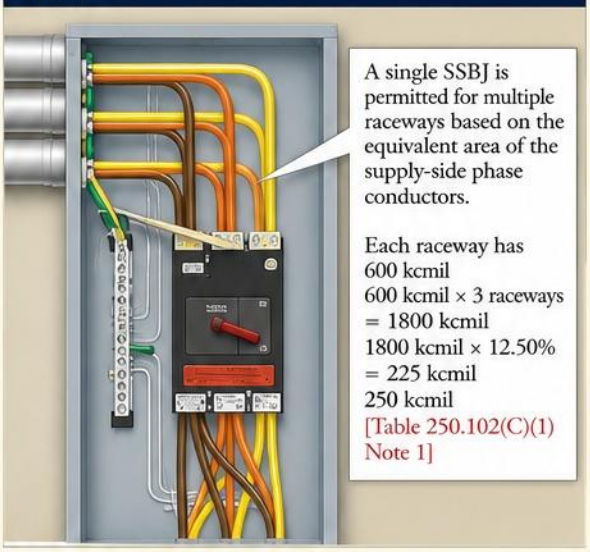
This illustration shows a single bonding jumper for two or more raceways connected in parallel.

▶ SUPPLY-SIDE BONDING JUMPER SIZE—PARALLEL RACEWAY [250.102(C)(2)(2)] EXAMPLE

Question: *What size single copper supply-side bonding jumper is required for all three metal raceways—if each raceway contains 600 kcmil copper service conductors in parallel?*

(a) 4/0 AWG (b) 250 kcmil (c) 300 kcmil (d) 350 kcmil

Figure 250–211 250.102(C)(2)(2)
Supply-Side Bonding Jumper, Sizing Parallel Raceways, Single Jumper Example



This example demonstrates how to size a single bonding jumper for multiple raceways in parallel using the equivalent area method.

Solution:

A single bonding jumper for two or more raceways or cables containing parallel conductors must be sized in accordance with Table 250.102(C)(1), based on the sum of the circular mil areas of all parallel phase conductors.

If the total area of the phase conductors exceeds 1,100 kcmil, then the size of the single bonding jumper is not permitted to be sized less than 125 percent of the total area of the parallel phase conductors.

Note: *Each raceway has 600 kcmil phase conductors.*

Step 1: *Determine total area.*

Three 600 kcmil phase = 1,800 kcmil

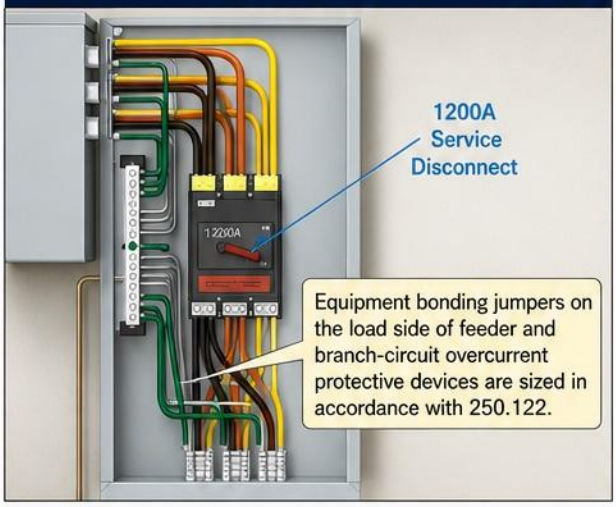
Step 2: *Size the single bonding jumper to 125 percent.*

1,800 kcmil × 12.5% = 225 kcmil

Answer: *(b) 250 kcmil*

(D) Load-Side Bonding Jumper Sizing. Equipment bonding jumpers on the load side of overcurrent protective devices are sized in accordance with 250.122. Figure 250–212

Figure 250–212 | Equipment Bonding Jumper Load-Side Sizing 250.102(D)

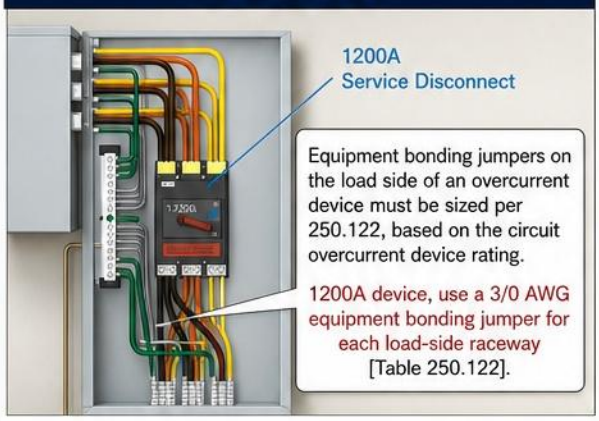


▶ Load-Side Bonding Jumper Size [250.102(D)] Example

Question: *What size equipment bonding jumper is required for each metal raceway where the circuit conductors are protected by a 1,200A overcurrent protective device?* ▶ Figure 250–213

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

Figure 250–213 | Equipment Bonding Jumper Load-Side Sizing 250.102(D) Example



▶ Figure 250–213

Answer: *(c) 3/0 AWG [Table 250.122]*

(E) Bonding Jumper Installation.

(2) Outside a Raceway. Equipment bonding jumpers can be installed outside a raceway if routed with the raceway and not longer than 6 ft. ▶ Figure 250–214

Figure 250–214 | Equipment Bonding Jumpers Outside a Raceway 250.102(E)(2)

250.104 Bonding of Metal Piping Systems and Exposed Structural Metal

(A) Bonding Metal Water Piping System. Metal water piping systems and metal sprinkler piping in or attached to a building must be bonded as follows:

(1) Buildings Supplied by a Service. Metal water piping systems in or attached to a building must be bonded to any of the following:

(1) Service disconnect enclosure

(2) Service neutral conductor

(3) Grounding electrode conductor, if of sufficient size

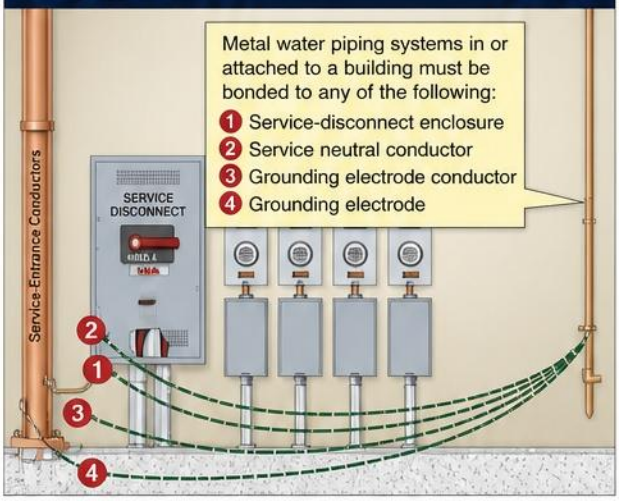
(4) One of the grounding electrodes of the grounding electrode system, if the grounding electrode conductor or bonding jumper to the electrode is of sufficient size ▶ Figure 250–215

Author's Comment:

- The intent of this rule is to remove dangerous voltage on metal parts from a ground fault to metal water piping systems and metal sprinkler piping in accordance with 250.4(A)(4).

The bonding jumpers for the metal water piping system must be sized in accordance with Table 250.102(C)(1), and are not required to be larger than 3/0 AWG copper or 250 kcmil aluminum or copper-clad aluminum.

Figure 250–215 Bonding, Metal Water Piping Systems Building Supplied by a Service 250.104(A)(1)



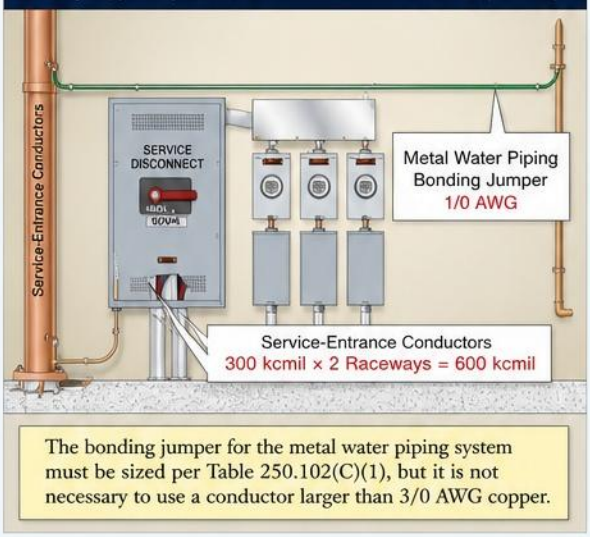
Metal water piping systems in or attached to the building must be bonded to one of the numbered points shown.

▶ Water Pipe Bonding Jumper Size [250.104(A)(1)] Example

Question: What size copper bonding jumper is required for a metal water piping system if the *300 kcmil* copper service conductors are paralleled in two raceways? See Figure 250–216.

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

Figure 250–216 Bonding, Metal Water Piping Systems Building Supplied by a Service 250.104(A)(1) Example



Solution:

A 1/0 AWG bonding jumper is required based on the 600 kcmil conductors (300 kcmil × 2 raceways) [250.102(C)(1)].

Answer: *(a) 1/0 AWG*

Author's Comment:

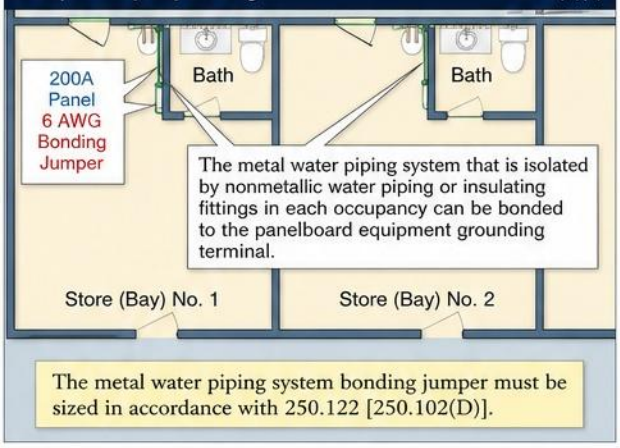
- Bonding is not required for isolated sections of metal water piping connected to a nonmetallic water piping system. In fact, these isolated sections of metal piping should not be bonded because they could become a shock hazard under certain conditions if they were bonded. ▶ Figure 250–217.

Figure 250–217 Bonding, Metal Water Piping Systems Isolated Metal Water Piping 250.104(A)(1) Comment

Isolated metal piping connected to nonmetallic piping is not bonded.

(2) Bonding Multiple-Occupancy Buildings. When metal water piping systems in an individual occupancy are metallically isolated from other occupancies by nonmetallic water piping or insulating fittings, the metal water piping system for that occupancy can be bonded to the equipment grounding terminal of the occupancy's panelboard. Bonding jumpers must be sized in accordance with 250.122 [250.102(D)]. ▶ Figure 250–218.

Figure 250–218 Bonding, Metal Water Piping Systems Multiple Occupancy Buildings 250.104(A)(2)



(3) Buildings Supplied by a Feeder. The metal water piping system of a building supplied by a feeder must be connected to one of the following:

(1) Building disconnect enclosure

(2) Feeder equipment grounding conductor

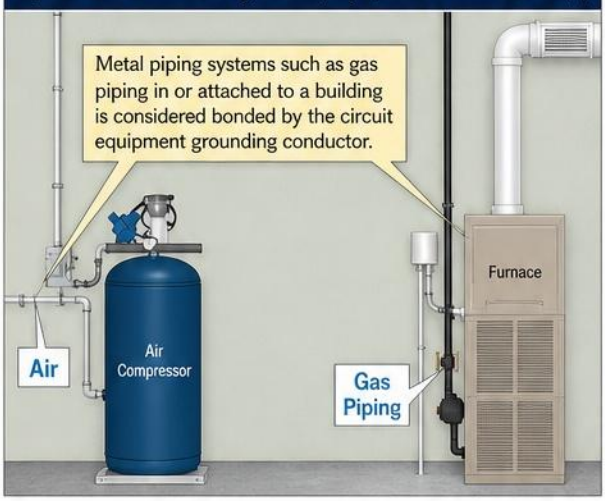
(3) One of the building's grounding electrodes of the grounding electrode system, if the grounding electrode or bonding jumper to the electrode is of sufficient size

The bonding jumper is sized in accordance with 250.102(D) and is not required to be larger than the largest feeder phase or branch-circuit conductor supplying the building.

(B) Bonding Other Metal Piping Systems. Metal piping systems such as gas piping in or attached to a building that are likely to become energized must be bonded.

The metal piping is considered bonded when it is connected to an appliance that is connected to the circuit equipment grounding conductor.

Figure 250–219 Bonding, Metal Piping Systems 250.104(B)



The gas piping is bonded by connection to the appliance, which is connected to the circuit equipment grounding conductor.

Note 2: *See NFPA 54, National Fuel Gas Code and NFPA 780, Standard for the Installation of Lightning Protection Systems for additional bonding requirements of metal gas piping systems.*

(C) Bonding Exposed Structural Metal Building Frame. Exposed structural metal that is interconnected to form a metal building frame that is likely to become energized must be bonded to any of the following:

(1) Service-disconnect enclosure

(2) Neutral at the service disconnect

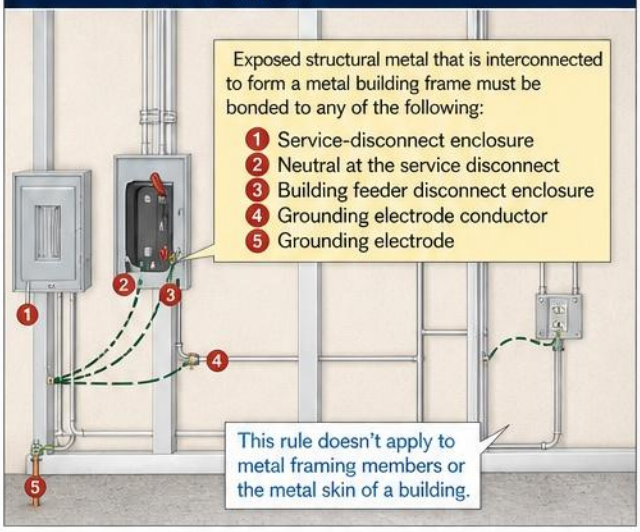
(3) Building's disconnect enclosure for those supplied by a feeder

Figure 250–220 Bonding, Metal Gas Piping Systems 250.104(B) Note 2

(4) Grounding electrode conductor sized in accordance with Table 250.102(C)(1)

(5) One of the grounding electrodes of the grounding electrodes system, if the grounding electrode conductor or bonding jumper to the electrode is sized in accordance with Table 250.102(C)(1)

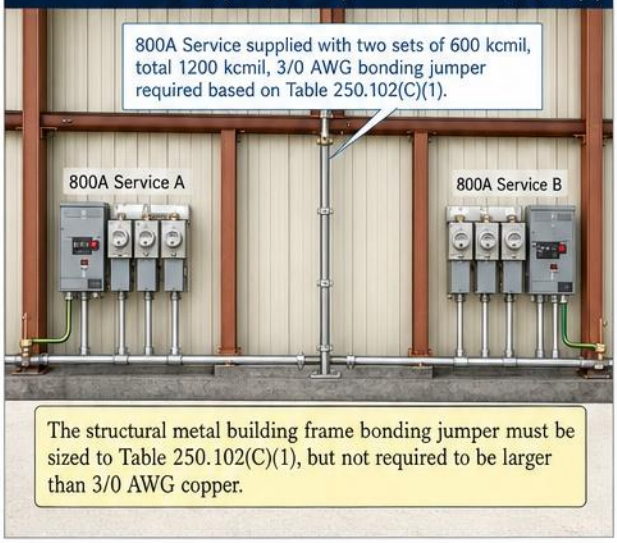
Figure 250–221 Bonding, Exposed Structural Metal Building Frame 250.104(C)



The enumerated bonding locations illustrate all five permitted points of connection.

The structural metal building frame bonding jumper must be sized in accordance with Table 250.102(C)(1), and is not required to be larger than 3/0 AWG copper or 250 kcmil aluminum or copper-clad aluminum.

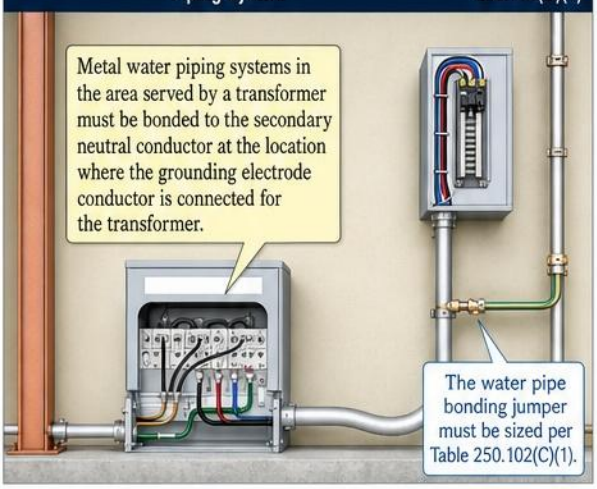
Figure 250–222 Bonding, Exposed Structural Metal Building Frame Bonding Jumper Sizing 250.104(C)



(D) Transformers. Metal water piping systems and structural metal framing that is interconnected to form a building frame must be bonded to the transformer secondary winding in accordance with the following:

(1) Bonding Metal Water Pipe. Metal water piping systems in the area served by a transformer must be bonded to the secondary neutral conductor at the location where the grounding electrode conductor is connected for the transformer.

Figure 250–223 Bonding, Transformer Metal Water Piping System 250.104(D)(1)



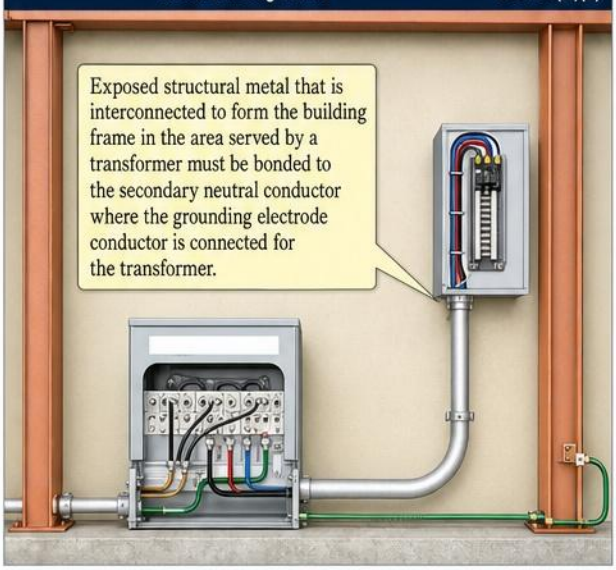
The bonding jumper must be sized in accordance with Table 250.102(C)(1), and is not required to be larger than 3/0 AWG copper or 250 kcmil aluminum or copper-clad aluminum.

Ex 2: The metal water piping system can be bonded to the metal structural building frame if it serves as the grounding electrode conductor [250.68(C)(2)] for the transformer. 250.104(D)(1) Ex 2

Figure 250–224 Bonding, Transformer Metal Water Piping System 250.104(D)(1) Ex 2

(2) Bonding Exposed Structural Metal Building Frame. Exposed structural metal that is interconnected to form the building frame in the area served by a transformer must be bonded to the secondary neutral conductor where the grounding electrode conductor is connected for the transformer.

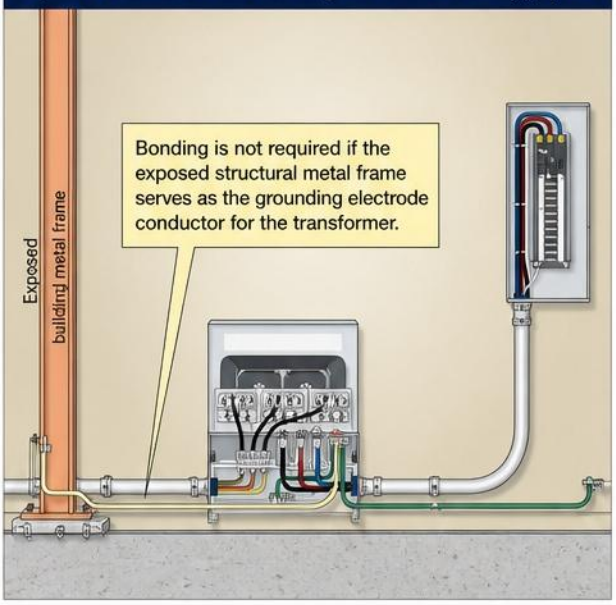
Figure 250–225 Bonding, Transformer Exposed Structural Metal Building Frame 250.104(D)(2)



The bonding jumper must be sized in accordance with Table 250.102(C)(1), and is not required to be larger than 3/0 AWG copper or 250 kcmil aluminum or copper-clad aluminum.

Ex 1: Bonding of the exposed structural metal is not required if the exposed structural metal frame serves as the grounding electrode conductor [250.68(C)(2)] for the transformer. 250.104(D)(2) Ex 1

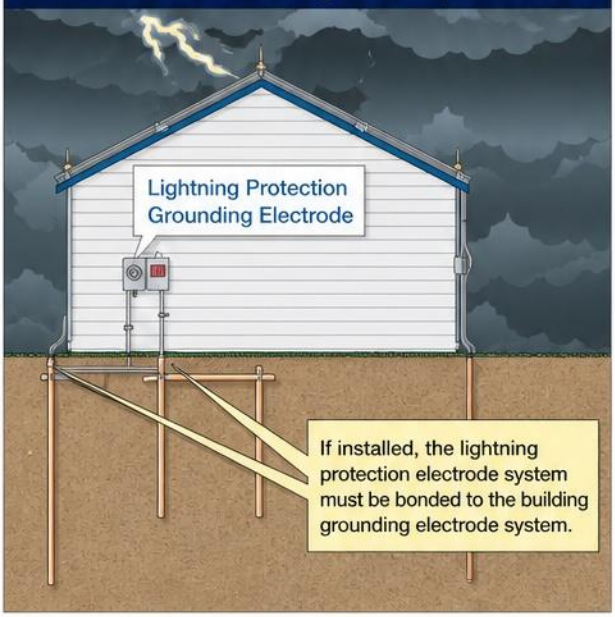
Figure 250–226 Bonding, Transformer Exposed Structural Metal Building Frame 250.104(D)(2) Ex 1



250.106 Lightning Protection Systems

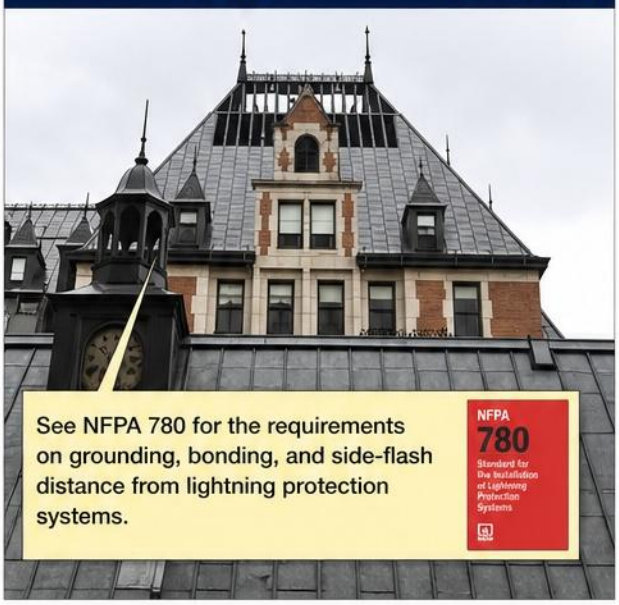
When a lightning protection system is installed, the lightning protection electrode system must be bonded to the building grounding electrode system. (See Figure 250–227.)

Figure 250–227 Lightning Protection Systems Bonded to Grounding Electrode System 250.106



Note 2: See *NFPA 780* for the requirements on grounding, bonding, and side-flash distance from lightning protection systems. (See Figure 250–228.)

Figure 250–228 Lightning Protection System NFPA 780 250.106 Note 2



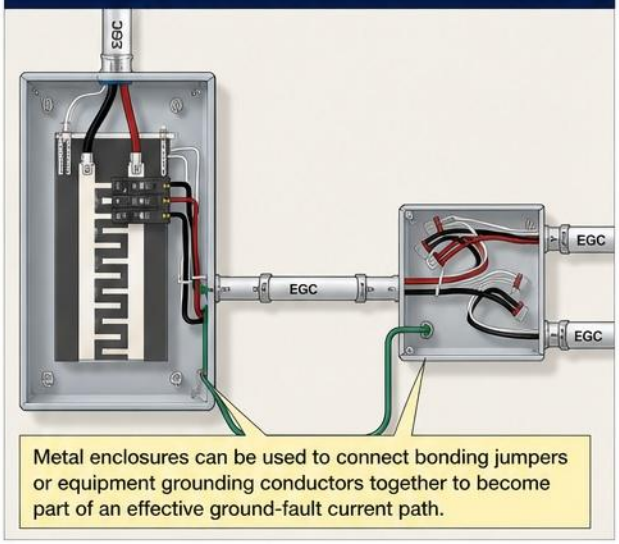
Part VI. Equipment Grounding Conductors

250.109 Bonding Metal and Nonmetallic Enclosures

(A) Metal Enclosures.

(1) Metal enclosures can be used to connect bonding jumpers or equipment grounding conductors together to become a part of an effective ground-fault current path. (See Figure 250–229.)

Figure 250–229 Metal Enclosures Suitable as Effective Ground-Fault Current Path 250.109(A)(1)



(2) Metal covers, metal plaster rings, and metal extension rings must be attached to metal enclosures in a manner that will ensure that they are connected to an effective ground-fault current path. (See Figure 250–230.)

Figure 250–230 Metal Covers, Plaster Rings, and Extension Rings 250.109(A)(2)

Metal covers, metal plaster rings, and metal extension rings must be secured to metal enclosures in a way that ensures they are connected to an effective ground-fault current path.

(B) Nonmetallic Enclosures With Metal Wiring Methods. Nonmetallic enclosures installed with metal wiring methods must comply with the following:

(1) Bonding.

(1) Listed nonmetallic enclosures with integral bonding means are intended to interconnect all metal wiring method connections.

(2) Equipment bonding jumpers are required for each metal wiring method connection. **Figure 250–231**

Figure 250–231 Nonmetallic Enclosures With Metal Wiring Methods 250.109(B)(1)(2)

Nonmetallic enclosures installed with metal wiring methods must have equipment bonding jumpers for each metal wiring method connection.

(2) Metal Covers. Metal covers on nonmetallic enclosures must be connected to the circuit equipment grounding conductor or integral bonding means.

250.114 Equipment Connected by Cord and Plug

Metal parts of cord-and-plug-connected equipment must be connected to the equipment grounding conductor of the circuit supplying the equipment under any of the following conditions:

Ex: Listed tools, appliances, and equipment covered in 250.114 list items (2) through (4) are not required to be connected to an equipment grounding conductor if protected by a system of double insulation or its equivalent. Double-insulated equipment must be distinctively marked.

(1) In hazardous locations [Articles 500 through 517]

(2) If operated at over 150V to ground (480Y/277V system)

(3) In residential occupancies:

a. Refrigerators, freezers, ice makers, and air conditioners

b. Clothes washing/drying machines, dish-washing machines, ranges, kitchen waste disposals, sump pumps, and electrical aquarium equipment

c. Hand-held (stationary or fixed) and light industrial motor-operated tools

d. Motor-operated hedge clippers, lawn mowers, snow-blowers, and wet scrubbers

e. Portable handlamps

(4) In other than residential occupancies:

a. Refrigerators, freezers, ice makers, and air conditioners

b. Clothes washing/drying machines, dish-washing machines, IT equipment, sump pumps, and electrical aquarium equipment

c. Hand-held (stationary or fixed) and light industrial motor-operated tools

d. Motor-operated hedge clippers, lawn mowers, snow-blowers, and wet scrubbers

e. Portable handlamps

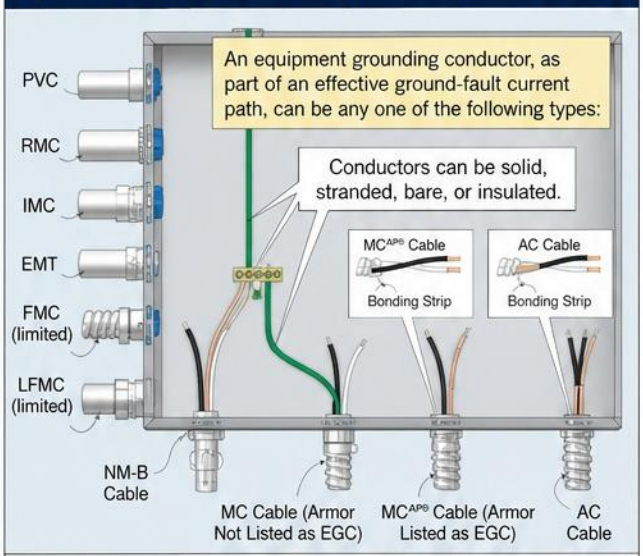
f. Appliances used in damp or wet locations, or by persons standing on the ground, standing on metal floors, or working inside metal tanks or boilers

g. Tools likely to be used in wet or conductive locations

250.118 TYPES OF EQUIPMENT GROUNDING CONDUCTORS

(A) Permitted. An equipment grounding conductor, as part of an effective ground-fault current path, can be any one of the following types: ▶ Figure 250–232

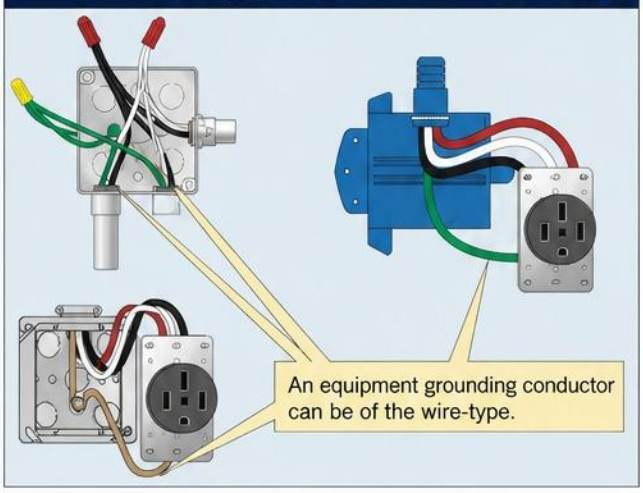
Figure 250–232 Equipment Grounding Conductor Types 250.118(A)



Equipment grounding conductors may be solid, stranded, bare, or insulated and may be of any one of the listed types.

(1) Conductor of the wire-type ▶ Figure 250–233

Figure 250–233 Equipment Grounding Conductors Wire-Type, Bare or Insulated 250.118(A)(1)



(2) Rigid metal conduit ▶ Figure 250–234

(3) Intermediate metal conduit ▶ Figure 250–235

(4) Electrical metallic tubing ▶ Figure 250–236

(5) Flexible metal conduit where: ▶ Figure 250–237

Figure 250–234 Equipment Grounding Conductor Rigid Metal Conduit 250.118(A)(2)

Rigid metal conduit can serve as an equipment grounding conductor.

Figure 250–235 Equipment Grounding Conductor Intermediate Metal Conduit 250.118(A)(3)

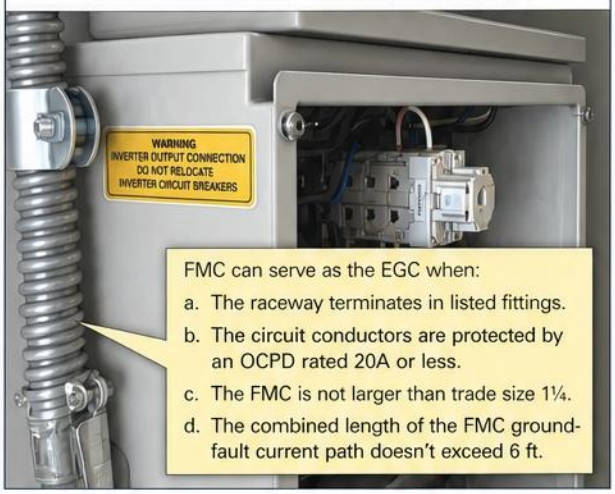
Intermediate metal conduit can serve as an equipment grounding conductor.

Figure 250–236 Equipment Grounding Conductor Electrical Metallic Tubing 250.118(A)(4)

Electrical metallic tubing can serve as an equipment grounding conductor.

Figure 250–237 **250.118(A)(5)**

Equipment Grounding Conductor
Flexible Metal Conduit, Flexibility Not Required



Flexible metal conduit (FMC) can be the equipment grounding conductor when all listed conditions are met.

a. Raceway terminates in listed fittings

b. Circuit conductors are protected by an overcurrent protective device rated 20A or less

c. Conduit size does not exceed 1¼ in.

d. Combined length of the conduit in the same effective ground-fault current path does not exceed 6 ft

e. If flexibility is required to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation as determined by the AHJ, an equipment grounding conductor or a bonding jumper of the wire-type must be installed with the circuit conductors in accordance with 250.102(E)(2) ▸ Figure 250–238

Figure 250–238 **250.118(A)(5)e.**

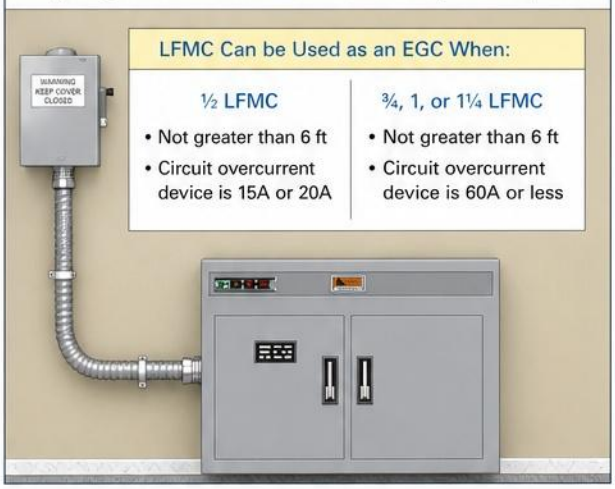
Equipment Grounding Conductor
Flexible Metal Conduit, Flexibility Required

When flexibility is required, an equipment grounding conductor or a bonding jumper of the wire type must be installed.

(6) Liquidtight flexible metal conduit where: ▸ Figure 250–239

Figure 250–239 **250.118(A)(6)**

Equipment Grounding Conductor
Liquidtight Flexible Metal Conduit, Flexibility Not Required



Liquidtight flexible metal conduit (LFMC) can serve as the equipment grounding conductor when the conditions above are satisfied.

a. Raceway terminates in listed fittings

b. Conduits size ½ in. are protected by overcurrent protective devices rated 20A or less

c. Conduits size ¾ through 1¼ in. are protected by overcurrent protective devices rated 60A or less

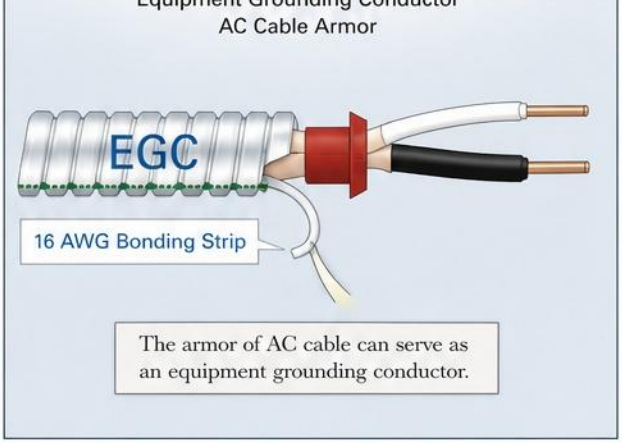
d. Combined length of the conduit in the same effective ground-fault current path does not exceed 6 ft

e. If flexibility is required to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, an equipment grounding conductor of the wire-type or a bonding jumper must be installed with the circuit conductors in accordance with 250.102(E)(2)

(8) Armor of AC cable ▸ Figure 250–240

Figure 250–240 **250.118(A)(8)**

Equipment Grounding Conductor
AC Cable Armor



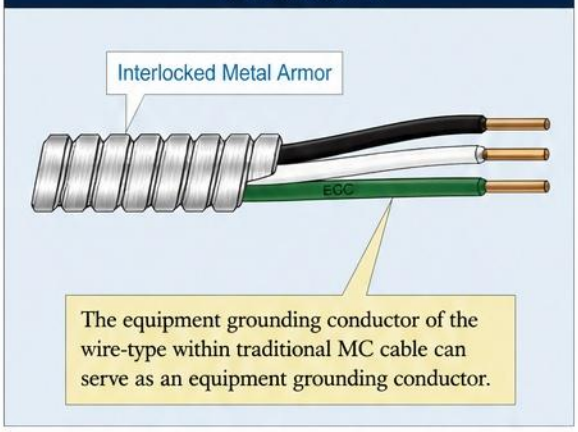
Author's Comment:

The internal aluminum 16 AWG bonding strip of AC cable is not an equipment grounding conductor, but in combination with the interlocked armor of the cable it reduces the impedance of the cable armor to ensure a ground fault will be cleared when used as the circuit equipment grounding conductor. Once the 16 AWG bonding strip exits the cable, it can be cut off because it no longer serves any purpose. The effective ground-fault current path must be maintained using fittings specifically listed for AC cable [320.2].

(10) MC cable as follows:

a. The equipment grounding conductor of the wire-type Figure 250–241

Figure 250–241 Equipment Grounding Conductor MC Cable, Traditional 250.118(A)(10)a



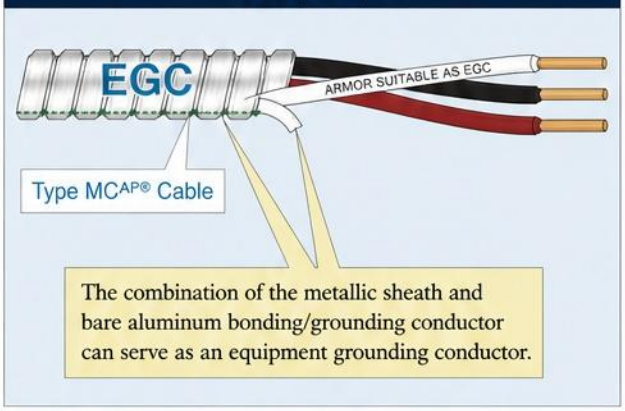
The green insulated wire-type equipment grounding conductor (EGC) is part of the cable and is protected by the interlocked metal armor.

b. Combination of the metallic sheath and bare 10 AWG aluminum bonding/grounding conductor Figure 250–242

Author's Comment:

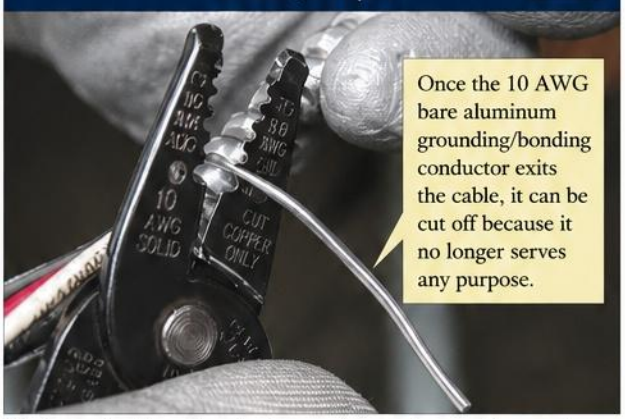
Once the 10 AWG bare aluminum grounding and bonding conductor of MC cable exits the cable, it can be cut off because it no longer serves any purpose. The effective ground-fault current path must be maintained using fittings specifically listed for MC$^{AP®}$ cable [330.6].

Figure 250–242 Equipment Grounding Conductor MC Cable, All Purpose 250.118(A)(10)b



The interlocked metal armor in combination with the bare aluminum bonding/grounding conductor provides an effective ground-fault current path.

Figure 250–243 Equipment Grounding Conductor MC Cable, All Purpose 250.118(A)(10)b Comment



The bare aluminum bonding/grounding conductor plays a role only while it is within the cable assembly.

(11) Metal cable trays in accordance with 392.10 and 392.60 Figure 250–244

(13) Other listed metal raceways, such as metal wireways Figure 250–245

(14) Surface metal raceways listed for grounding Figure 250–246

(B) Not Permitted. The following must not be used as equipment grounding conductors.

(1) Grounding electrode conductors

Ex: A wire-type equipment grounding conductor can serve as both an equipment grounding conductor and a grounding electrode conductor when it is installed in accordance with all of the requirements of Article 250.

Figure 250–247

Figure 250–244 250.118(A)(11)

Equipment Grounding Conductor
Metal Cable Tray

Metal cable trays that comply with 392.10 and 392.60 can be used as an equipment grounding conductor.

Figure 250–245 250.118(A)(13)

Equipment Grounding Conductor
Metal Wireways

Listed metal wireways can be used as an equipment grounding conductor.

Figure 250–246 250.118(A)(14)

Equipment Grounding Conductor
Surface Metal Raceways

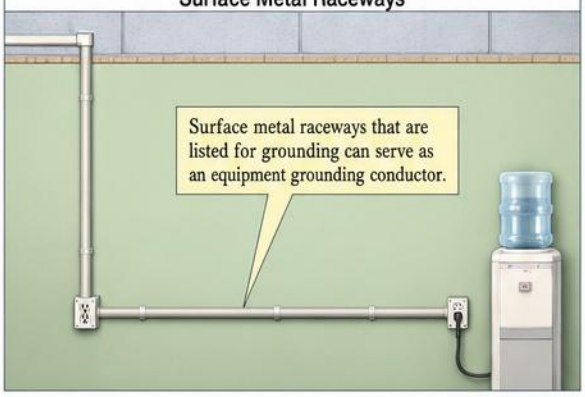
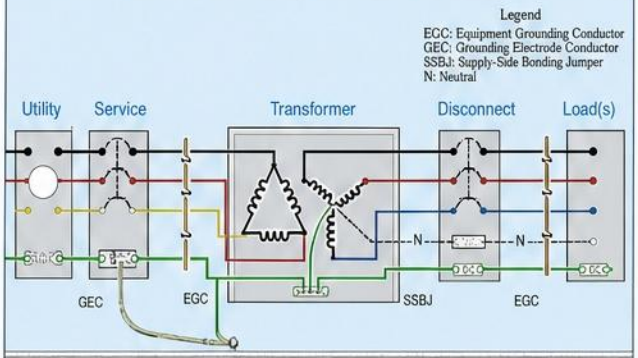


Figure 250–247 250.118(B)(1) Ex and 250.64(C)(2)

Equipment Grounding Conductor
Used as Grounding Electrode Conductor



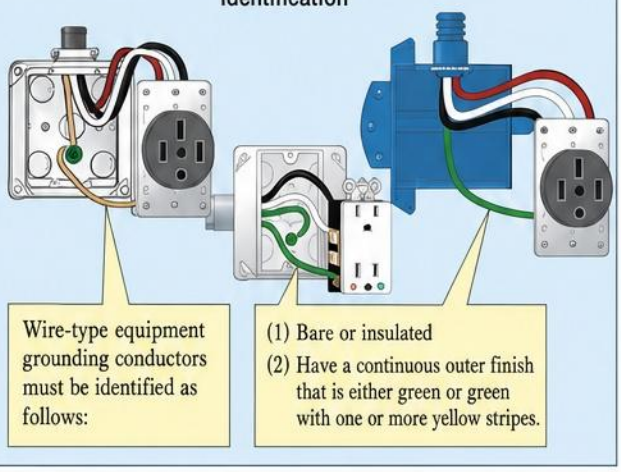
A wire-type equipment grounding conductor can function as both an equipment grounding conductor and a grounding electrode conductor when installed in accordance with Article 250 Part III.

250.119 Identification of Wire-Type Equipment Grounding Conductors

(A) General. Wire-type equipment grounding conductors must be identified by one of the following: Figure 250–248

Figure 250–248 250.119(A)

Equipment Grounding Conductor
Identification



(1) Bare or insulated.

(2) Have a continuous outer finish that is either green or green with one or more yellow stripes.

(3) Insulation that is green, green with one or more yellow stripes, or yellow with one or more green stripes is not permitted to be used as phase or neutral conductors.

AUTHOR'S COMMENT:

The NEC does not require green identification for the grounding electrode conductor.

(B) Conductors 4 AWG and Larger. Conductors used as equipment grounding conductors that are 4 AWG and larger must meet the following requirements:

(2) Identification at Terminals. Insulated equipment grounding conductors that are not green must be identified by one of the following methods:

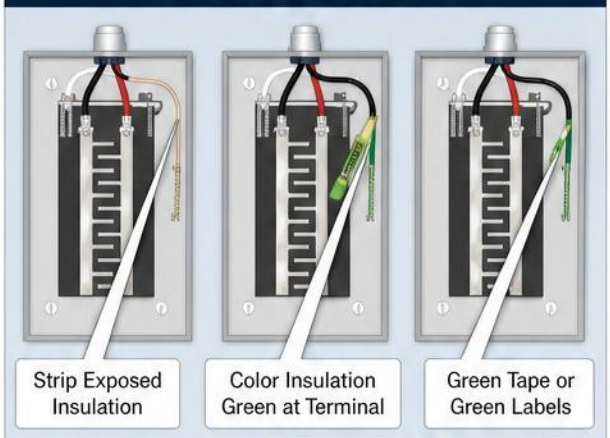
a. Remove the insulation from the conductor

b. Apply green color to the insulation

c. Mark the insulation with green tape or green adhesive labels

Figure 250–249 **250.119(B)(2)**

Equipment Grounding Conductor Identification
4 AWG and Larger, Marking Methods



Insulated equipment grounding conductor that are not of the color green must comply with one of the methods shown above.

(C) Multiconductor Cable. Equipment grounding conductors in multiconductor cables must be identified by one of the following means:

(1) Strip the insulation from the entire exposed length

(2) Color the exposed insulation green

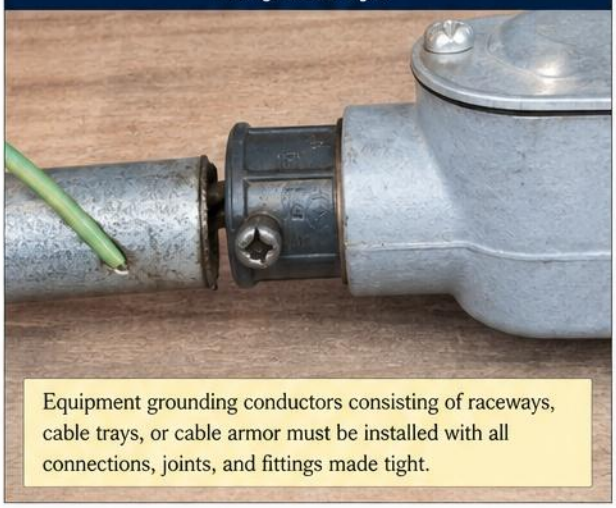
(3) Mark the exposed insulation with green tape or green adhesive labels encircling the conductor

250.120 Equipment Grounding Conductor Installation

(A) Fittings Made Tight. Equipment grounding conductors consisting of raceways, cable trays, or cable armor must be installed with all connections, joints, and fittings made tight.

Figure 250–250 **250.120(A)**

Equipment Grounding Conductor Installation
Fittings Made Tight



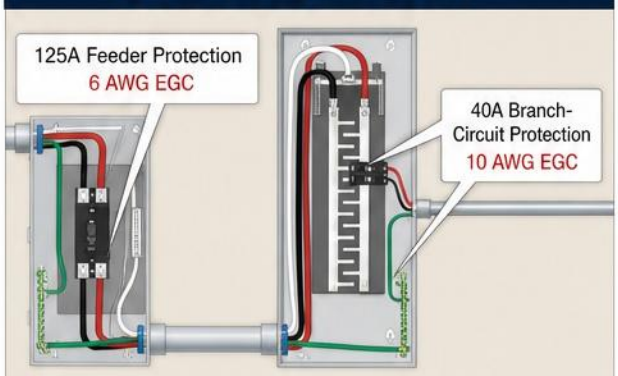
Equipment grounding conductors consisting of raceways, cable trays, or cable armor must be installed with all connections, joints, and fittings made tight.

250.122 Sizing Wire-Type Equipment Grounding Conductors

Equipment grounding conductors must be sized in accordance with Table 250.122, except as permitted by 250.122(A) through (I).

Figure 250–251 **250.122**

Equipment Grounding Conductors, Sizing



Equipment grounding conductors must be sized in accordance with Table 250.122, except as permitted by 250.122(A) through (I).

(A) NOT LARGER THAN CIRCUIT CONDUCTORS

Equipment grounding conductors are not required to be larger than the circuit phase conductors.

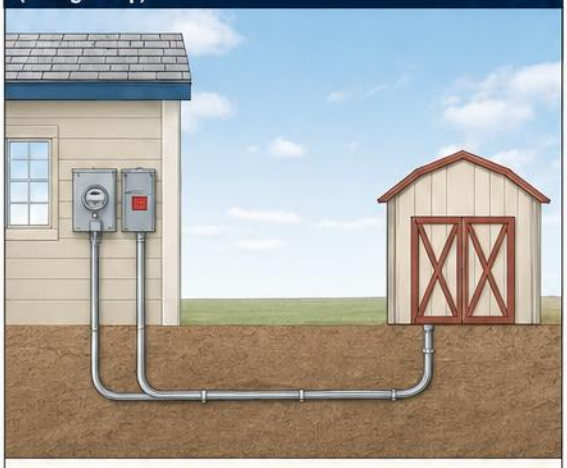
Figure 250-122A Sizing Equipment Grounding Conductor 250.122

Overcurrent Protective Device Rating	Copper Conductor
15A	14 AWG
20A	12 AWG
25A–60A	10 AWG
70A–100A	8 AWG
110A–200A	6 AWG
225A–300A	4 AWG
350A–400A	3 AWG
450A–500A	2 AWG
600A	1 AWG
700A–800A	1/0 AWG
1000A	2/0 AWG
1200A	3/0 AWG

(D) INCREASED IN SIZE

If phase conductors are larger than required by the *NEC* (such as for voltage drop), the equipment grounding conductors must be proportionately increased in size based on the circular mil area of the phase conductors.

Figure 250-122D Increased in Size (Voltage Drop) 250.122(D)

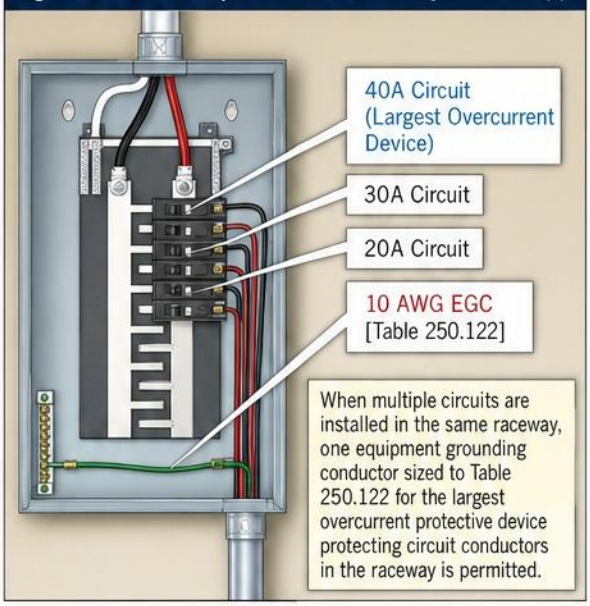


If phase conductors are larger than required by the *NEC* (such as for voltage drop), the equipment grounding conductor of the wire type must be proportionately increased in size based on the circular mil area of the phase conductors.

(E) MULTIPLE CIRCUITS

When multiple circuits are installed in the same raceway or cable tray, one equipment grounding conductor sized to Table 250.122 for the largest overcurrent protective device protecting circuit conductors in the raceway or cable tray is permitted.

Figure 250-122E Multiple Circuits in a Raceway 250.122(E)

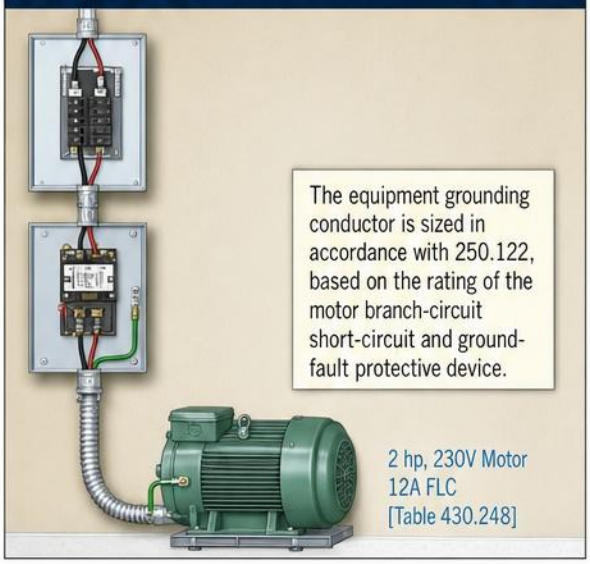


(F) MOTOR BRANCH-CIRCUITS

Equipment grounding conductors for motor circuits must be sized as follows:

(1) General. The equipment grounding conductor is sized in accordance with 250.122, based on the rating of the motor branch-circuit short-circuit and ground-fault protective device as determined by 430.52(C)(1)(a).

Figure 250-122F(1) Motor Branch Circuits 250.122(F)(1)



AUTHOR'S COMMENT

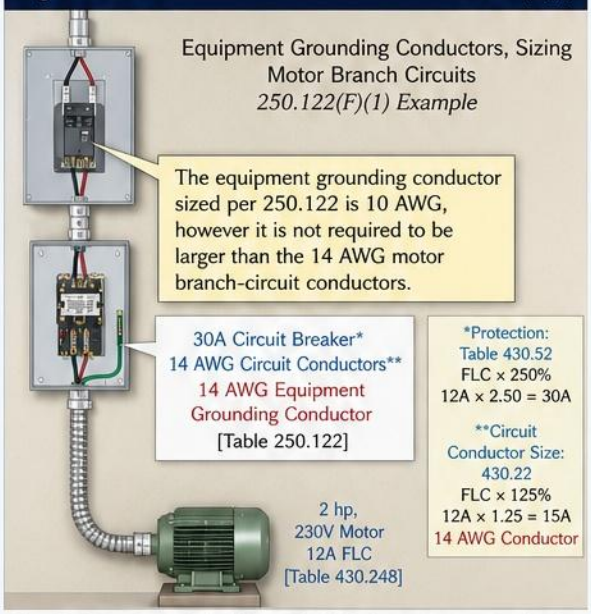
- The equipment grounding conductor is not required to be larger than the motor circuit conductors [250.122(A)].

▶ Motor Branch-Circuit–EGC Sizing [250.122(F)(1)] Example

Question: *What size wire-type equipment grounding conductor is needed for a 14 AWG motor branch-circuit [430.22], protected by a 2-pole, 40A circuit breaker in accordance with 430.22 and 430.52(C)(1)?*

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG

Figure 250–255 **250.122(F)(1)**



The EGC sized per 250.122 is 10 AWG, but it is permitted to be no larger than the 14 AWG motor branch-circuit conductors.

Solution:

The equipment grounding conductor determined by 250.122 is 10 AWG [250.122(E)(1)], but it is not required to be larger than the 14 AWG motor branch-circuit conductors [250.122(A)].

Answer: *(a) 14 AWG*

(H) Parallel Conductors. Parallel conductors must be sized as follows:

(1) Raceways.

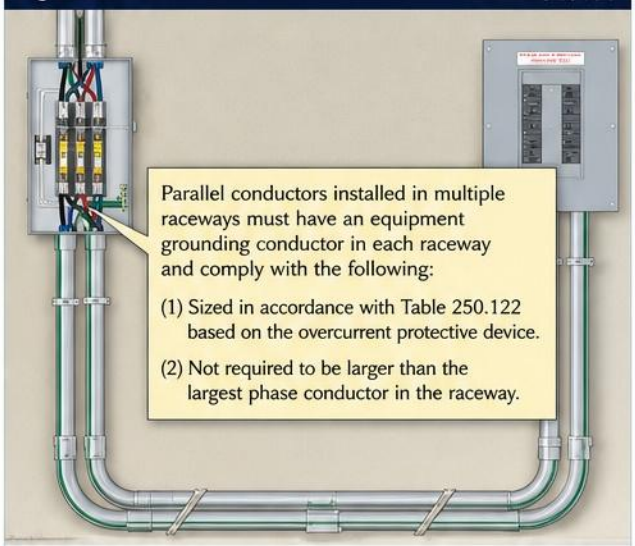
(a) Single Raceway. Parallel conductors installed in a single raceway must have the equipment grounding conductor sized in accordance with Table 250.122, based on the overcurrent protective device for the feeder or branch circuit.

(b) Multiple Raceways. Parallel conductors installed in multiple raceways must have an equipment grounding conductor in each raceway and comply with the following:

(1) The equipment grounding conductor must be sized in accordance with Table 250.122, based on the overcurrent protective device for the feeder or branch circuit.

(2) The equipment grounding conductor in each raceway is not required to be larger than the largest phase conductor in the raceway.

Figure 250–256 **250.122(H)(1)(b)**



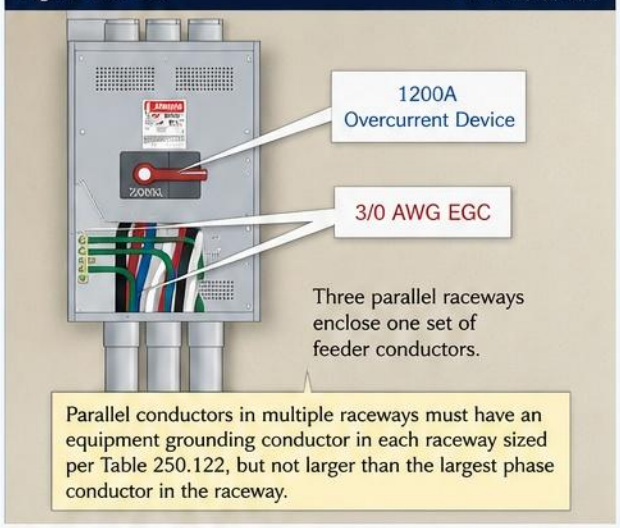
Each raceway contains an equipment grounding conductor that meets both requirements above.

▶ Parallel Circuits—EGC Sizing [250.122(H)(1)(b)] Example 1

Question: *What size wire-type equipment grounding conductor is required for a 1200A feeder containing three parallel sets of 600 kcmil conductor per phase in PVC? [Figure 250–257]*

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

Figure 250–257 **250.122(H)(1)(b)**



Based on Table 250.122, the equipment grounding conductor sized for 1200A is 3/0 AWG and complies with 250.122(H)(1)(b).

Solution:

Per Table 250.122, the equipment grounding conductor in each raceway must be no smaller than 3/0 AWG.

Answer: (c) 3/0 AWG

▶ Parallel Circuits—EGC Sizing [250.122(H)(1)(b)] Example 2

Question: *What size aluminum wire-type equipment grounding conductor is required for a 4000A feeder containing twelve parallel sets of 600 kcmil aluminum conductors per phase in PVC?*

(a) 600 kcmil (b) 750 kcmil (c) 800 kcmil (d) 1000 kcmil

Solution:

Table 250.122 requires a 750 kcmil aluminum equipment grounding conductor for a 4000A circuit, but 250.122(H)(1)(b) explains that the equipment grounding conductor in each raceway is not required to be larger than the largest phase conductor. Because we are using 600 kcmil phase conductors, an 800 kcmil equipment grounding conductor is permitted.

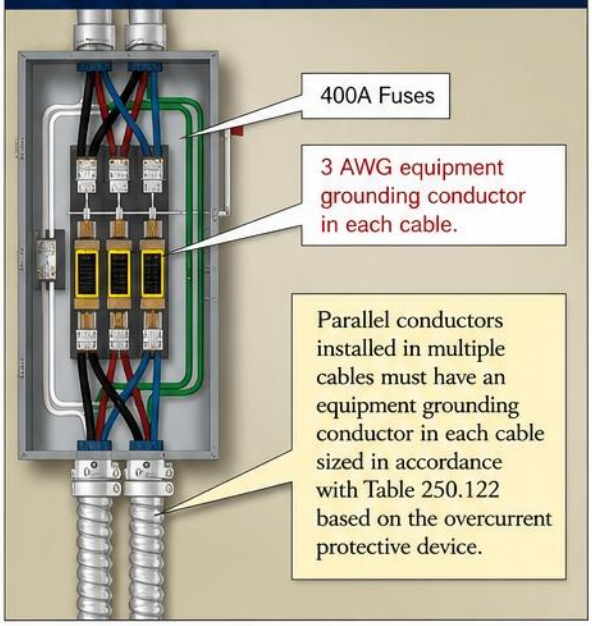
Answer: *(a) 600 kcmil*

(2) *In Multiple Cables.*

(a) Parallel conductors installed in multiple cables must have an equipment grounding conductor in each cable sized in accordance with Table 250.122, based on the overcurrent protective device for the feeder or branch circuit.

Figure 250–258

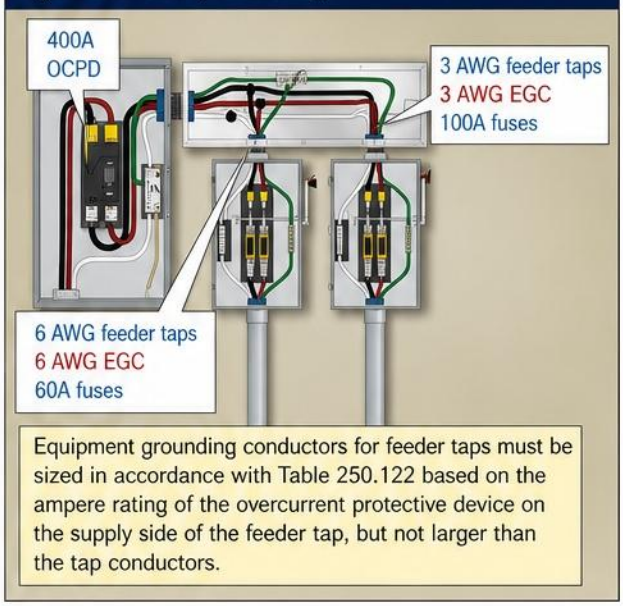
Figure 250–258 | 250.122(H)(2)(a)



(1) Feeder Tap Conductors. Equipment grounding conductors for feeder taps must be sized in accordance with Table 250.122, based on the ampere rating of the overcurrent protective device on the supply side of the feeder tap, but not larger than the tap conductors.

Figure 250–259

Figure 250–259 | 250.122(I)

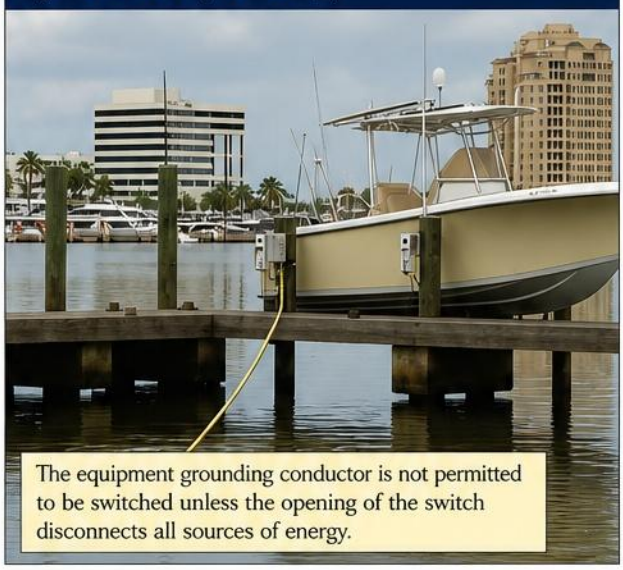


250.124 EQUIPMENT GROUNDING CONDUCTOR CONTINUITY

(B) *Switches.* The equipment grounding conductor is not permitted to be switched unless the opening of the switch disconnects all sources of energy.

Figure 250–260

Figure 250–260 | 250.124(B)



Part VII. Equipment Grounding Conductor Connections

250.134 Equipment Connected by Permanent Wiring Methods

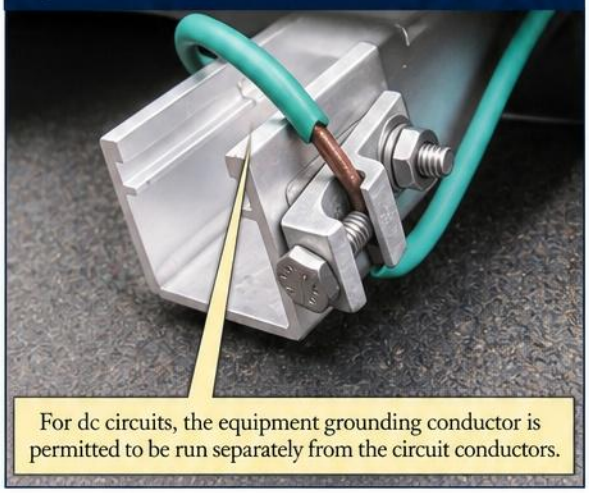
Except as permitted for services or separately derived systems [250.142(A)], metallic parts of equipment, raceways, and enclosures must be connected to an equipment grounding conductor in one of the following methods:

(1) Connecting to an equipment grounding conductor as permitted by 250.118(A)(2) through 250.118(A)(14)

(2) Connecting to a wire-type equipment grounding conductor that is contained within the same raceway, cable, or otherwise run with the circuit conductors

Ex 2: For direct-current circuits, the equipment grounding conductor is permitted to be run separately from the circuit conductors. ▶ Figure 250–261

Figure 250–261 250.134(2) Ex 2



For dc circuits, the equipment grounding conductor is permitted to be run separately from the circuit conductors.

250.138 Cord-and-Plug-Connected

(A) Equipment Grounding Conductor. Metal parts of cord-and-plug equipment must be connected to the circuit equipment grounding conductor contained within the power-supply cord. ▶ Figure 250–262

Figure 250–262 250.138(A)

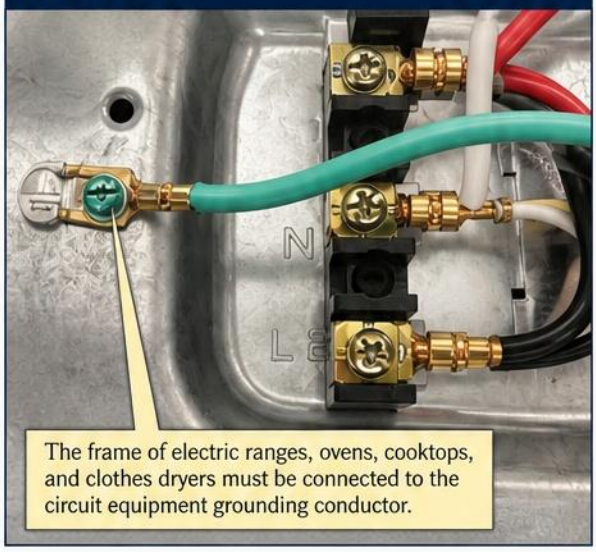
Metal parts of cord-and-plug equipment must be connected to the circuit equipment grounding conductor contained within the power-supply cord.

250.140 Ranges, Ovens, Cooktops, and Clothes Dryers

The frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, and clothes dryers must be connected to the circuit equipment grounding conductor as follows:

(A) Equipment Grounding Conductor. For new installations, the frame of electric ranges, ovens, cooktops, and clothes dryers must be connected to the circuit equipment grounding conductor. ▶ Figure 250–263

Figure 250–263 250.140(A)

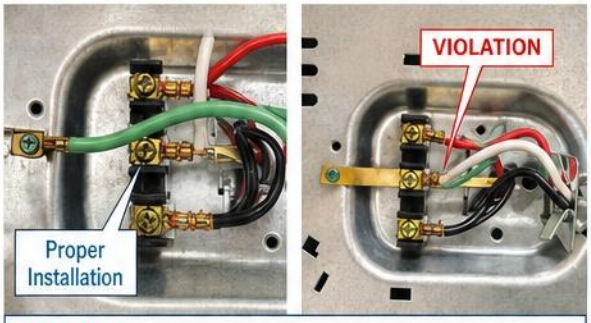


The frame of electric ranges, ovens, cooktops, and clothes dryers must be connected to the circuit equipment grounding conductor.

CAUTION: Electric ranges and clothes dryers are shipped from the factory with a bonding strap that bonds the metal frame of the appllance to the neutral termination of the cord connection terminal block. The Code requires an insulated neutral for ranges and dryers using a 4-wire cord, so the bonding strap must be removed from the appliance. If an existing 3-wire branch circuit is to supply a replacement appliance, the factory-installed bonding strap must remain in place [250.140(B)].

▶ Figure 250–264

Figure 250–264 Ranges, Ovens, Cooktops, and Clothes Dryers—EGC versus Neutral 250.140(A)

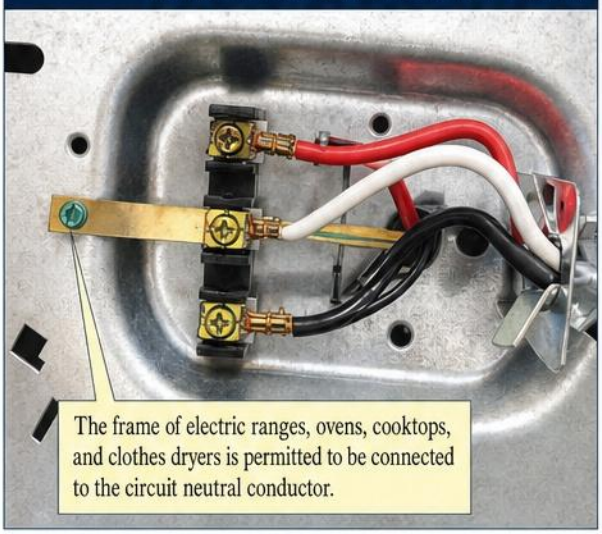


CAUTION: Ranges and clothes dryers are shipped from the factory with a bonding strap from the metal frame to the neutral terminal, which must be removed for new installations.

(B) Neutral Conductor. For existing installations, the frame of electric ranges, ovens, cooktops, and clothes dryers is permitted to be connected to the circuit neutral conductor.

▶ Figure 250–265

Figure 250–265 Ranges, Ovens, Cooktops, and Clothes Dryer—Existing Installation, Neutral Connected to Frame 250.140(B)

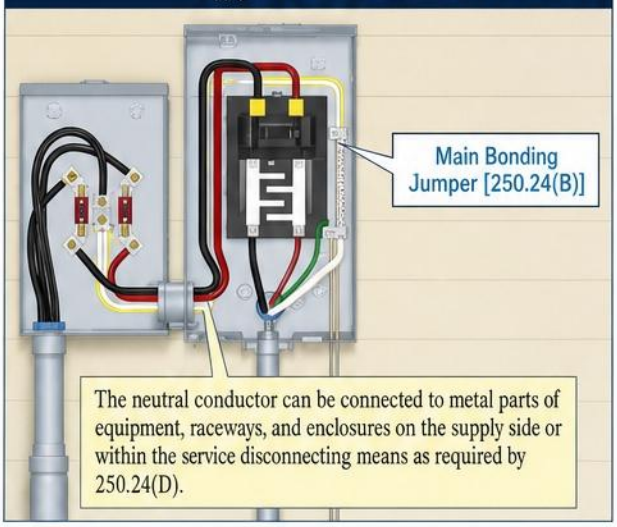


250.142 Use of Neutral Conductor for Grounding Equipment

(A) Neutral Conductor Bonded to Metal Parts, Supply-Side of Equipment. The neutral conductor can be connected to metal parts of equipment, raceways, and enclosures at any of the following locations:

(1) Supply side or within the service disconnecting means as required by 250.24(D) ▶ Figure 250–266

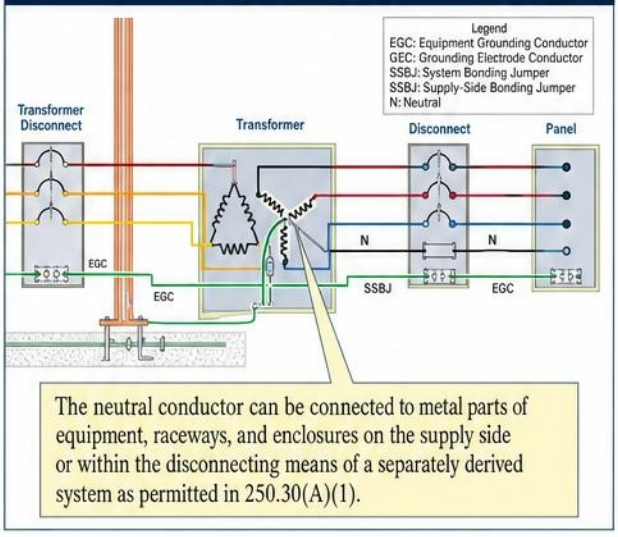
Figure 250–266 Neutral Conductor Bonded to Metal Parts—Supply Side of Service Disconnect 250.142(A)(1)



(2) Supply side or within the disconnecting means for separate buildings as permitted in 250.32(B)(1) Ex 1

(3) Supply side or within the disconnecting means of a separately derived system as permitted in 250.30(A)(1) ▶ Figure 250–267

Figure 250–267 Neutral Conductor Bonded to Metal Parts—Separately Derived Systems 250.142(A)(3)



(B) NEUTRAL CONDUCTOR BONDED TO METAL PARTS, LOAD-SIDE EQUIPMENT.

The neutral conductor is not allowed to be connected to metal parts of equipment on the load side of the service disconnecting means or on the load side of a separately derived system disconnecting means.

See Figure 250–268, Figure 250–269, and Figure 250–270.

Figure 250–268 Neutral Conductor Bonded to Metal Parts, Load-Side of Service Disconnect 250.142(B)

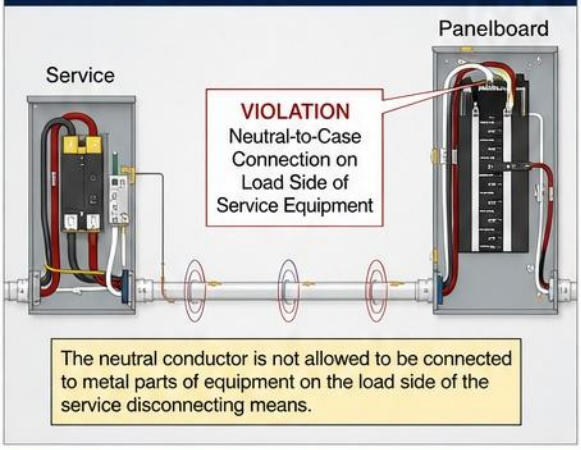
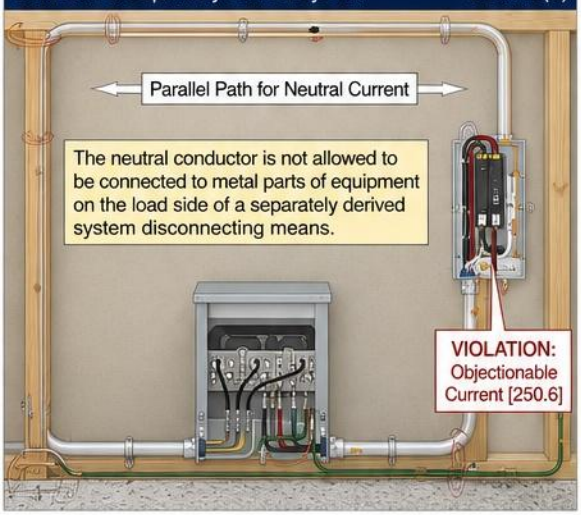


Figure 250–269 Neutral Conductor Bonded to Metal Parts, Load Side of Separately Derived System 250.142(B)



Ex 1: The frames of ranges, wall-mounted ovens, counter-mounted cooking units, and clothes dryers can use the neutral-to-case bond for existing installations in accordance with 250.140(B). See **Figure 250–271.**

Ex 2: It is permissible to connect meter enclosures to the neutral conductor on the load side of the service disconnect—if all of the following conditions apply: See **Figure 250–272.**

(1) Ground-fault protection of equipment is not installed.

Figure 250–270 Neutral Conductor Bonded to Metal Parts, Load-Side of Service Disconnect 250.142(B)

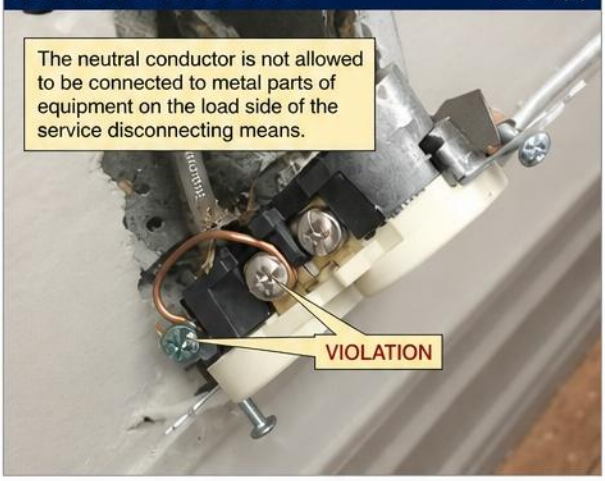


Figure 250–271 Neutral Conductor Bonded to Metal Parts, Frames of Ranges, Ovens, and Clothes Dryer 250.142(B) Ex 1

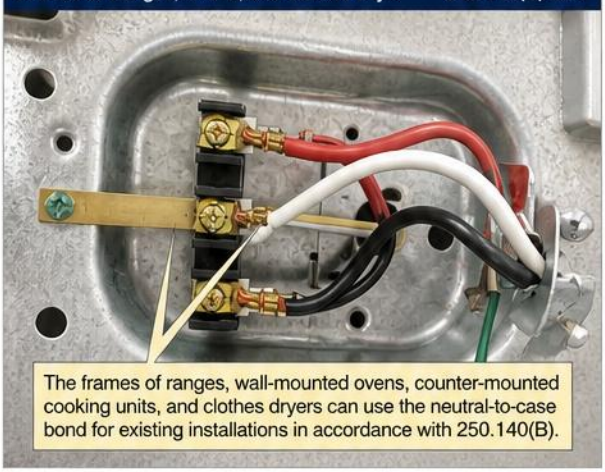
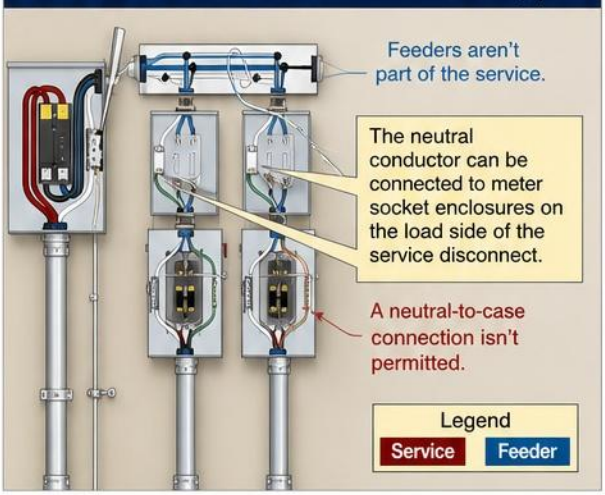


Figure 250–272 Neutral Conductor Bonded to Metal Parts, Load-Side Meter Socket Enclosures 250.142(B) Ex 2



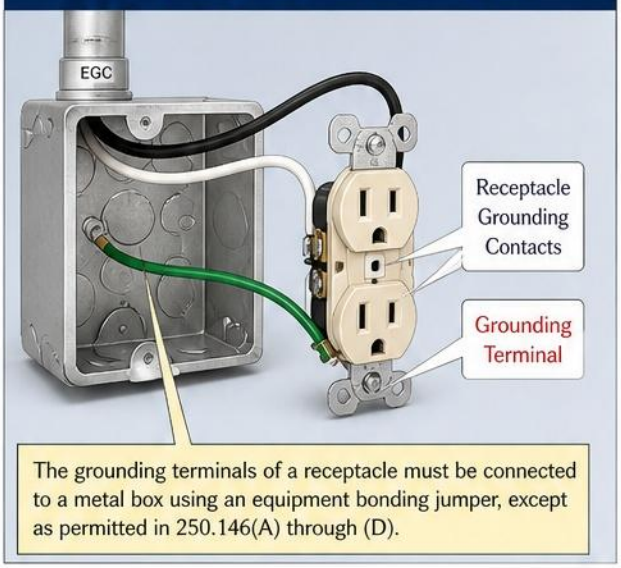
(2) All meter enclosures are immediately adjacent to the service disconnecting means

(3) Grounded circuit conductor is not smaller than the size specified in Table 250.122

250.146 Receptacle Grounding Terminal Bonding

The grounding terminals of a receptacle must be connected to a metal box using an equipment bonding jumper, except as permitted in 250.146(A) through (D).

Figure 250–273 **250.146**
Receptacle Bonding, Metal Boxes Connected to EGC



The equipment bonding jumper from a receptacle grounding terminal to a metal box must be sized in accordance with Table 250.122.

Author's Comment:

- The *NEC* does not restrict the position of the receptacle grounding terminal; it can be up, down, or sideways, *Code* proposals to specify the mounting position of receptacles have always been rejected. 250.146 Comment

(A) Surface-Mounted Box.

(1) Receptacle Mounted to Metal Box. A bonding jumper from the receptacle grounding terminal to the metal box is not required if:

(a) The receptacle has direct metal-to-metal contact between the receptacle mounting yoke and a surface-mounted metal box

(b) To ensure metal-to-metal contact, one of the insulating retaining washers on the yoke screw must be removed. Figure 250–275

Figure 250–274 **250.146 Comment**
Receptacle Bonding
Grounding Terminal Orientation

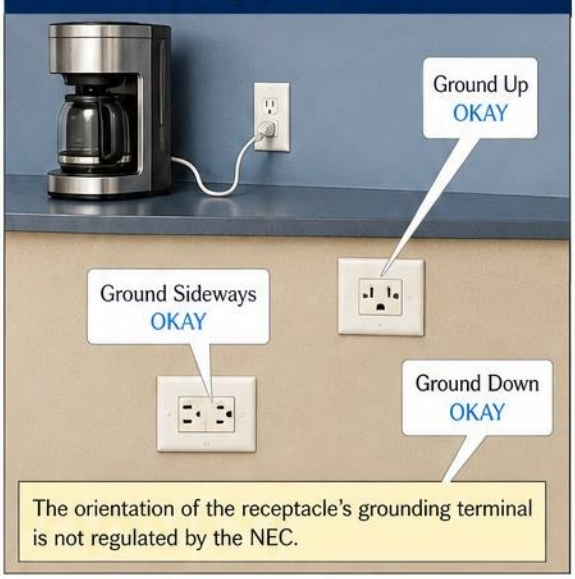


Figure 250–275 **250.146(A)(1)**
Receptacle Bonding
Surface-Mounted Metal Box

Yoke (Strap). The structural frame of a wiring device (such as a receptacle or switch) that serves as the mounting means. Figure 250–276

(2) Receptacle Mounted to Cover. A bonding jumper from the receptacle grounding terminal to the metal box is not required if:

(1) Receptacle is attached to the raised metal cover with two fasteners with a thread-locking means or two fasteners with a nut-locking means

(2) Raised metal cover mounting holes are on a flat non-raised portion of the cover ▸Figure 250–277

Figure 250–276 Yoke
Article 100 Definition

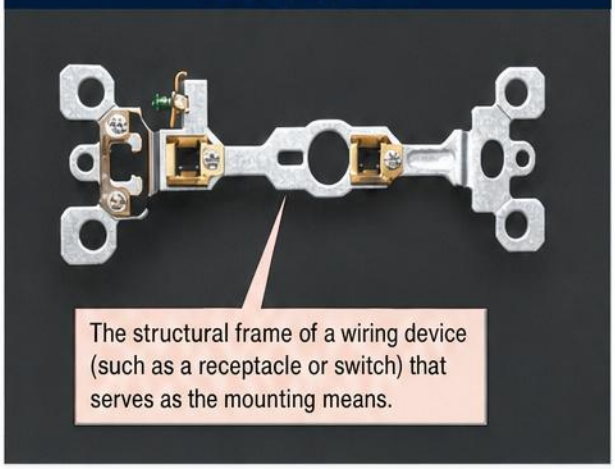
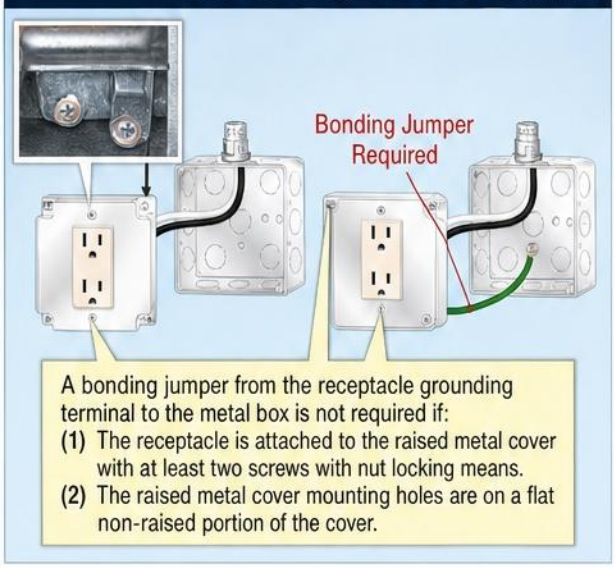


Figure 250–277 Receptacle Bonding, Metal Boxes
Raised Metal Cover, Two Fasteners 250.146(A)(2)



(B) Self-Grounding Receptacles. A bonding jumper from the grounding terminal of a self-grounding receptacle to a flush-type metal box is not required. Figure 250–278

Author's Comment:

- Receptacle yokes listed as "self-grounding" are considered bonded through the supporting screws connected to the metal box. Figure 250–279

(D) Isolated Ground Receptacles.

(1) Insulated Equipment Grounding Conductor. The grounding terminal of an isolated ground receptacle must be connected to an insulated equipment grounding conductor of the circuit. Figure 250–280

Figure 250–278 Receptacle Bonding, Metal Boxes
Self-Grounding Receptacle 250.146(B)

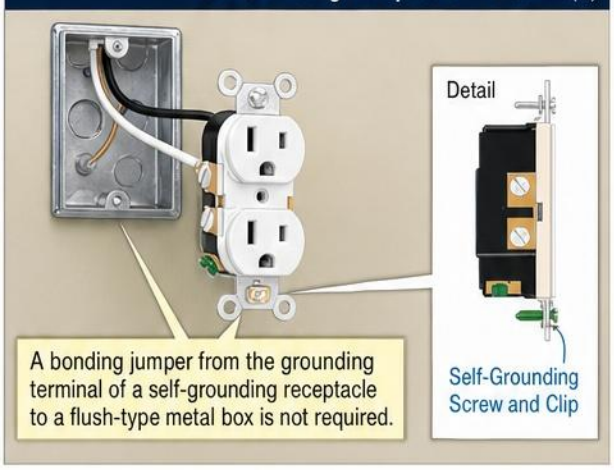


Figure 250–279 Receptacle Bonding
Self-Grounding Receptacle 250.146(B) Comment

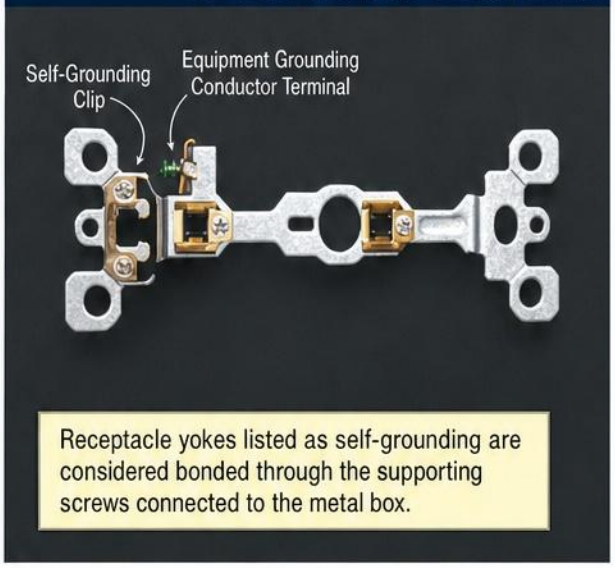
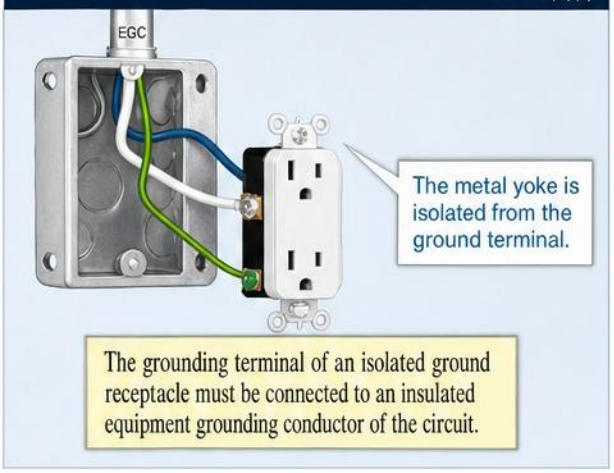


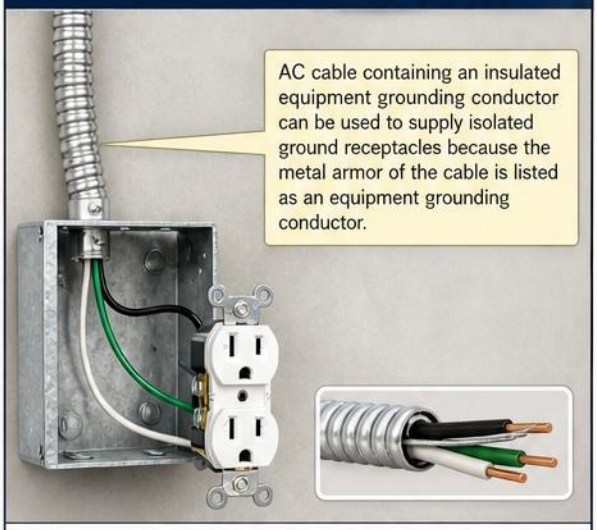
Figure 250–280 Isolated Ground Receptacle Bonding
Insulated Equipment Grounding Conductor 250.146(D)(1)



Author's Comment:

- AC cable containing an insulated equipment grounding conductor can be used to supply isolated ground receptacles because the metal armor of the cable is listed as an equipment grounding conductor [250.118(A)(8)]. Figure 250–281

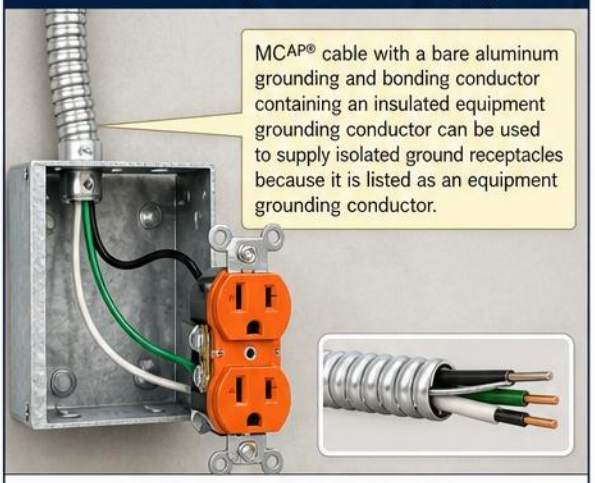
Figure 250–281 Isolated Ground Receptacle Bonding, AC Cable Insulated Equipment Grounding Conductor 250.146(D)(1) Comment



Qualifies as EGC [250.118(A)(8)]

- MC^AP® cable with a bare aluminum grounding and bonding conductor containing an insulated equipment grounding conductor can be used to supply isolated ground receptacles because it is listed as an equipment grounding conductor [250.118(A)(10)(b)]. Figure 250–282

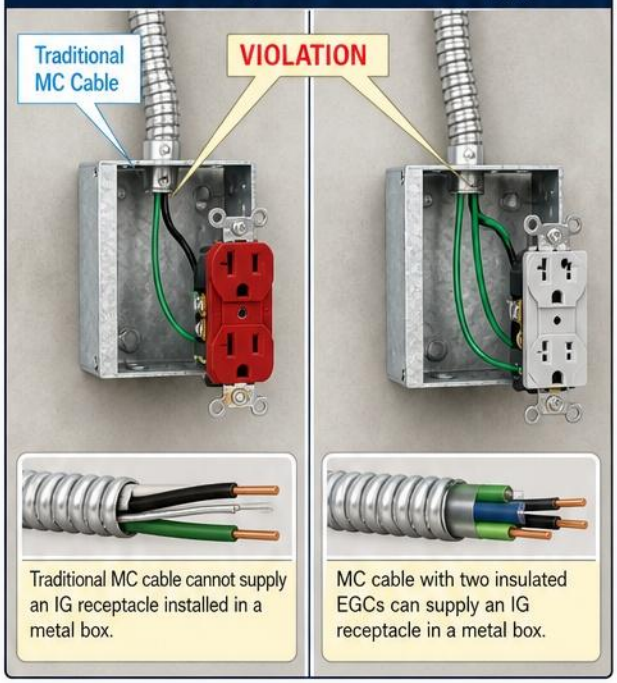
Figure 250–282 Isolated Ground Receptacle Bonding, MC^AP® Cable Insulated Equipment Grounding Conductor 250.146(D)(1) Comment



Qualifies as EGC [250.118(A)(10)(b)]

CAUTION: The metal armor sheath of traditional interlocked MC cable containing an insulated equipment grounding conductor is not listed as an equipment grounding conductor. Therefore, a single equipment grounding conductor with this wiring method cannot supply an isolated ground receptacle. MC cable with two insulated equipment grounding conductors is acceptable because one bonds to the metal box, and the other one connects to the isolated ground receptacle. Figure 250–283

Figure 250–283 Isolated Ground Receptacle Bonding, Wiring Method Insulated Equipment Grounding Conductor 250.146(D)(1) Caution



(2) Connection to Grounding Terminals.

(a) Insulated equipment grounding conductors can pass through one or more panelboard enclosures without connections to grounding terminal bars as permitted in 408.40 Ex

(b) If installed in accordance with this section, insulated equipment grounding conductors can pass through boxes, wireways, or other enclosures without being connected to such enclosures

Note: Use of an isolated equipment grounding conductor does not relieve the requirement for connecting the raceway system and outlet box to an equipment grounding conductor.

Author's Comment:

- When should an isolated ground receptacle be installed and how should the isolated ground system be designed? These questions are design issues and are not answered based on the *NEC* alone. In most cases, using isolated ground receptacles is a waste of money. For example, *IEEE 1100, Powering and Grounding Electronic Equipment* (Emerald Book) section 8.5.3.2 states, "The results from the use of the isolated ground method range from no observable effects, the desired effects, or worse noise conditions than when standard equipment bonding configurations are used to serve electronic load equipment."

- Few electrical installations truly require an isolated ground system. For those systems that can benefit from one, engineering opinions differ as to what is a proper design. Making matters worse, of those properly designed, few are correctly installed, and even fewer are properly maintained.

250.148 Continuity and Connections of Equipment Grounding Conductors in Boxes

Equipment grounding conductors in boxes must be installed as follows:

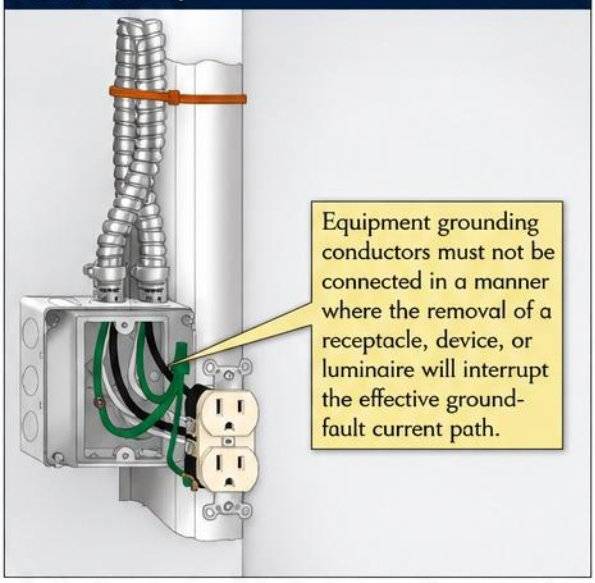
(A) Connected Together. All equipment grounding conductors that are spliced or terminate in a box must be connected together.

Figure 250–284: Equipment Grounding Conductors Connected Together 250.148(A)

All equipment grounding conductors that are spliced or terminate in a box must be connected together.

(B) Continuity of Equipment Grounding Conductors. Equipment grounding conductors must not be connected in a manner where the removal of a receptacle, device, or luminaire will interrupt the effective ground-fault current path.

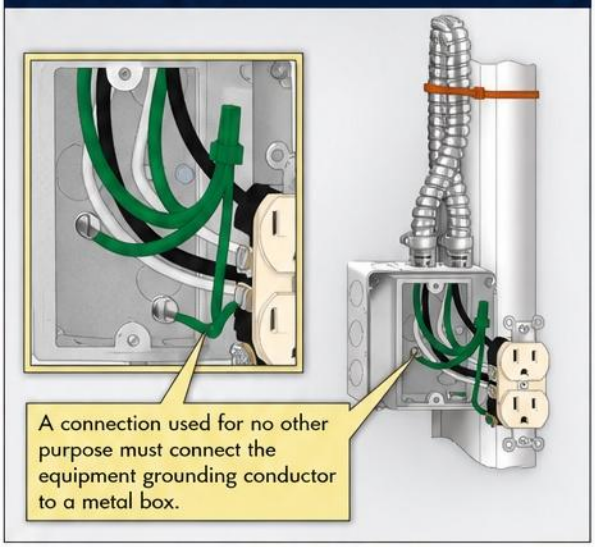
Figure 250–285: Equipment Grounding Conductors Electrical Continuity 250.148(B)



A break in the equipment grounding conductor caused by removing this receptacle would interrupt the effective ground-fault current path.

(C) Metal Boxes. A connection used for no other purpose must connect the equipment grounding conductor to a metal box.

Figure 250–286: Equipment Grounding Conductors Connection to Metal Boxes 250.148(C)

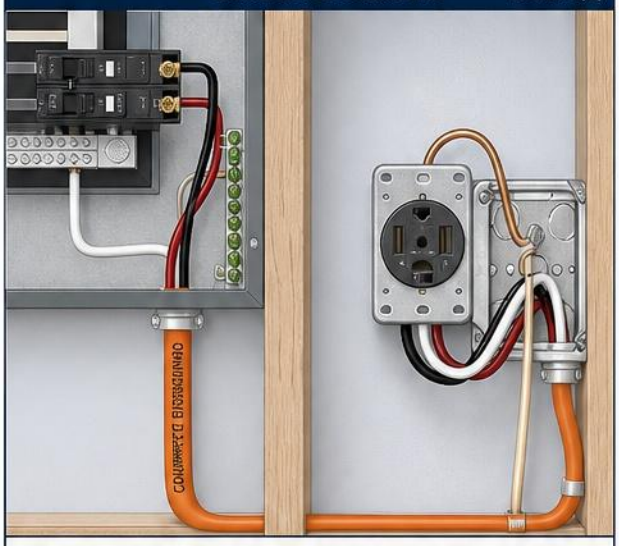


The green equipment grounding conductor is attached to the metal box using a dedicated grounding screw.

The equipment bonding jumper or equipment grounding conductor to the metal box must be sized from Table 250.122, based on the largest overcurrent protective device protecting circuit conductors in the box.

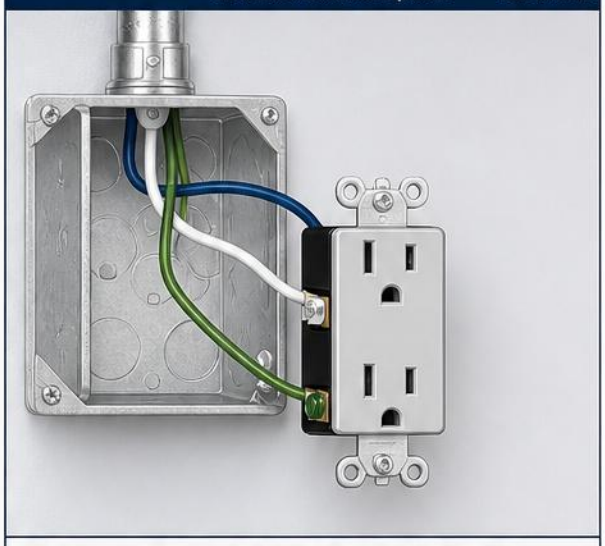
Example: The equipment grounding conductor for an *isolated ground receptacle [250.148(Ex)] is not required to be bonded to other equipment grounding conductors* or the metal box.

Figure 250–287 Equipment Grounding Conductors Connection to Metal Boxes 250.148(C)



The equipment bonding jumper or equipment grounding conductor to the metal box must be sized from Table 250.122 based on the largest overcurrent protective device protecting circuit conductors in the box.

Figure 250–288 Equipment Grounding Conductors Isolated Ground Receptacle 250.148 Ex



The equipment grounding conductor for an isolated ground receptacle is not required to be bonded to other equipment grounding conductors or the metal box.

Article 230 Services

Article 230 provides requirements for conductors and equipment that deliver power from the service point to the service disconnecting means and the load.

230.1 Scope

This article covers the installation of service conductors and service equipment that supply electrical power from the serving utility to the service disconnecting means and the premises wiring or utilization equipment.

230.2 General

(A) Service conductors and equipment must comply with the applicable requirements of this Code.

(B) Service conductors and equipment must comply with 110.12.

230.3 Service Equipment

Service equipment must comply with Parts II and III of Article 408.

(A) **Service Disconnecting Means.** Service equipment must include a means by which the ungrounded conductors can be disconnected.

(B) **Service Connections.** Terminal lugs or approved means must be provided for connecting the service conductors to the service disconnecting means.

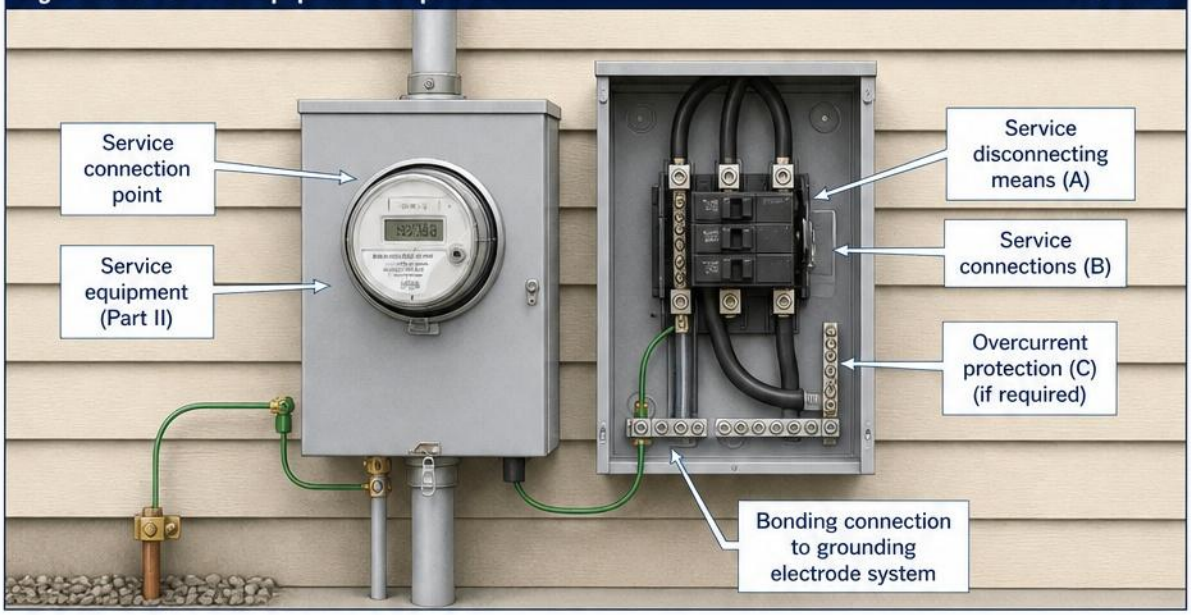
(C) **Overcurrent Protection.** Service equipment must include overcurrent protection for the service conductors unless all of the following conditions are met:

(1) The service conductors are at least 10 AWG copper or 8 AWG aluminum.

(2) The service conductors are installed in accordance with 230.43.

(3) The service conductors are protected from physical damage in accordance with 230.43.

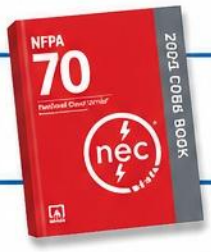
Figure 230.3 Service Equipment Components **NEC 230.3**



Service equipment must include a service disconnecting means, lugs or other approved means for connecting service conductors, and overcurrent protection unless all conditions in 230.3(C) are met.

CHAPTER 2

REVIEW QUESTIONS



Please use the *2026 Code* book to answer the following questions.

1. All 125V through 250V receptacles installed in crawl spaces at or below grade level of dwelling units shall have _____ protection.

(a) AFCI
(b) GFCI
(c) GFPE
(d) AFCI and GFCI

2. In dwelling unit kitchens, all 125V through 250V receptacles _____ shall be provided with GFCI protection.

(a) installed to serve the countertop surfaces
(b) installed to serve island or peninsula countertops
(c) installed to serve above or below the countertop surfaces
(d) serving the kitchen

3. In other than dwelling units, all single-phase receptacles rated 150V to ground or less, 50A or less and three-phase receptacles rated 150V to ground or less, _____ or less installed in locker rooms with associated showering facilities shall be GFCI protected.

(a) 60A
(b) 75A
(c) 100A
(d) 125A

4. At least one 120V, 20A branch circuit shall be installed to supply receptacle outlets in attached and detached _____ with electric power.

(a) decks
(b) basements
(c) accessory buildings
(d) garages

5. Conductors for branch circuits are sized to prevent a voltage drop exceeding _____ at the farthest outlet of power, heating, and lighting loads.

(a) 2 percent
(b) 3 percent
(c) 4 percent
(d) 6 percent

6. Where a branch circuit supplies continuous loads and/or noncontinuous loads, the ampere rating of the OCPD shall not be less than the noncontinuous load plus _____ of the continuous load.

(a) 80 percent
(b) 115 percent
(c) 120 percent
(d) 125 percent

7. Where connected to a branch circuit supplying two or more receptacles or outlets, a 15A receptacle shall not supply a total cord-and-plug-connected load exceeding _____.

(a) 7.5A (b) 10A (c) 12A (d) 15A

Figure 7 15A Receptacle—Cord-and-Plug Load Limit NEC 210.21(B)(3)

The total load of cord-and-plug-connected equipment on a single 15A receptacle cannot be more than 15A.

8. If a 20A branch circuit supplies multiple receptacles, the receptacles shall have an ampere rating of no less than _____.

(a) 10A (b) 15A (c) 20A (d) 30A

Figure 8 20A Branch Circuit Receptacle Rating NEC 210.21(B)(3)

Receptacles on a 20A branch circuit must be rated 20A or higher.

9. A receptacle outlet for a specific appliance shall be installed within _____ of the intended location of the appliance.

(a) 2 ft (b) 3 ft (c) 6 ft (d) 10 ft

Figure 9 Appliance Receptacle Location NEC 210.63

The receptacle for a specific appliance must be within 6 ft of the appliance's intended location.

10. Floor receptacle outlets shall not be counted as part of the required number of receptacle outlets for dwelling unit wall spaces, unless they are located within _____ of the wall.

(a) 6 in. (b) 12 in. (c) 18 in. (d) 24 in.

Figure 10 Floor Receptacle Counting Rule NEC 210.52(A)(1)

A floor receptacle is counted toward wall space requirements only if it is within 18 in. of the wall.

11. Receptacles installed in a dwelling unit kitchen to serve countertop surfaces shall be supplied by not fewer than _____ small-appliance branch circuit(s).

(a) one (b) two (c) three (d) four

Figure 11 Kitchen Countertop Circuits NEC 210.52(C)(1)

Kitchen countertop receptacles must be served by at least two small-appliance branch circuits.

12. Dwelling unit kitchen countertop receptacle outlets shall be installed so that no point along the wall line is more than _____ measured horizontally from a receptacle outlet in that space.

(a) 2 ft (b) 3 ft (c) 4 ft (d) 5 ft

Figure 12 Kitchen Countertop Spacing NEC 210.52(C)(2)

Every point along the wall line must be within 4 ft of a countertop receptacle.

13. Dwelling unit foyers that are not part of a hallway with an area greater than _____ shall have a receptacle located in each wall space 3 ft or more in width.

(a) 40 sq ft (b) 60 sq ft (c) 80 sq ft (d) 100 sq ft

Figure 13 Foyer Area Exception NEC 210.52(A)(2)

Foyers not part of a hallway with more than 60 sq ft of area require receptacles in wall spaces 3 ft or wider.

14. In rooms other than kitchens, laundry areas, and bathrooms of dwelling units, one or more _____ controlled by a wall switch or listed wall-mounted control device shall be permitted in lieu of lighting outlets.

(a) receptacles (b) switches (c) disconnects (d) outlets

Figure 14 Wall-Controlled Receptacles NEC 210.70(A)(1)

A wall switch or listed wall-mounted control may be used to control receptacles instead of a lighting outlet.

15. If a feeder supplies _____, a surge-protective device shall be installed.

(a) dwelling units
(b) dormitories
(c) guest rooms and suites of hotels and motels
(d) any of these

Figure 15 Surge-Protective Device NEC 215.7

SPDs are required when a feeder supplies any of the listed occupancies.

16. Article 225 covers requirements for _____ branch circuits and feeders not over 1000V ac, 1500V dc run on or between buildings or poles on the premises.

(a) interior (b) exterior (c) inside (d) outside

Figure 16 Article 225 Scope NEC 225.1

Article 225 covers outside branch circuits and feeders on the premises.

17. If located outside of the building, the outdoor feeder disconnecting means shall be located on or _____ of the building in accordance with 110.29.

(a) out of sight (b) within sight
(b) within sight (d) within view

Figure 17 Outdoor Disconnect Location NEC 225.30

The outdoor feeder disconnect must be located on or within view of the building.

18. Where a building has multiple outside feeders and services, a permanent _____ shall be installed at each outside feeder and service disconnect location denoting all other feeders and services supplying that building and the area served by each.

Figure 18 Permanent Directory or Plaque — Article 230.70(A)(1)

(a) plaque or directory
(b) map or plan
(c) label or marking
(d) guide or document

19. A building disconnecting means in accordance 225.31 that supplies not more than two 2-wire branch circuits shall have a rating of not less than _____.

(a) 15A
(b) 20A
(c) 25A
(d) 30A

Figure 19 Two 2-Wire Branch Circuits — 225.31

20. Under special conditions, additional services are permitted for a(an) _____.

(a) fire pump
(b) emergency system
(c) optional standby system
(d) any of these

Figure 20 Additional Services — Article 230.2

21. Vegetation shall not be used for support of _____.

(a) service conductors
(b) service equipment
(c) service conductors or service equipment
(d) none of these

Figure 21 Unsuppurted by Vegetation — Article 300.11

22. Overhead service conductors that pass over public streets, alleys, roads, and parking areas subject to truck traffic shall have a minimum vertical clearance of _____.

(a) 10 ft
(b) 12 ft
(c) 15 ft
(d) 18 ft

Figure 22 Minimum Vertical Clearance — Article 230.24(B)

23. To prevent the entrance of _____, service-entrance conductors shall be connected to the service drop or overhead service conductors either below the level of the service head or below the level of the termination of the service-entrance cable sheath.

(a) rain
(b) snow
(c) ice crystals
(d) moisture

Figure 23 Preventing Moisture Entrances — 230.28

24. The _____ service disconnects can consist of separate enclosures with a single service disconnect in each enclosure.

(a) two to three
(b) two to four
(c) two to five
(d) two to six

Figure 24 Multiple Service Disconnects — 230.71(A)(1)

25. The service disconnecting means shall have a rating of not less than _____, for installations that supply only limited loads of a single branch circuit.

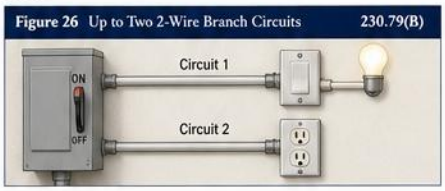
(a) 15A
(b) 20A
(c) 25A
(d) 30A

Figure 25 Single Branch Circuit (Limited Load) — 230.79(A)

26. The service disconnecting means shall have a rating of not less than _____, for installations consisting of not more than two 2-wire branch circuits.

(a) 15A
(b) 20A
(c) 25A
(d) 30A

Figure 26 Up to Two 2-Wire Branch Circuits — 230.79(B)



27. The service disconnecting means shall have a rating of not less than _____, for a one-family dwelling.

(a) 90A
(b) 100A
(c) 125A
(d) 200A

Figure 27 One-Family Dwelling — 230.79(C)

28. Interconnected electric power production sources are permitted to be connected to the _____ side of the service disconnect.

(a) top
(b) load
(c) supply
(d) bottom

Figure 28 Connection on Supply Side — 705.12(A)(2)(3)(a)

29. Outside feeder tap conductors can be of unlimited length without overcurrent protection at the point they receive their supply if the tap conductors _____.

(a) are protected from physical damage
(b) terminate at a circuit breaker or set of fuses that limits the load to the ampacity of the tap conductors
(c) the overcurrent device is an integral part of a disconnecting means or located immediately adjacent thereto
(d) all of these

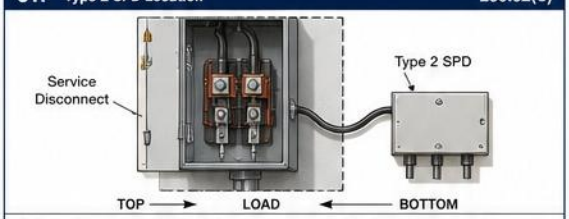
Figure 29 Outside Feeder Tap Conductors — Article 215.9(A)

30. Transformer Secondary Conductors 250.102(C)

Outside transformer secondary conductors can be of unlimited length without overcurrent protection at the point they receive their supply if the transformer secondary conductors _____.

(a) are protected from physical damage
(b) terminate at a circuit breaker or set of fuses that limits the load to the ampacity of the secondary conductors
(c) overcurrent device is an integral part of a disconnecting means or located immediately adjacent thereto
(d) all of these

31. Type 2 SPD Location 230.62(C)



A Type 2 surge-protective device is permitted to be connected on the _____ side of a service disconnect overcurrent protective device.

(a) top
(b) load
(c) bottom
(d) any of these

32. Grounding Connection to Earth 250.4(A)(5)

Electrical systems that are grounded shall be connected to earth such that the voltage imposed by _____ is limited and the voltage to earth is stabilized during normal operation.

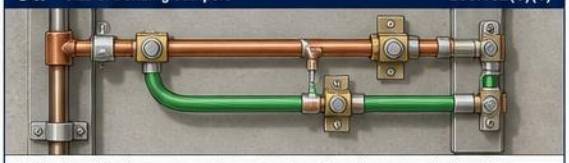
(a) lightning
(b) line surges
(c) unintentional contact with higher-voltage lines
(d) all of these

33. Bonding of Enclosures 250.8(A)

Normally non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be bonded together and to the _____ such that an effective ground-fault current path is established.

(a) ground
(b) earth
(c) electrical supply source
(d) enclosure

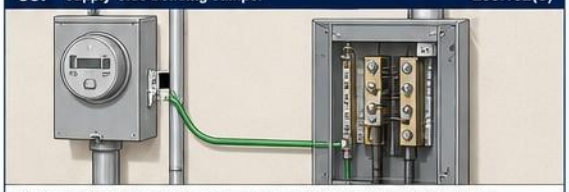
34. Size of Bonding Jumpers 250.102(C)(1)



Main bonding jumpers and system bonding jumpers shall not be smaller than specified in _____.

(a) Table 250.102(C)(1)
(b) Table 250.122
(c) Table 250.66
(d) Chapter 9, Table 8

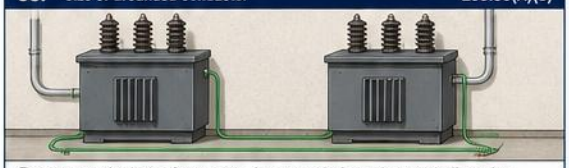
35. Supply-Side Bonding Jumper 250.102(C)



A supply-side bonding jumper of the wire type installed between a separately derived system and the first disconnecting means enclosure shall comply with 250.102(C), based on _____.

(a) the size of the primary conductors
(b) the size of the secondary overcurrent protection
(c) the size of the derived ungrounded conductors
(d) one-third the size of the primary grounded conductor

36. Size of Grounded Conductor 250.30(A)(5)



For separately derived systems, the grounded conductor shall not be required to be larger than the derived _____.

(a) neutral conductors
(b) ungrounded conductors
(c) equipment grounding conductors
(d) grounding electrode conductors

37. Common Grounding Electrode Conductor 250.30(A)(2)(a)

The common grounding electrode conductor installed for multiple separately derived systems shall be permitted to be the _____ of the building.

(a) fiberglass structural frame
(b) plastic structural frame
(c) metal structural frame
(d) wood structural frame

38. Electrode Coatings 250.52(A)(1)

_____ electrodes shall be free from nonconductive coatings such as paint or enamel.

(a) Rod
(b) Pipe
(c) Plate
(d) all of these

39. Embedding Electrodes 250.52(A)(5)

If practicable, rod, pipe, and plate electrodes shall be embedded _____.

(a) directly below the electrical meter
(b) on the north side of the building
(c) below permanent moisture level
(d) all of these

40. Protection of Grounding Electrode Conductors 250.64(B)

Grounding electrode conductors _____ or larger exposed to physical damage shall be protected.

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

41. A rebar-type concrete-encased electrode installed in accordance with 250.52(A)(3) in an accessible location that is not subject to _____ shall be permitted for connection of grounding electrode conductors.

Figure 41 Rebar-Type Concrete-Encased Electrode 250.52(A)(3)

(a) physical damage
(b) moisture
(c) corrosion
(d) any of these

42. The grounding or bonding conductors connection to the grounding electrode shall be made by _____.

Figure 42 Grounding Electrode Connections 250.64(C)

(a) listed lugs and listed clamps
(b) exothermic welding
(c) listed pressure connectors
(d) any of these

43. Metal raceways containing service conductors can be bonded with _____ couplings, entries, or listed hubs.

Figure 43 Raceways 250.97(A)

(a) loose
(b) threaded
(c) damaged
(d) unsecured

44. Metal raceways containing service conductors can be bonded using _____ couplings and connectors if made up tight for metal raceways or metal-clad cables.

Figure 44 Bonded Coupling Examples 250.97(A)

(a) broken
(b) threadless
(c) sealed
(d) classified

45. An intersystem _____ termination device shall be provided externally to the service equipment enclosure, metering enclosure, and the disconnect enclosure of buildings supplied by a feeder.

Figure 45 Intersystem Bonding Termination 250.30(A)(1)

(a) bonding
(b) ungrounded
(c) secondary
(d) bonding and ungrounded

46. If installed, metal covers, metal plaster rings, metal extension rings, and metal fittings shall be attached to metal enclosures in a manner that will ensure an _____.

Figure 46 Metal Covers and Fittings 250.96

(a) effective ground-fault current path
(b) electrically continuous metal system
(c) equipment bonding conductor
(d) approved bonding method

47. Exposed normally non-current carrying metal parts of cord-and-plug-connected equipment shall be connected to the equipment grounding conductor if operated at over _____ to ground.

Figure 47 Cord-and-Plug Equipment Grounding 250.114

(a) 24V
(b) 50V
(c) 120V
(d) 150V

48. Insulated conductors in a multiconductor cable shall be permitted to be permanently identified as equipment grounding conductors at every point where the conductors are accessible, by coloring the insulation _____.

Figure 48 Equipment Grounding Conductor Identification 250.119

(a) green
(b) grey
(c) green with a yellow stripe
(d) white or silver

49. For multiconductor cables connected in parallel, the _____ in each multiconductor cable shall be sized in accordance with 250.122.

Figure 49 Parallel Multiconductor Cables 250.122

(a) grounding electrode conductor
(b) equipment grounding conductor
(c) ungrounded conductor
(d) all of these

50. Equipment grounding conductors for feeder taps are not required to be _____ than the tap conductors.

Figure 50 Feeder Tap Grounding 250.122

(a) larger
(d) smaller
(c) less
(d) none of these

Article 100 Definitions

100 Definitions

The following terms are defined in Article 100 and are used throughout the NEC.

Approved. Acceptable to the authority having jurisdiction.

Electrical Equipment. Equipment used in electric circuits or systems.

Electrical Installation. The assembly of all electrical equipment.

Exposed, normally. Subject to accidental contact.

Suitable. Acceptable for use under the conditions involved.

Additional defined terms are located in Part II, List of Defined Terms.

Article 110 General Requirements for Electrical Installations

110.1 Scope

These requirements cover the installation of conductors and equipment.

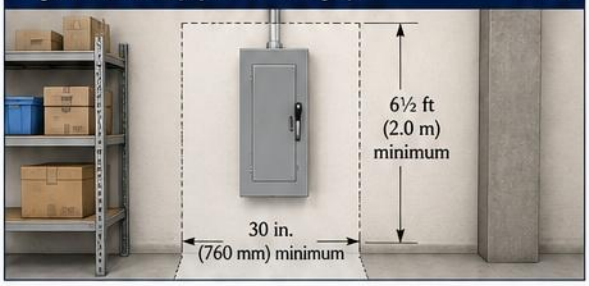
110.2 Approval

Electrical equipment shall be listed or labeled in accordance with 110.2.

110.3 Installation and Use

Electrical equipment shall be installed and used in accordance with any instructions included in the listing or labeling.

Figure 110.12 Equipment Working Space 110.12



Sufficient space shall be provided and maintained in front of electrical equipment to permit ready and safe operation and maintenance.

Figure 110.26 Unused Openings in Equipment 110.26

Unused openings in equipment, including spare conduit openings, shall be effectively closed to afford protection substantially equivalent to the wall of the equipment.

Article 110 General Requirements for Electrical Installations

110.10 Electrical Connections

Electrical connections shall be made in accordance with 110.10.

110.12 Equipment Working Space

Sufficient space shall be provided and maintained in front of electrical equipment to permit ready and safe operation and maintenance.

110.26 Unused Openings in Equipment

Unused openings in equipment, including spare conduit openings, shall be effectively closed to afford protection substantially equivalent to the wall of the equipment.

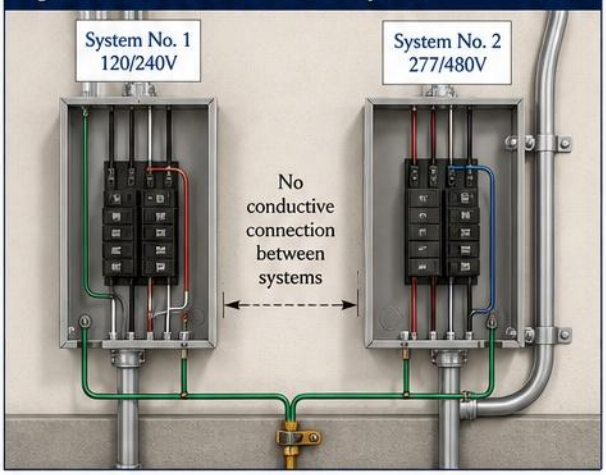
110.26(A) Disassembly Not Required

Closures used to close openings in equipment shall not be required to be secured in place if such closures can be removed only by the use of a tool.

110.26(B) List of Acceptable Closures

A list of acceptable closures for openings in electrical equipment shall be provided as part of the listing.

Figure 110.34 Live Parts of Different Systems 110.34



Live parts of different systems shall not be connected together unless required by 110.34(D).

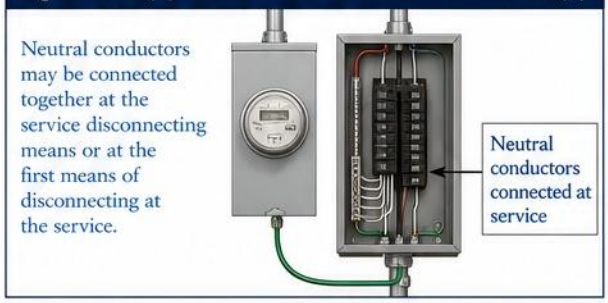
110.34 Live Parts of Different Systems

Live parts of different systems shall not be connected together unless required by 110.34(D).

110.34(D) Connection of Neutral Conductors

Neutral conductors of systems having a grounded conductor shall be connected together only in accordance with 250.24(A)(5).

Figure 110.34(D) Neutral Connection 110.34(D)



Neutral conductors may be connected together only at the service disconnecting means or at the first means of disconnecting at the service.

CHAPTER

3 WIRING METHODS AND MATERIALS

Introduction to Chapter 3—Wiring Methods and Materials

Wiring Method Articles

Article 300—General Requirements for Wiring Methods and Materials

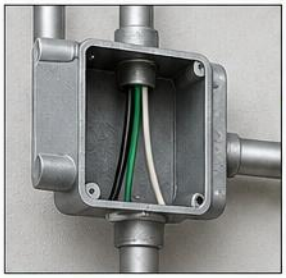
This article sets forth the overall requirements for wiring methods, with the exception of limited-energy circuits that are addressed in Articles 720 and 722.

Article 310—Conductors for General Wiring

This article establishes the general requirements for conductors, including insulation markings, ampacity ratings, and conditions of use.

Article 312—Cabinets and Meter Socket Enclosures

This article describes the installation and construction specifications for panelboard cabinets and meter socket enclosures.



Article 314—Boxes, Conduit Bodies, and Handhole Enclosures

This article outlines the installation requirements for outlet boxes, pull and junction boxes, as well as conduit bodies and handhole enclosures.

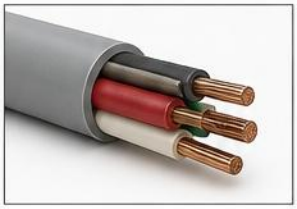
Cable Articles

Article 320—Armored Cable (Type AC)

This article covers AC cable, a factory assembly of conductors protected by interlocked metallic armor with an internal bonding strip. This type is commonly referred to as "BX".

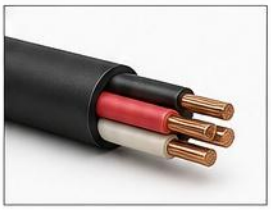
Article 330—Metal-Clad Cable (Type MC)

This article covers MC cable, a factory assembly of insulated conductors encased in a metal sheath of spiral interlocked steel or aluminum.



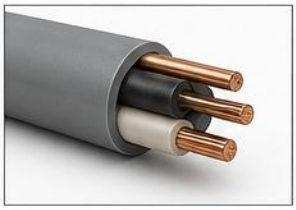
Article 334—Nonmetallic-Sheathed Cable (Type NM)

This article covers NM cable, a factory assembly of insulated conductors and an equipment grounding conductor within an overall nonmetallic flame-retardant sheath.



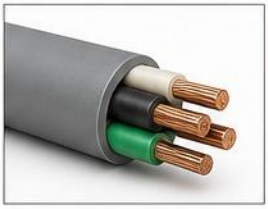
Article 336—Power and Control Tray Cable (Type TC)

This article covers TC cable, a factory assembly of conductors (with or without bare or covered equipment grounding conductors) under a nonmetallic jacket.



Article 338—Service-Entrance Cable (Types SE and USE)

This article covers SE and USE cables, constructed with a single conductor or a multiconductor assembly inside an overall nonmetallic outer jacket or covering.



Article 340—Underground Feeder and Branch-Circuit Cable (Type UF)

This article covers UF cable, a factory assembly of conductors with an integral or overall covering of nonmetallic material suitable for direct burial.

Raceway Articles

Article 342—Intermediate Metal Conduit (IMC)

This article addresses IMC, which is a steel raceway of circular cross section that can be threaded (with integral or associated couplings) and listed for the installation of electrical conductors.

Article 344—Rigid Metal Conduit (RMC)

This article addresses RMC, which is a metal raceway of circular cross section that can be threaded (with integral or associated couplings) and listed for the installation of electrical conductors.

Article 348—Flexible Metal Conduit (FMC)

This article addresses FMC, which is a raceway of circular cross section (made of a helically wound, formed, interlocked metal strip) and listed for the installation of electrical conductors. This type is commonly referred to as "Greenfield®" (after its inventor) or "Flex."

Article 350—Liquidtight Flexible Metal Conduit (LFMC)

This article addresses LFMC, which is a raceway of circular cross section (having an outer liquidtight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core) with connectors and fittings listed for the installation of electrical conductors. This type is commonly referred to as "Sealtite®" or simply "liquidtight."

Article 352—Rigid Polyvinyl Chloride Conduit (PVC)

This article addresses PVC, a rigid nonmetallic raceway of circular cross section with couplings, connectors, and fittings listed for the installation of electrical conductors.

Article 356—Liquidtight Flexible Nonmetallic Conduit (LFNC)

This article addresses LFNC, which is a raceway of circular cross section (constructed of an outer liquidtight, nonmetallic, sunlight-resistant jacket over a flexible inner core) with connectors and fittings listed for the installation of electrical conductors. This type is conmonly referred to as "Carlflex®".

Article 358—Electrical Metallic Tubing (EMT)

This article addresses EMT, which is a threadless, thinwall circular metallic raceway designed for the physical protection and routing of conductors. When joined together with fittings, it can be used as an equipment grounding conductor.

Article 362—Electrical Nonmetallic Tubing (ENT)

This article addresses ENT, which is a pliable corrugated circular raceway with couplings, connectors, and fittings of the same material as PVC conduit. ENT is flame-retardant and resistant to moisture and chemical atmospheres.

Article 376—Metal Wireways

This article addresses metal wireways, which are sheet metal troughs with hinged or removable covers for housing and protecting electrical conductors and cables installed after completing the raceway.

Article 380—Multioutlet Assemblies

This article addresses multioutlet assemblies, which are surface, flush, or freestanding raceway assembly designed to contain receptacles and conductors.

Article 386—Surface Metal Raceways

This article addresses surface metal raceways (with associated fittings intended to be mounted on the surface of a structure) in which conductors are placed after the raceway has been installed as a complete system.

Cable Trays

Article 392—Cable Trays

This article addresses cable tray systems, which are a unit (assembly of units or sections with associated fittings forming a rigid structural system), used to securely fasten or support cables and raceways.

ARTICLE 300 General Requirements for Wiring Methods and Materials

Introduction to Article 300—General Requirements for Wiring Methods and Materials

Article 300 includes the general requirements for every installed wiring method described in the *NEC*, provided they are not rated higher than 1000 Vac, 1500 Vdc, nominal. Because the *Code* is an installation standard, this article does not apply where these wiring methods form an integral part of electrical equipment. Article 300 establishes the foundational requirements for all wiring methods found in Chapter 3, addressing subjects like conductor spacing, protection against physical damage, and securing or supporting.

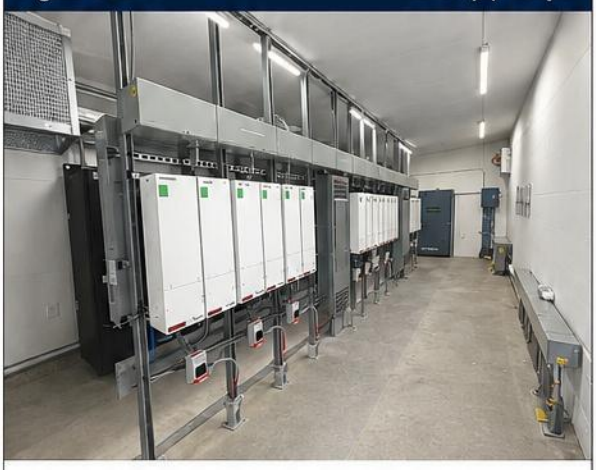
To ensure a safe installation, it's essential to understand and apply the general rules in Article 300 before moving on to the details of any Chapter 3 wiring method.

Part I. General Requirements

300.1 Scope

(A) Covered. Article 300 contains the general requirements for wiring methods and materials used for power and lighting.

Figure 300–1 300.1(A) Scope



Article 300 contains the general requirements for wiring methods and materials used for power and lighting.

(B) Not Covered in Article 300. Article 300 does not apply to the following:

(1) Class 2 circuits, antenna systems, and power-limited fire alarm systems

(2) Integral parts of electrical equipment See Figure 300–2.

Figure 300–2 300.1(B)(2) Scope

Article 300 does not apply to integral parts of electrical equipment.

Author's Comment

- Listed factory-installed internal wiring of equipment does not need to be inspected. See 90.7.

300.4 FIRE AND WATER DAMAGE

(C) Damaged Conductors and Wiring Methods. Conductors and wiring methods that are no longer suitable for use because of overheating, fire damage, corrosive influences, or water exposure must be replaced.
▶ Figure 300–3 and ▶ Figure 300–4

Figure 300–3 Water-Damaged Conductors and Wiring Methods 300.4(C)

Conductors and wiring methods that are no longer suitable for use because of overheating, fire damage, corrosive influences, or water exposure must be replaced.

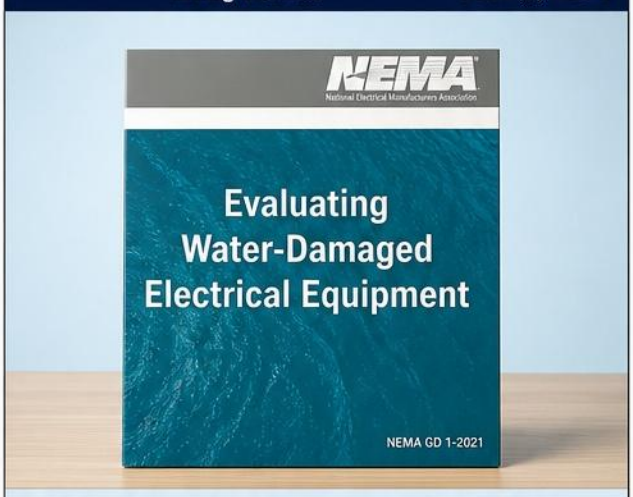
Figure 300–4 Fire-Damaged Conductors and Wiring Methods 300.4(C)

Conductors and wiring methods that are no longer suitable for use because of overheating, fire damage, corrosive influences, or water exposure must be replaced.

Note 1: For information on electrical equipment and wiring methods damaged by water, see *NEMA GD 1, Evaluating Water-Damaged Electrical Equipment.* ▶ Figure 300–5

Note 2: For information on electrical equipment and wiring methods damaged by fire or heat, see *NEMA GD 2, Evaluating Fire- and Heat-Damaged Electrical Equipment.* ▶ Figure 300–6

Figure 300–5 Water-Damaged Conductors and Wiring Methods 300.4(C) Note 1



For information on electrical equipment and wiring methods damaged by water, see *NEMA GD 1, Evaluating Water-Damaged Electrical Equipment.*

Figure 300–6 Fire-Damaged Conductors and Wiring Methods 300.4(C) Note 2

For information on electrical equipment and wiring methods damaged by fire or heat, see *NEMA GD 2, Evaluating Fire- and Heat-Damaged Electrical Equipment.*

300.5 CONDUCTORS

(A) Conductors. Single conductors specified in Table 310.4(1) must be installed in a Chapter 3 wiring method. ▶ Figure 300–7

(B) Conductors Grouped Together. All conductors of a circuit — including the neutral and equipment grounding conductors — must be installed together in the same raceway, cable, trench, or cable tray, except as permitted by the following: ▶ Figure 300–8 and ▶ Figure 300–9

(1) Paralleled Installations. All circuit conductors of a parallel set must be installed within the same raceway, cable, or cable tray in accordance with 310.10(G). ▶ Figure 300–10

Figure 300–7 Single Conductors in a Chapter 3 Wiring Method 300.5(A)(1)

Individual conductors listed in Table 310.4(A)(1) are required to be installed using a wiring method permitted in Chapter 3.

Figure 300–8 Conductors in the Same Raceway 300.5(B)

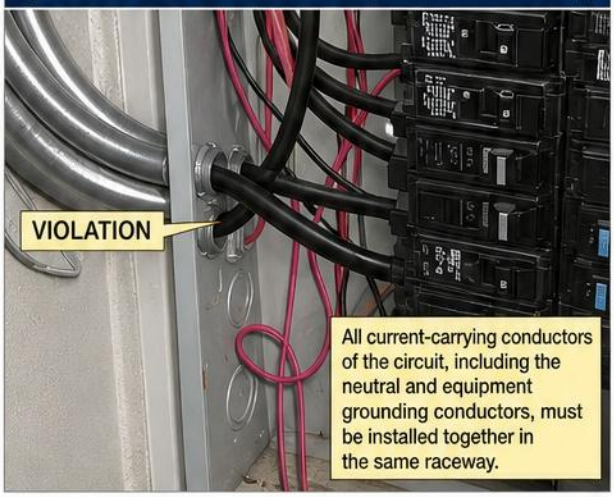


Figure 300–9 Conductors in the Same Raceway 300.5(B)

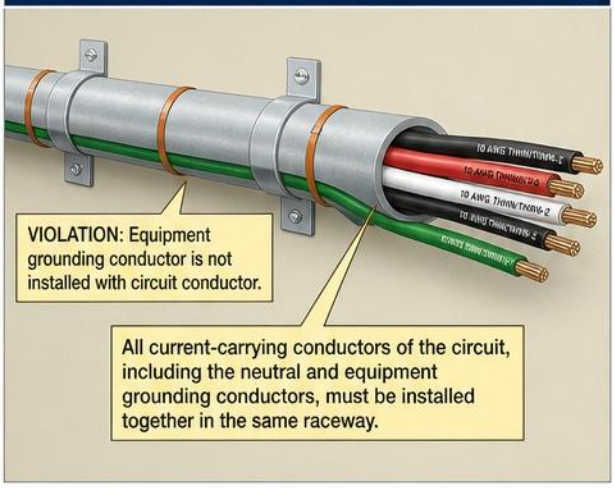
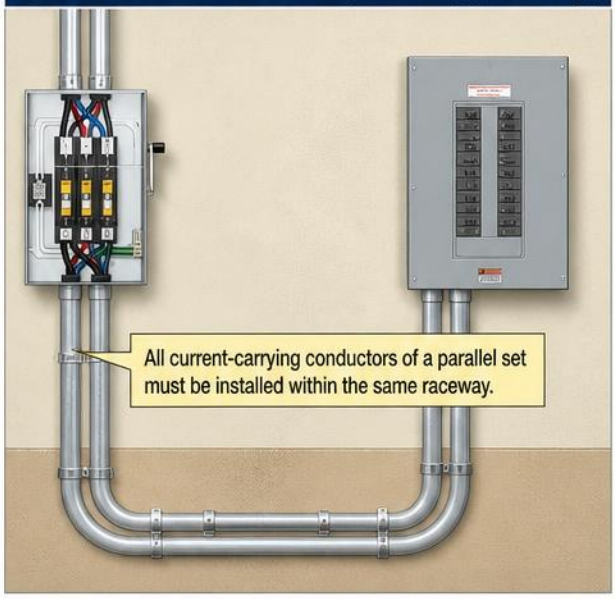


Figure 300–10 Parallel Conductors in a Group 300.5(B)(1) and 310.10(G)



Splices, taps, or extensions made to conductors that are part of a parallel conductor set must be connected to every conductor in that set.

Figure 300–11 Connections to Parallel Conductors 300.5(B)(1)

Author's Comment

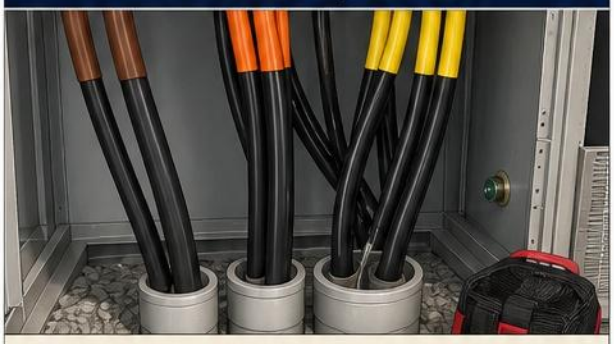
- Grouping all of the phase, neutral, and equipment grounding conductors of a circuit together reduces the inductive heating effects of the surrounding steel raceways and enclosures [300.22(A)]. **Figure 300–12**

Example: *Parallel insulated conductors installed in separate underground nonmetallic raceways are permitted when the installation complies with 300.22(B).* **Figure 300–13**

Figure 300–12 Conductors Grouped Together Minimize Inductive Heating **300.5(B)(1) Comment**

VIOLATION: Combining all ungrounded (phase), neutral, and equipment grounding conductors of a circuit in the same bundle decreases the inductive heating effects on adjacent steel raceways and enclosures [300.22(A)].

Figure 300–13 Conductors Grouped Together Isolated Parallel Underground Installations **300.5(B)(1) Ex**



Isolated parallel conductors in underground nonmetallic raceways are allowed when the installation complies with 300.22(B).

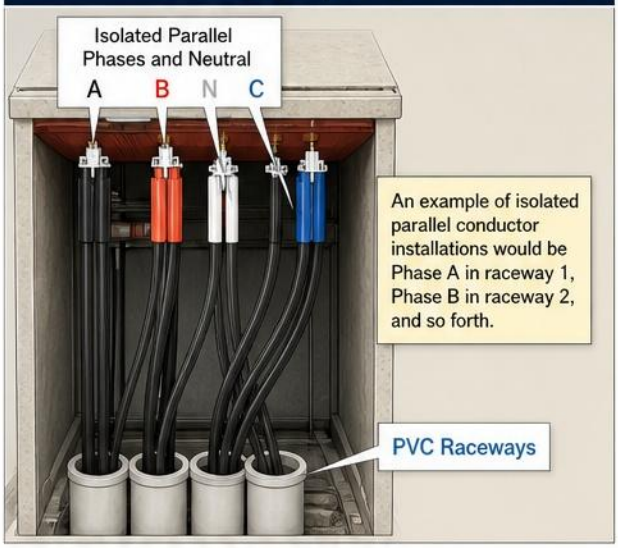
Author's Comment:

- An illustration of isolated parallel conductor installations would be Phase A in raceway 1, Phase B in raceway 2, and so forth. **See Figure 300–14.**

(2) Bonding Jumpers Outside the Raceway. Equipment grounding conductors for dc circuits can be run separately from the circuit conductors. **See Figure 300–15.**

Equipment bonding jumpers for ac circuits can be run outside the circuit raceway in accordance with 250.102(E)(2). **See Figure 300–16.**

Figure 300–14 Conductors Grouped Together Isolated Parallel Underground Installations **300.5(B)(1) Ex Comment**



Example: Isolated parallel conductor installations with each phase in a separate raceway, as shown.

Figure 300–15 Conductors Grouped Together EGC Separate in dc Circuits **300.5(B)(2)**

Equipment grounding conductors for dc circuits may be routed separately from the circuit conductors.

Figure 300–16 Conductors Grouped Together Bonding Jumpers Outside the Raceway **300.5(B)(2)**

Equipment bonding jumpers for ac circuits may be routed outside the circuit raceway in accordance with 250.102(E)(2).

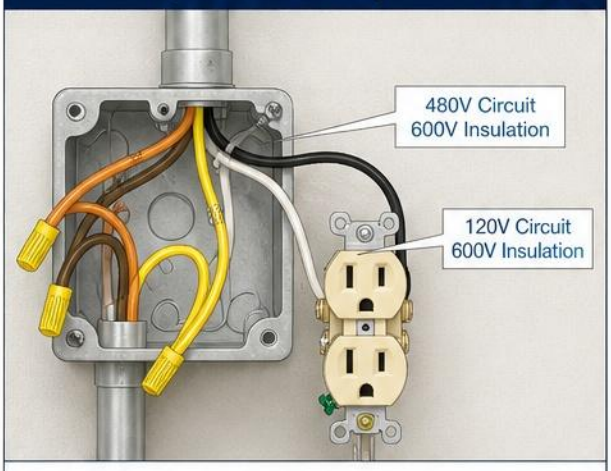
(C) Mixing Conductors of Different Voltage Systems.

(1) 1000V Nominal, or Less.

(a) Voltage Insulation Rating. Power conductors of ac and dc circuits can occupy the same raceway, cable, or enclosure if all conductors have an insulation voltage rating not less than the maximum circuit voltage applied to any conductors.

▸ Figure 300–17

Figure 300–17 Mixing Conductors of Different Voltage Systems – Insulation Rating 300.5(C)(1)(a)



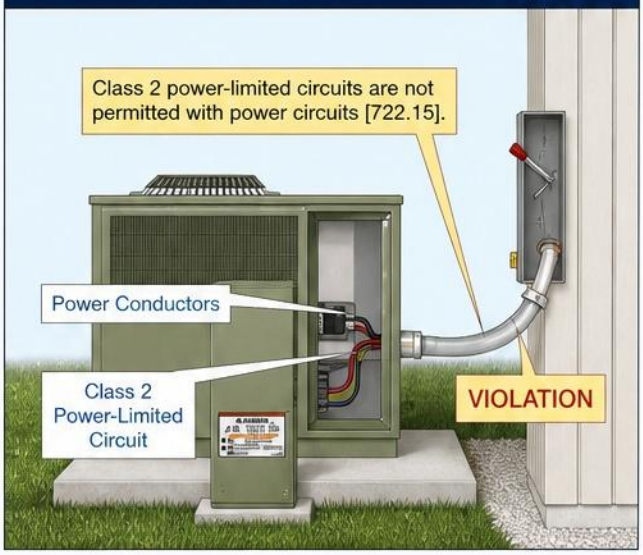
Circuit conductors can occupy the same raceway, cable, or enclosure if all conductors have an insulation voltage rating not less than the maximum circuit voltage applied to any conductor.

Author's Comment:

- Power conductors and non-power-limited remote control and signaling conductors can occupy the same raceway, cable, or enclosure—if all conductors have an insulation voltage rating not less than the maximum circuit voltage applied to the circuit conductors and the equipment powered is functionally associated [206.4(C)].
- The maximum circuit voltage applied to the circuit conductors in a raceway or enclosure is what determines the minimum conductor insulation voltage rating of all conductors in the raceway. For example, a 120/240V circuit installed in a raceway must have all conductors with a minimum insulation voltage rating of 240V.

Note 1: Class 2 power-limited circuits are not permitted with power circuits to prevent the higher-voltage conductors from accidentally energizing the Class 2 power-limited circuits [722.15]. ▸ Figure 300–18

Figure 300–18 Mixing Conductors of Different Voltage Systems – Power and Class 2 Power-Limited Circuits 300.5(C)(1) Note 1



300.6 Protection Against Physical Damage

Where subject to physical damage, conductors, raceways, and cables must be protected in accordance with the following:

(A) Cables and Raceways Through Wood Members.

Author's Comment:

- When the following wiring methods are installed through wood members, they must comply with 300.6(A)(1) or (2):
  - Armored cable, Article 320
  - Electrical nonmetallic tubing, Article 362
  - Flexible metal conduit, Article 348
  - Liquidtight flexible metal conduit, Article 350
  - Liquidtight flexible nonmetallic conduit, Article 356
  - Metal-clad cable, Article 330
  - Nonmetallic-sheathed cable, Article 334
  - Service-entrance cable, Article 338
  - Underground feeder and branch-circuit cable, Article 340

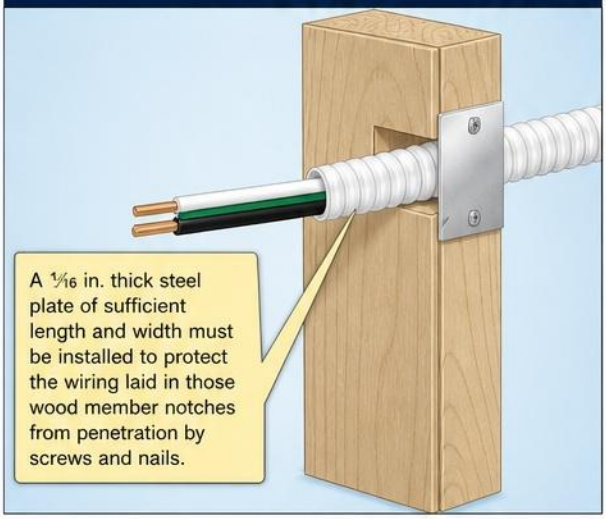
(1) Bored Holes in Wood Members. Holes through wood framing members for cables or raceways must be not less than 1¼ in. from the edge of the wood member. If the edge of a bored hole is less than 1¼ in. from the edge of the framing member, a steel plate ⅛ in. thick of sufficient length and width must be installed to protect the wiring method from screws and nails. ▸ Figure 300–19

Figure 300–19 Cables and Raceways Through Bored Holes in Wood Members 300.6(A)(1)

Ex 1: A steel plate is not required to protect rigid metal conduit, intermediate metal conduit, polyvinyl chloride conduit, or electrical metallic tubing.

(2) Notches in Wood Members. If notching of wood framing members for cables and raceways is permitted by the building code, a 1⁄16 in. thick steel plate of sufficient length and width must be installed to protect the wiring method laid in those wood member notches from penetration by screws and nails.

Figure 300–20 Cables and Raceways Through Notches in Wood Members 300.6(A)(2)



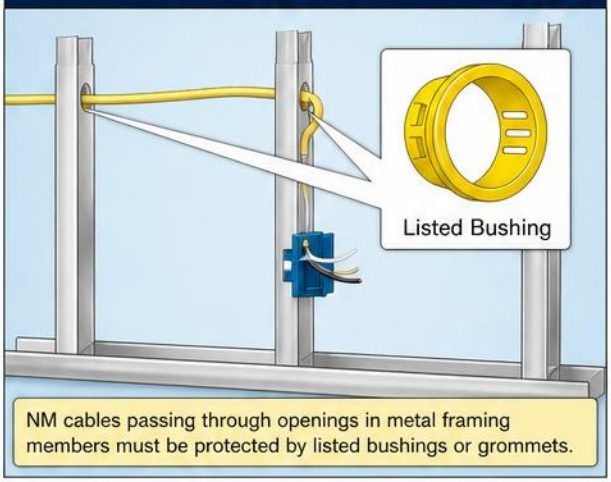
Ex 1: A steel plate is not required to protect rigid metal conduit, intermediate metal conduit, polyvinyl chloride conduit, or electrical metallic tubing.

CAUTION: Many wood framing members (especially joists and beams) have specific drilling or notching instructions to maintain structural integrity. Building code requirements limit the diameter of the hole to ⅓ the joist framing member depth. Notching is limited to ¼ of the joist framing member depth in accordance with the *IBC 2308, International Building Code* and *IRC 5208, International Residential Code.*

(B) Nonmetallic-Sheathed Cable (NM) and Electrical Nonmetallic Tubing (ENT) Through Metal Framing Members.

(1) NM Cable, Metal Framing Members. NM cables passing through openings in metal framing members must be protected by listed bushings or grommets. The fitting must be securely fastened in the opening before the installation of the cable.

Figure 300–21 Nonmetallic-Sheathed Cable in Metal Framing Members 300.6(B)(1)



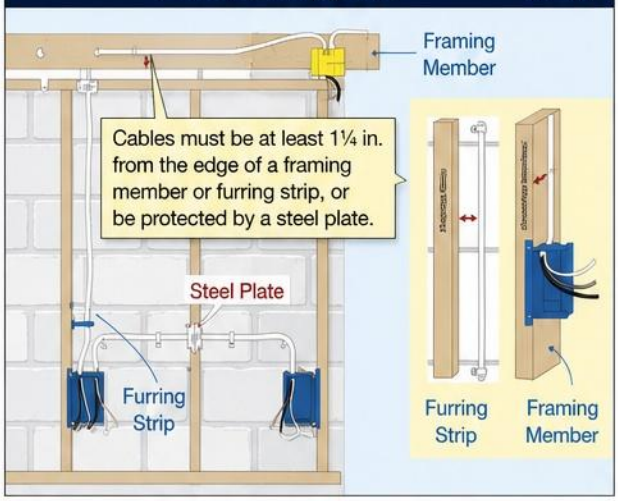
(2) NM Cable and ENT. If nails or screws are likely to penetrate NM cable or ENT, a steel sleeve, steel plate, or steel clip (not less than 1⁄16 in. thick) must be installed to protect the cable or tubing.

Ex: A listed and marked steel plate less than 1⁄16 in. thick that provides equal or better protection against nail or screw penetration is permitted.

(D) Parallel to Framing Members and Furring Strips. Cables or raceways run parallel to framing members or furring strips must be protected by installing the wiring method not less than 1¼ in. from the nearest edge of the framing member or furring strip.

If the edge of the framing member or furring strip is less than 1¼ in. away, a 1⁄16 in. thick steel plate (of sufficient length and width) must be installed to protect the wiring method from screws and nails.

Figure 300–22 Cables and Raceways Parallel to Framing Members and Furring Strips 300.6(D)

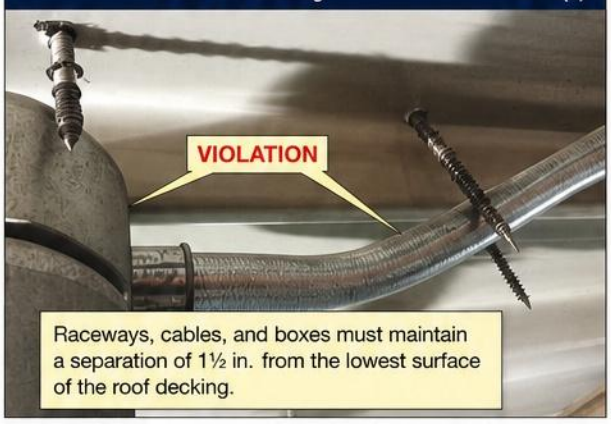


Cables run parallel to framing members must be spaced at least 1¼ in. from the edge of the member or furring strip unless protected by a steel plate.

Ex 1: Protection is not required for rigid metal conduit, intermediate metal conduit, polyvinyl chloride conduit, or electrical metallic tubing.

(E) Raceways, Cables, and Boxes Under Roof Decking. Raceways, cables, and boxes under roof decking must maintain a separation of 1½ in. from the lowest surface of the roof decking. **Figure 300–23**

Figure 300–23 Raceways, Cables, and Boxes Under Roof Decking 300.6(E)



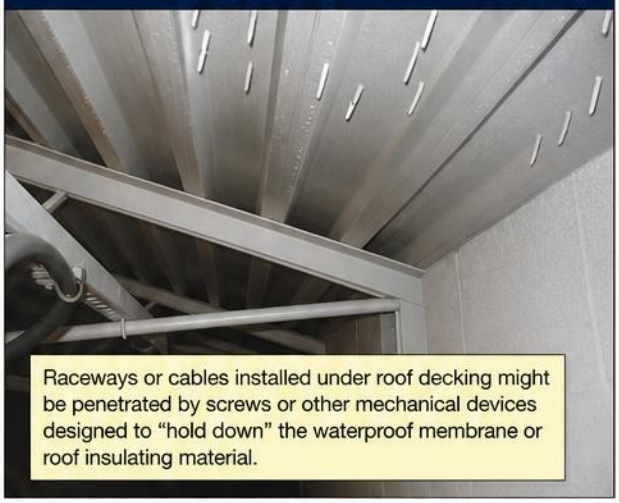
Raceways that are too close to the underside of roof decking and may be struck by screws or other fasteners.

Note: Raceways or cables installed under roof decking might be penetrated by screws or other mechanical devices designed to "hold down" the waterproof membrane or roof insulating material. **Figure 300–24**

Ex 1: Spacing under roof decking does not apply to rigid metal conduit and intermediate metal conduit.

Ex 2: The 1½ in. spacing under roof decking is not required where metal-corrugated sheet roof decking is covered with a minimum of 2 in. of concrete (measured from the top of the corrugated roofing).

Figure 300–24 Raceways, Cables, and Boxes Under Roof Decking 300.6(E) Note



Raceways or cables under roof decking can be penetrated by screws or other fasteners used to secure the waterproof membrane or roof insulating material.

AUTHOR'S COMMENT:

- Luminaires under roof decks have similar requirements found in 410.10(F).

(G) Raceway Termination Fittings. Raceways containing insulated conductors 4 AWG and larger that enter a cabinet, box, enclosure, or raceway must be protected as follows:

(1) Identified raceway fitting providing a smoothly rounded insulating surface **Figure 300–25** and **Figure 300–26**

Figure 300–25 Raceways with 4 AWG and Larger Conductors Plastic Bushing Termination Fitting 300.6(G)(1)

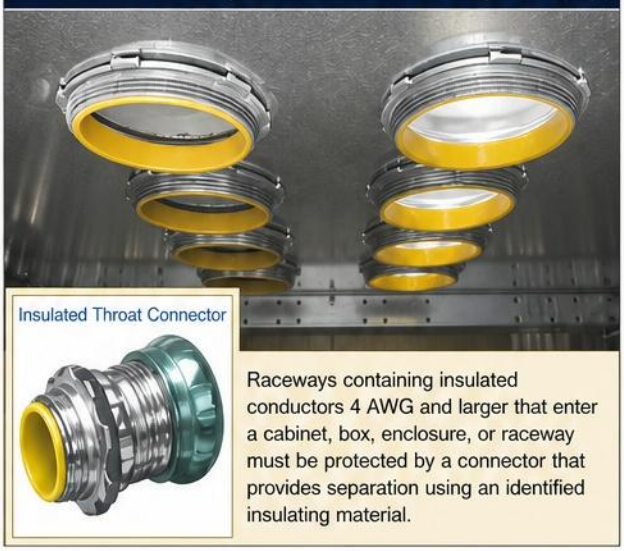
Plastic bushing termination fitting provides a smooth insulating entrance for large conductors.

(2) Listed metal raceway fitting with smoothly rounded edges **Figure 300–27**

Figure 300–26 Raceway with 4 AWG and Larger Conductors Plastic Bushing Termination Fitting 300.6(G)(1)

Raceways containing insulated conductors 4 AWG and larger that enter a cabinet, box, enclosure, or raceway must be protected by an identified fitting providing a smoothly rounded insulating surface.

Figure 300–28 Raceways with 4 AWG and Larger Conductors Insulating Connector Termination Fitting 300.6(G)(3)

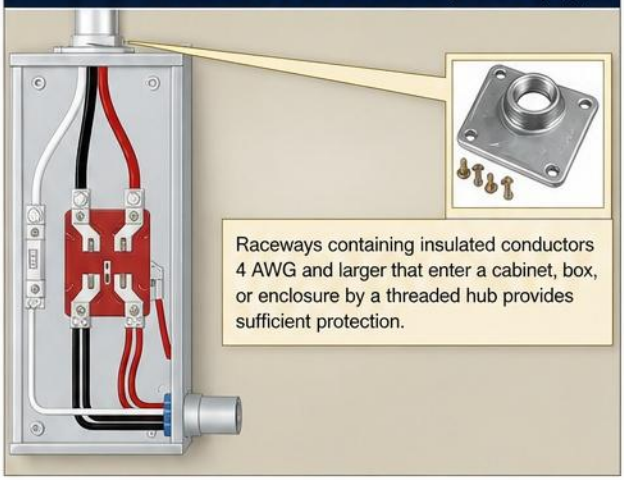


Raceways containing insulated conductors 4 AWG and larger that enter a cabinet, box, enclosure, or raceway must be protected by a connector that provides separation using an identified insulating material.

Figure 300–27 Raceways with 4 AWG and Larger Conductors Metal Bushing Termination Fitting 300.6(G)(2)

Raceways containing insulated conductors 4 AWG and larger that enter a cabinet, box, enclosure, or raceway must be protected by a listed metal fitting with smoothly rounded edges.

Figure 300–29 Raceways with 4 AWG and Larger Conductors Threaded Hub Termination Fitting 300.6(G)(4)



Raceways containing insulated conductors 4 AWG and larger that enter a cabinet, box, or enclosure by a threaded hub provides sufficient protection.

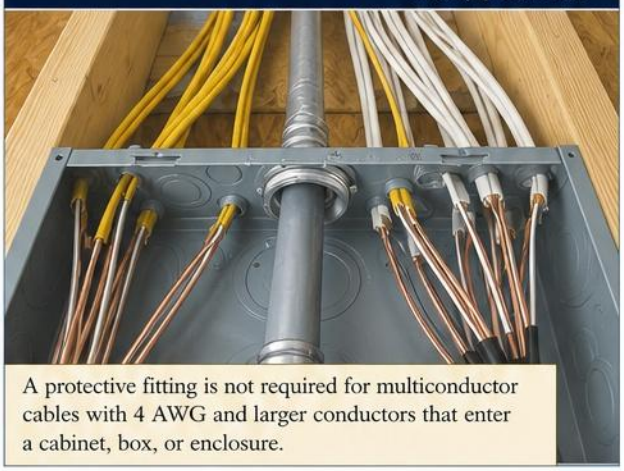
(3) Separation from the fitting or raceway using an identified insulating material that is securely fastened in place ▸ **Figure 300–28**

(4) Threaded hubs ▸ **Figure 300–29**

Author's Comment:

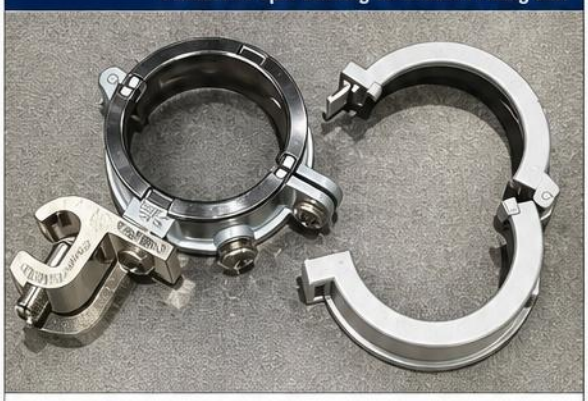
- A protective fitting is not required for multiconductor cables with conductors 4 AWG and larger that enter a cabinet, box, or enclosure. ▸ **Figure 300–30**
- A listed split-bushing fitting can provide a practical solution to install the protective fitting after the conductors are in place—no need to pull them back out. ▸ **Figure 300–31**

Figure 300–30 Cables with 4 AWG and Larger Conductors Plastic Bushing Termination Fitting Not Required 300.6(G) Comment



A protective fitting is not required for multiconductor cables with 4 AWG and larger conductors that enter a cabinet, box, or enclosure.

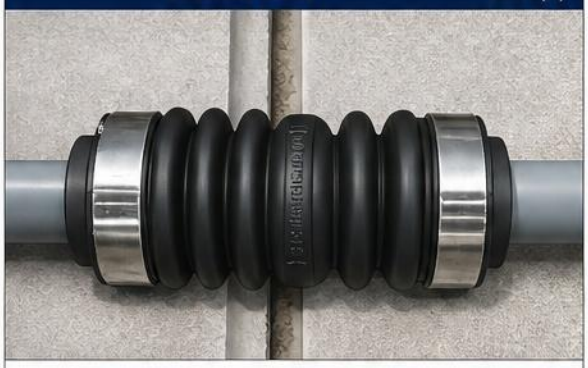
Figure 300–31 Raceways with 4 AWG and Larger Conductors Split-Bushing Termination Fitting 6011



A listed split-bushing fitting can provide a practical solution to install the protective fitting after the conductors are in place—no need to pull them back out.

(H) Structural Joints. A listed expansion/deflection fitting, or other means approved by the authority having jurisdiction (AHJ), must be used where a raceway crosses a structural joint intended for expansion, contraction, or deflection. **Figure 300–32**

Figure 300–32 Expansion/Deflection Fitting Structural Joints 300.6(H)



A listed expansion/deflection fitting, or other means approved by the authority having jurisdiction (AHJ), must be used where a raceway crosses a structural joint intended for expansion, contraction, or deflection.

300.7 Underground Installations

(A) Minimum Burial Cover Requirements. When raceways or cables are installed underground, they must have a minimum burial cover in accordance with Table 300.7(A). **Figure 300–33**

Figure 300–33 Minimum Underground Cover Depth Table 300.7(A)

Michael Hayes 2026®	Column 1 UF or USE Cables or Conductors	Column 2 RMC or IMC	Column 3 EMT or Nonmetallic Raceways	Column 4 Residential 15A & 20A GFCI 120V Branch Ckts
Dwelling Unit Driveway and Parking Area	18 in.	18 in.	18 in.	12 in.
Under Roadway Driveway Parking Lot	24 in.	24 in.	24 in.	24 in.
Other Locations	24 in.	6 in.	18 in.	12 in.

Table 300.7(A) Minimum Cover Requirements in Inches

Location	Column 1 Buried Cables	Column 2 RMC or IMC	Column 3 EMT or Nonmetallic Raceways
Under Building **Figure 300–34**	0	0	0
Dwelling Unit	24/12*	6	18
Dwelling Unit Driveway	18/12*	6	18/12*
Under Roadway	24	24	24
Other Locations	24	6	18

**Residential branch circuits (raceways/cables) rated 120V or less with GFCI protection and maximum protection of 20A.*

See the table in the NEC for full details.

***Note 1 to Table 300.7(A):** "Cover" is measured as the shortest distance from the top of the cable or raceway to the finished grade.* **Figure 300–35**

(B) Wet Locations. The interior of raceways installed underground is considered to be a wet location. **Figure 300–36**

Author's Comment:

- The interior of a raceway above grade in a wet location is considered a wet location. See 300.11(A).

Figure 300–34 Minimum Underground Cover Depth Under a Building, No Cover Required 300.7(A)

Figure 300–35 Minimum Underground Cover Depth How Cover is Measured 300.7(A) Note 1

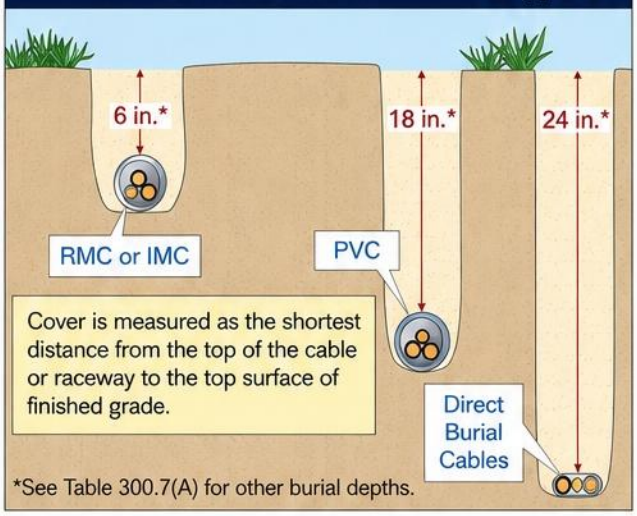


Figure 300–36 Underground Installations, Wet Locations 300.7(B)

(C) Cables and Conductors Under Buildings. Cables under a building must be contained in a raceway.

Ex 2: MC cable listed for direct burial or concrete encasement is permitted under a building without installation within a raceway [330.10(A)(5) and (11)].

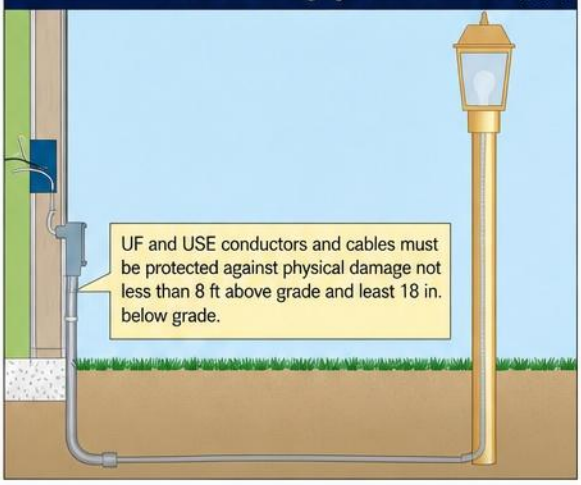
(D) Protecting Underground Cables and Conductors. Single conductors and multiconductor cables installed underground must be protected from damage as follows:

(1) Emerging from Grade.

Above Ground. UF and USE conductors and cables that emerge from the ground must be protected against physical damage by enclosures or raceways to a height of not less than 8 ft.

Underground. Protection below grade is required to extend not less than the cover requirements of Table 300.7 and at least 18 in. below grade.

Figure 300–37 Underground Cables and Conductors Protection Emerging from Grade 300.7(D)(1)



(3) Underground Service Conductors and Raceways. Direct buried service conductors and raceways containing service conductors must have their location identified by a warning ribbon placed in the trench at least 12 in. above the underground installations. [Figure 300–38]

(4) Raceway Subject to Physical Damage. Where an underground raceway emerging from grade is subject to physical damage as determined by the AHJ, it must be electrical metallic tubing, rigid metal conduit, intermediate metal conduit, or Schedule 80 PVC. [Figure 300–39]

(E) Underground Splices. Direct-buried UF or USE conductors or cables can be spliced underground without a splice box [300.17(G)] if the splice is made in accordance with 110.14(B). [Figure 300–40]

Figure 300–38 Underground Service Conductors and Raceways Warning Ribbon *300.7(D)(3)*

Direct-buried service conductors and raceways that contain service conductors must be identified with a warning ribbon positioned in the trench at least 12 in. above the underground installations.

Figure 300–39 Underground Raceway, Emerging from Grade Protecton from Physical Damage *300.7(D)(4)*

Where an underground raceway emerges from grade and is subject to physical damage, it must be protected by EMT, RMC, IMC, or Schedule 80 PVC.

Figure 300–40 Underground Splices and Taps Direct-Buried Conductors or Cables *300.7(E)*

Direct-buried UF or USE conductors or cables can be spliced underground without a splice box if the splice is made in accordance with 110.14(B).

(F) Backfill. Backfill used for underground wiring installations must not harm raceways, cables, or conductors.
Figure 300–41

Figure 300–41 Underground Wiring Backfill *300.7(F)*

Backfill material for underground wiring must not damage raceways, cables, or conductors.

AUTHOR'S COMMENT:

- Large rocks, chunks of concrete, steel rods, mesh, and other sharp-edged objects are not permitted to be used for back-filling material because they can damage the underground conductors, cables, or raceways.

(G) Raceway Seals. Raceways through which moisture might contact live parts must be sealed at either end. Sealants must be identified for use with the cable insulation, conductor insulation, bare conductor, shield, or other components.
Figure 300–42

Figure 300–42 Underground Installations Raceway Seals *300.7(G)*

Raceways through which moisture might contact live parts must be sealed at either end. Sealants must be identified for use with the cable insulation, conductor insulation, bare conductor, shield, or other components.

AUTHOR'S COMMENT

- Based on the *NEC Handbook* discussion, condensation can build up in raceways that are exposed to temperature differences because air moves through the raceway from a warmer section to a cooler one. The movement of air inside the raceway can be stopped by sealing the raceway with a suitable compound prior to it entering the colder part.

(H) BUSHING. Raceways that terminate underground must have a bushing or fitting at the end of the raceway to shield direct-buried conductors or cables.

Figure 300–43 NEC 300.7(H)
Underground Cables and Conductors
Raceway Protective Bushing

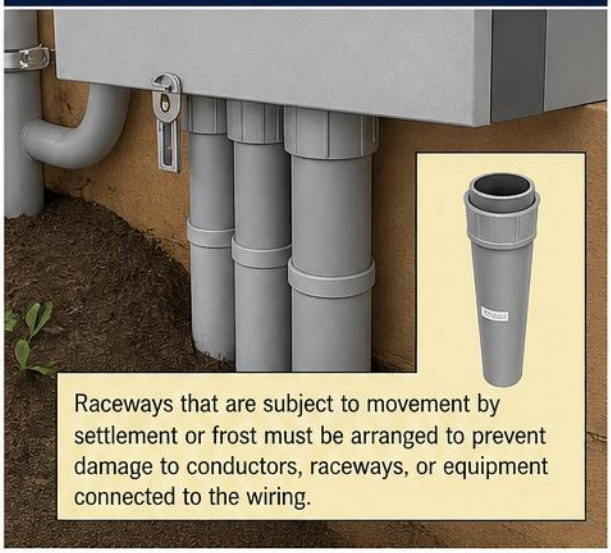
(I) CONDUCTORS OF THE SAME CIRCUIT. All conductors of the same circuit, grounded conductors, and equipment grounding conductors must be installed in the same raceway or cable or in close proximity within the same trench.

Ex 1: Conductors must be permitted to be installed in parallel in raceways, multiconductor cables, or direct-buried single conductor cables. Each raceway or multiconductor cable must contain all conductors of the same circuit (including equipment grounding conductors). Each direct-buried single conductor cable must be located in close proximity in the trench to the other single conductor cables in the same parallel set of conductors in the circuit (including equipment grounding conductors).

Ex 2: Isolated phase, polarity, grounded conductor, and equipment grounding and bonding conductor installations must be permitted in nonmetallic raceways or cables with a nonmetallic covering or nonmagnetic sheath in close proximity where conductors are paralleled as permitted in 310.10(G), and where the conditions of 300.22(B) are met.

(J) EARTH MOVEMENT. Raceways subjected to movement by settlement or frost must be arranged to prevent damage to conductors, raceways, or equipment connected to the wiring. Figure 300–44.

Figure 300–44 NEC 300.7(J)
Underground Installations
Earth Movements



300.8 PROTECTION AGAINST CORROSION

Raceways, cable trays, cable armor, cable sheathing, boxes, cabinets, enclosures, elbows, couplings, fittings, supports, and support hardware must be suitable for the environment.

(A) STEEL EQUIPMENT. Steel raceways, cables, cable trays, cabinets, enclosures, fittings, and support hardware must be protected against corrosion by a coating of approved corrosion-resistant material.

AUTHOR'S COMMENT

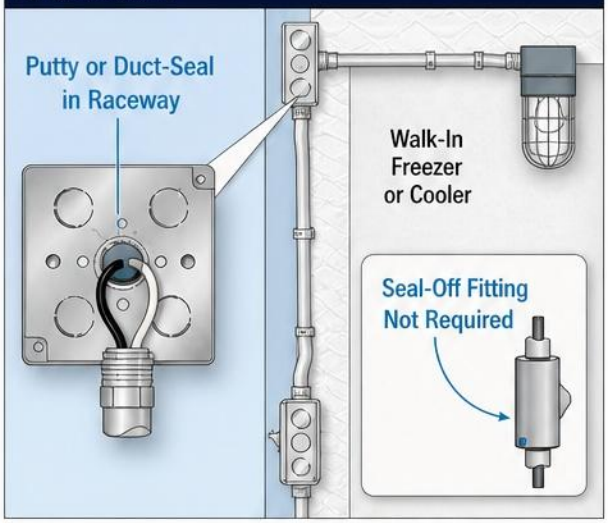
- Following UL Guide Information, DYX, supplemental corrosion protection is required when a steel raceway transitions from concrete encasement to the soil. Where RMC or IMC is threaded in the field, the threads must be coated with an approved electrically conductive, corrosion-resistant compound where corrosion protection is required.

300.9 RACEWAYS EXPOSSED TO DIFFERENT TEMPERATURES

(A) Condensation. Raceways subjected to different temperatures where condensation is known to be a problem must comply with the following:

(1) Sealing. Raceways must be filled with a sealant identified for use with the cable or conductor insulation to prevent the circulation of warm air to a colder section of the raceway.

Figure 300–45 Raceways Exposed to Different Temperatures — Sealing for Condensation 300.9(A)(1)



Raceways must be filled with a sealant identified for use with the cable or conductor insulation to prevent the circulation of warm air to a colder section of the raceway.

> ***Identified.*** Recognized as being suitable for a specific purpose, function, use, environment, or application.

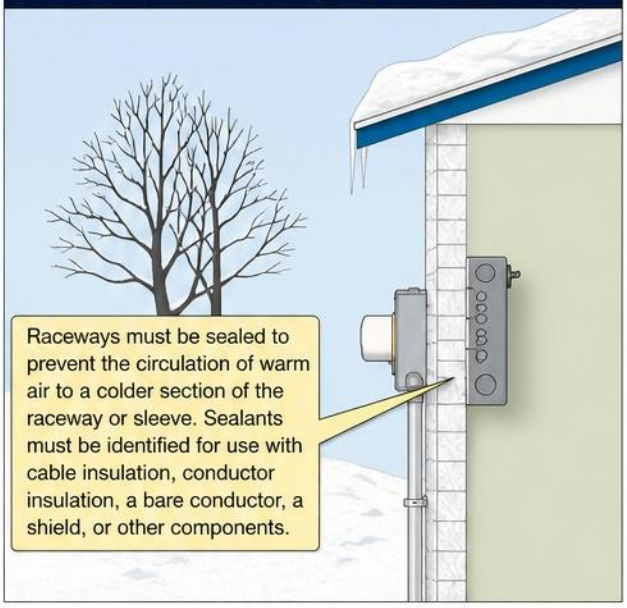
AUTHOR'S COMMENT:

- According to the *NEC Handbook* commentary, condensation could accumulate in raceways that are subjected to temperature differences as a result of air circulating through the raceway from a warmer to a colder section. The circulation of air within the raceway can be prevented by sealing the raceway with a suitable compound before it enters the colder section.

AUTHOR'S COMMENT:

- One common product used for this is "electrical duct seal" and it is identified for this application. There are other identified products such as Polywater's "FST Duct Sealant." Expanding foams used to seal buildings are not identified for this application.

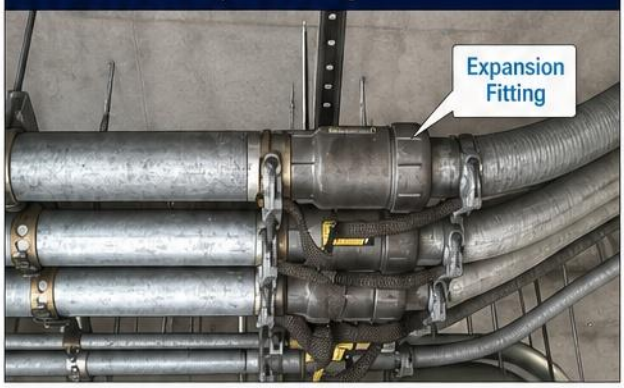
Figure 300–46 Raceways Exposed to Different Temperatures — Sealing for Condensation 300.9(A)(1)



Raceways must be sealed to prevent the circulation of warm air to a colder section of the raceway or sleeve. Sealants must be identified for use with cable insulation, conductor insulation, a bare conductor, a shield, or other components.

(B) Expansion, Expansion-Deflection, and Deflection Fittings. Raceways must be provided with expansion, expansion-deflection, or deflection fittings where necessary to compensate for thermal expansion, deflection, and contraction.

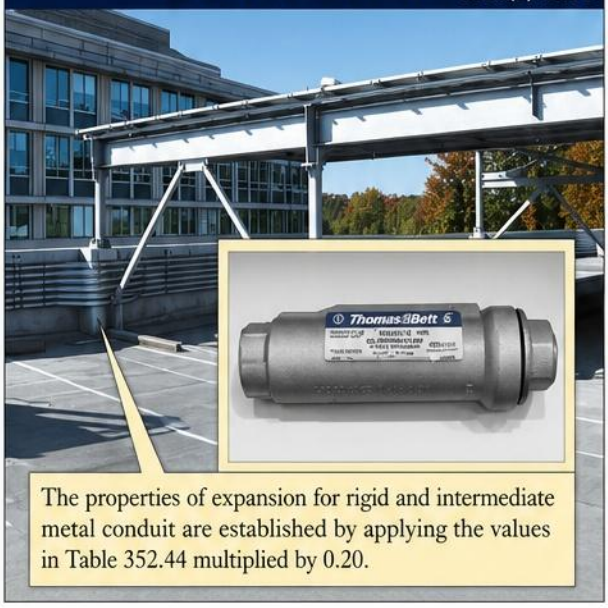
Figure 300–47 Raceway Thermal Expansion and Contraction — Expansion Fitting 300.9(B)



Raceways must be provided with expansion, expansion-deflection, or deflection fittings where necessary to compensate for thermal expansion, deflection, and contraction.

NOTE 1: Table 352.44 provides the expansion characteristics for PVC. The rigid metal conduit and intermediate metal expansion characteristics are determined by multiplying the values from Table 352.44 by 20 percent (0.20).

Figure 300–48 Raceway Thermal Expansion and Contraction RMC and IMC Characteristics 300.9(B) Note 1

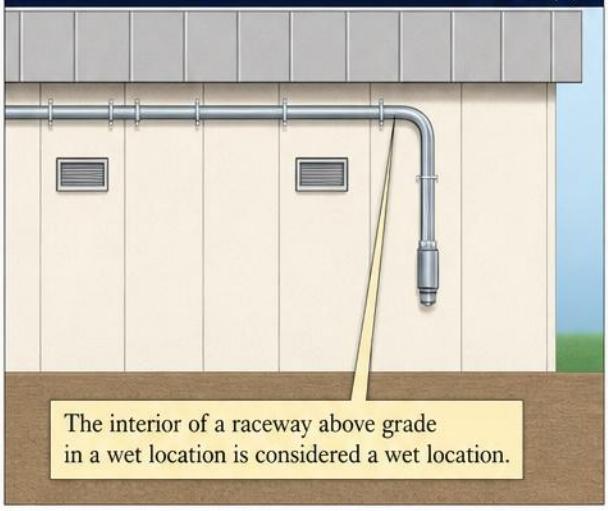


The properties of expansion for rigid and intermediate metal conduit are established by applying the values in Table 352.44 multiplied by 0.20.

300.11 Raceways in Wet Locations

(A) General. The interior of a raceway above grade in a wet location is considered a wet location.

Figure 300–49 Raceways in Wet Locations Above Grade 300.11(A)



The interior of a raceway above grade in a wet location is considered a wet location.

Author's Comment:

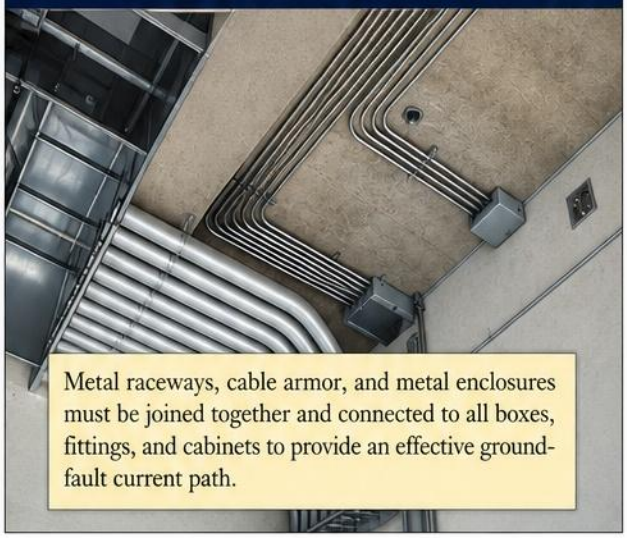
The interior of a raceway installed underground is considered to be a wet location. See 300.7(B).

(B) Drainage. Raceways installed in wet locations must be arranged to drain.

300.12 Electrical Continuity

Metal raceways, cable armor, and metal enclosures must be connected to boxes, fittings, and cabinets to provide an effective ground-fault current path in accordance with 250.4(A)(3).

Figure 300–50 Metal Raceways, Cables, and Enclosures Electrical Continuity 300.12

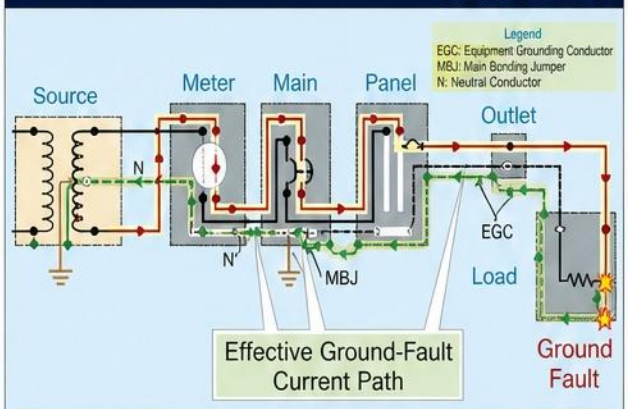


Metal raceways, cable armor, and metal enclosures must be joined together and connected to all boxes, fittings, and cabinets to provide an effective ground-fault current path.

Author's Comment:

The purpose of the effective ground-fault current path is to open the circuit overcurrent protective device in the event of a ground fault [250.4(A)(5)].

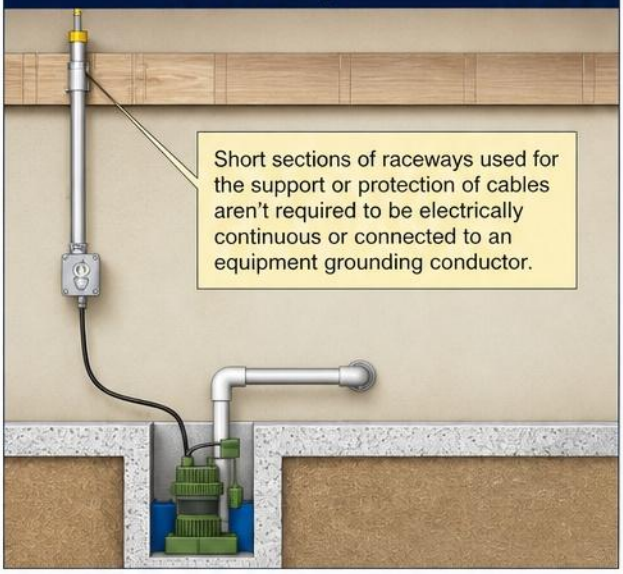
Figure 300–51 Metal Raceways, Cables, and Enclosures Purpose of Electrical Continuity 300.12 Comment



The purpose of electrical continuity between metal parts is to establish the effective ground-fault current path necessary to open the circuit overcurrent protective device in the event of a ground fault [250.4(A)(5)].

Ex 1: Short lengths of metal raceways used for the support or protection of cables are not required to be electrically continuous or connected to the circuit equipment grounding conductor [250.86 Ex 2 and 300.14 Ex 1]. ▶ **Figure 300–52**

Figure 300–52 | Metal Raceways, Cables, and Enclosures Electrical Continuity *300.12 Ex 1*



A short length of metal raceway supports a cable to the equipment. Electrical continuity to the equipment grounding conductor is not required.

300.13 Securing and Supporting

(B) Wiring Systems Installed Above Suspended Ceilings.

(1) General. Wiring including ceiling support wires cannot be secured to or supported by the ceiling grid system.

(2) Independent Support Wires. Independent support wires for wiring systems above a suspended ceiling must comply with the following:

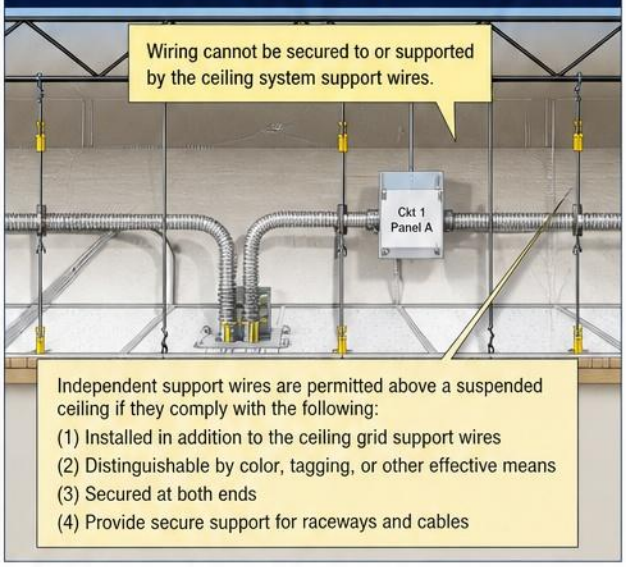
(1) Installed in addition to the ceiling grid support wires
(2) Distinguishable from the suspended-ceiling support wires by color, tagging, or other effective means from those parts of the ceiling system
(3) Secured at both ends
(4) Provide secure support for raceways and cables ▶ **Figure 300–53**

Author's Comment:

- Boxes above the suspended ceiling can be supported by identified fittings attached to independent ceiling support wires that are secured at both ends [314.23(D)(2)]. ▶ **Figure 300–54**

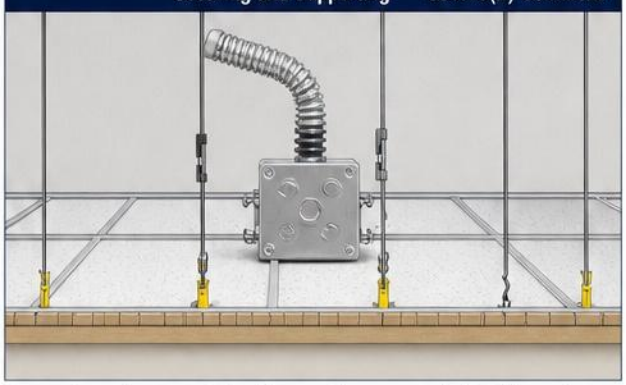
(C) Raceways Used for Support. Raceways are not permitted to support raceways or cables except as follows: ▶ **Figure 300–55** and ▶ **Figure 300–56**

Figure 300–53 | Raceways and Cables Above Suspended Ceilings Securing and Supporting 300.13(B)(2)



Independent support must meet all four requirements to be used above a suspended ceiling.

Figure 300–54 | Boxes Above Suspended Ceilings Securing and Supporting 300.13(B) Comment

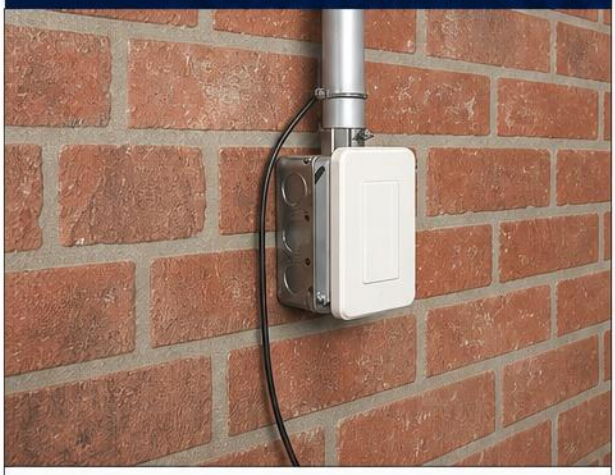


Boxes above the suspended ceiling can be supported with fittings that attach to independent support wires secured at both ends [314.23(D)(2)].

Figure 300–55 | Raceways Not Permitted to Support Raceways, Cables, Equipment 300.13(C)

Raceways must not be used as structural support for other raceways, cables, or equipment.

Figure 300–56 Raceway Not Permitted To Support Raceways, Cables, Equipment 300.13(C)



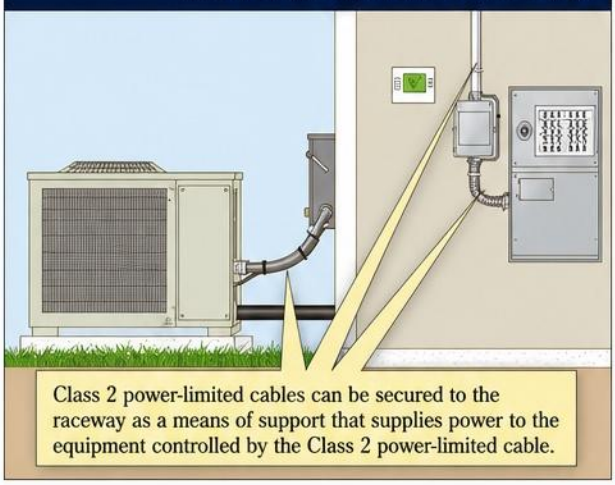
VIOLATION: Raceways are not permitted to support raceways, cables, or other equipment.

Figure 300–58 Raceways Used for Support Equipment Bonding Jumper 300.13(C)(4)

Raceways are permitted to support an equipment bonding jumper in accordance with 250.102(E)(2).

(2) Class 2 Power-Limited Cables. Class 2 power-limited cables can be secured to the raceway as a means of support that supplies power to the equipment controlled by the Class 2 power-limited cable. Figure 300–57.

Figure 300–57 Raceways Used to Support Class 2 Power-Limited Cables 300.13(C)(2)



(3) Boxes. Raceways are permitted to support boxes in accordance with 314.23.

(4) Equipment Bonding Jumper. Raceways are permitted to support an equipment bonding jumper in accordance with 250.102(E)(2). Figure 300–58.

(D) Cables Not Used as Means of Support. Cables are not permitted to support cables, conductors, raceways, or other equipment. Figure 300–59.

Figure 300–59 Cable Not Used as Means of Support 300.13(D)

(E) Cable Ties Used as Means of Securement and Support.

(1) Cable Ties. *Cable ties* used as a means for securement and support for cable, flexible conduit, and flexible tubing must be listed and identified for securement and support. Figure 300–60.

(2) Cable Tie Fixing Devices. If a cable tie fixing device is installed, the cable tie fixing device must be listed and identified for securement and support. Figure 300–61.

Note: Type 2S and 21S cable ties cable tie and fixing devices are evaluated for securing and supporting cable, flexible conduit, and flexible tubing. Figure 300–62.

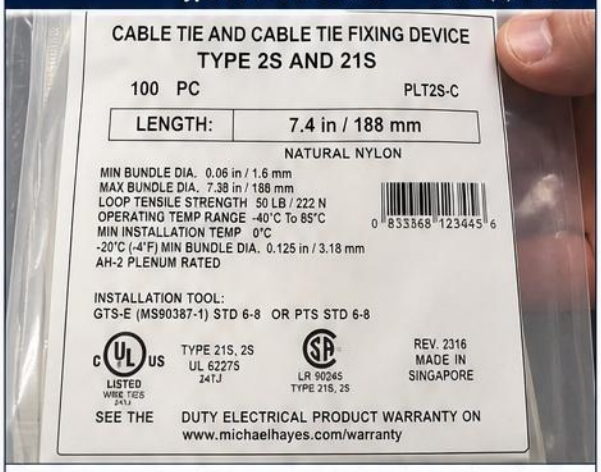
Figure 300-60 Cable Ties Used as Means of Securement and Support *300.13(E)(1)*

Cable ties may be used to secure and support cables, flexible raceways, and flexible tubing, provided the ties are listed and identified for those purposes.

Figure 300-61 Cable Tie Fixing Devices, Securement and Support Listed and Identified *300.13(E)(2)*

When a cable tie anchoring device is installed, the device itself must be listed and identified for securement and support.

Figure 300-62 Cable Tie and Cable Tie Fixing Device Type 2S and 21S Note *300.13(E) Note*



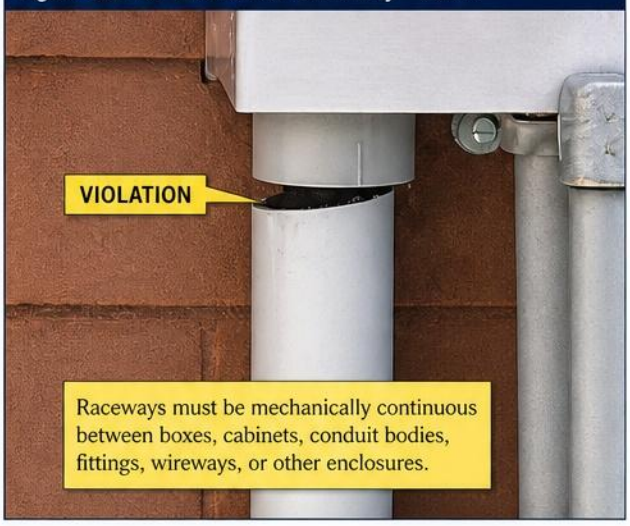
Type 2S and 21S cable ties and anchoring devices have been evaluated for securing and supporting cables, flexible raceways, and flexible tubing.

300.14 Mechanical Continuity

Raceways and cable sheaths must be mechanically continuous between boxes, cabinets, conduit bodies, fittings, wireways, or other enclosures, unless specifically permitted elsewhere in this *Code*. Raceways and cables must be mechanically secured to boxes, fittings, cabinets, and other enclosures.

See Figure 300-63

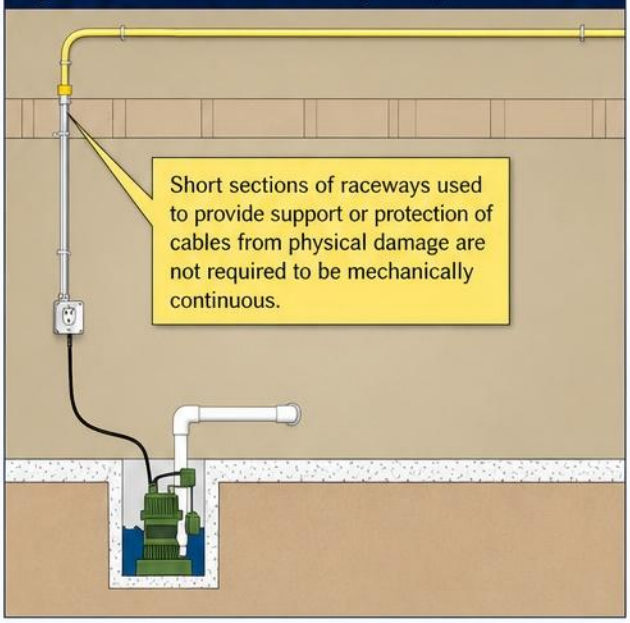
Figure 300-63 Mechanical Continuity *300.14*



Ex 1: Short sections of raceway used to provide support or protection of cables from physical damage are not required to be mechanically continuous [250.86 Ex 2 and 300.12 Ex 1].

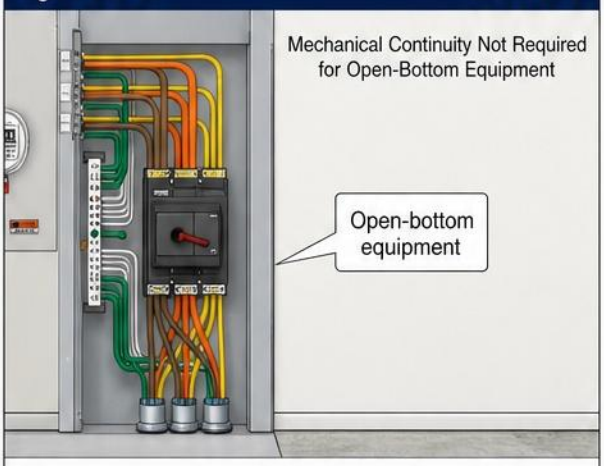
See Figure 300-64

Figure 300-64 Mechanical Continuity Not Required *300.14 Ex 1*



Example 2: Raceways and cables at the bottom of open-bottom equipment, such as switchboards, motor control centers, and floor- or pad-mounted transformers, are not required to be mechanically secured to the equipment.

Figure 300–65 **300.14 Ex 2**



Raceways and cables at the bottom of open-bottom equipment are not required to be mechanically secured to the equipment.

300.15 Mechanical and Electrical Continuity of Conductors

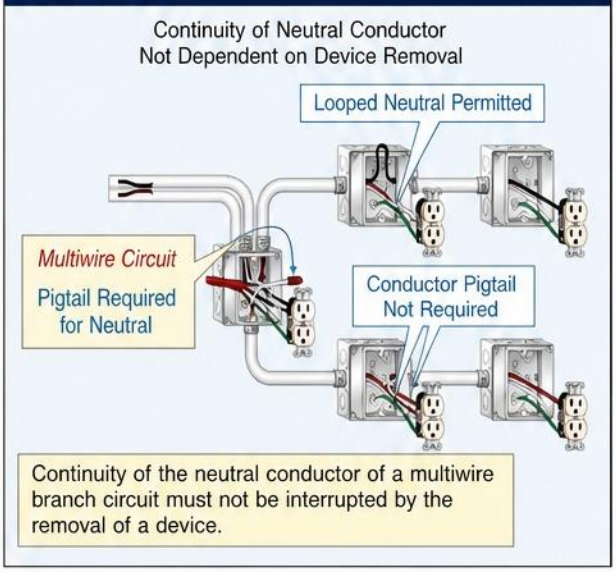
(A) Splices. Conductor splices must be made inside enclosures in accordance with 300.15. Splices are not permitted inside a raceway, except for wireways in accordance with 376.56.

Figure 300–66 **300.15(A)**

Conductor splices are not permitted inside a raceway, except for wireways in accordance with 376.56.

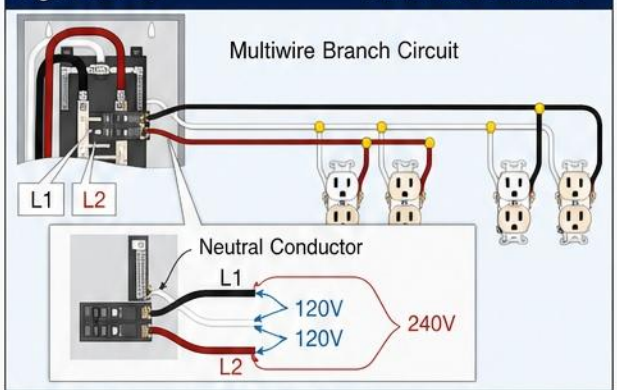
(B) Device Removal Neutral Continuity. Continuity of the neutral conductor of a multiwire branch circuit is not permitted to be interrupted by the removal of a wiring device.

Figure 300–67 **300.15(B)**



Branch Circuit, Multiwire. A branch circuit consisting of two or more phase conductors with a neutral conductor that has a voltage between the phase conductors and an equal voltage from each phase conductor to the neutral conductor.

Figure 300–68 **Article 100 Definition**



A branch circuit consisting of two or more phase conductors with a neutral conductor that has a voltage between the phase conductors and an equal voltage from each phase conductor to the neutral conductor.

Author's Comment:

- For multiwire branch circuit applications, the neutral conductors must be spliced together, and a pigtail is required for the wiring device.

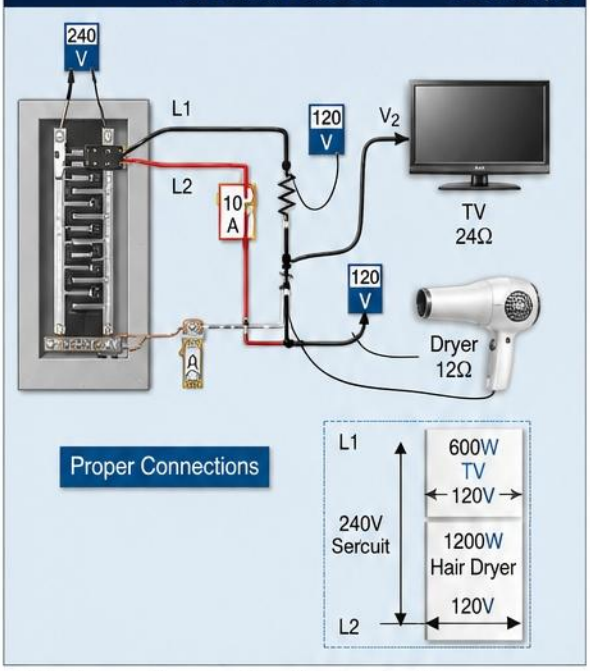
- The opening of the phase conductors or the neutral conductor of a 2-wire circuit while a device is replaced, does not cause a safety hazard. Therefore, pigtailing those conductors is not required [110.14(B)].

CAUTION: If the continuity of the neutral conductor of a multiwire branch circuit is interrupted (opened), the resulting over- or undervoltage can cause a fire and/or destruction of electrical equipment.

Hazard of Open Neutral Example

Example: If the neutral conductor is interrupted on a 3-wire, 120/240V multiwire circuit that supplies a 1,200W, 120V hair dryer and a 600W, 120V television, it will cause the 120V television to momentarily operate at 160V before it burns up. This can be determined as follows: **Figure 300–69** and **Figure 300–70**

Figure 300–69 Proper Phase and Neutral Connection 210.4 Example



With the neutral intact, each appliance receives its rated 120V.

Solution:

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

$R = E^2/P$

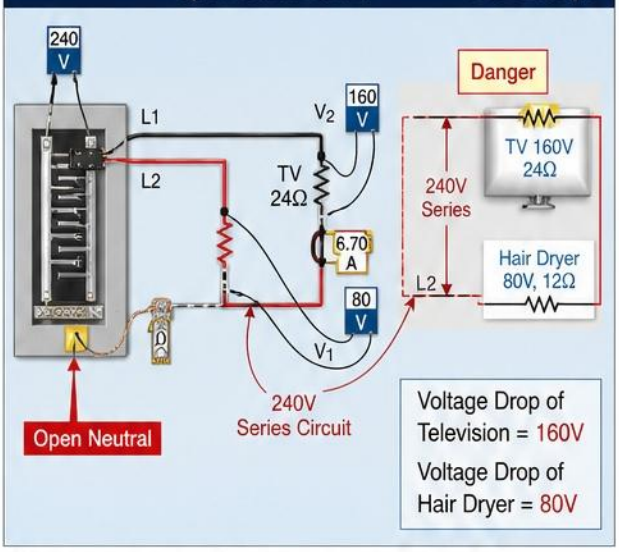
R of Hair Dryer $= 120V^2/1{,}200W$

R of Hair Dryer $= 12\Omega$

R of Television $= 120V^2/600W$

R of Television $= 24\Omega$

Figure 300–70 Multiwire Branch Circuit Open Neutral Hazard 210.4 Example



With the neutral open, the appliances are in series and the voltages rise dangerously.

Step 2: Determine the current of the circuit.

I = Volts/Resistance

Volts $= 240V$

$R = 12\Omega + 24\Omega$

$R = 36\Omega$

$I = 240V/36\Omega$

$I = 6.70A$

Step 3: Determine the operating voltage for each appliance.

Volts $= I \times R$

$I = 6.70A$

R = 12Ω for the hair dryer and 24Ω for the television

Voltage of Hair Dryer $= 6.70A \times 12\Omega$

Voltage of Hair Dryer $= 80V$

Voltage of Television $= 6.70A \times 24\Omega$

Voltage of Television $= 160V$

300.16 Conductor Length at Boxes

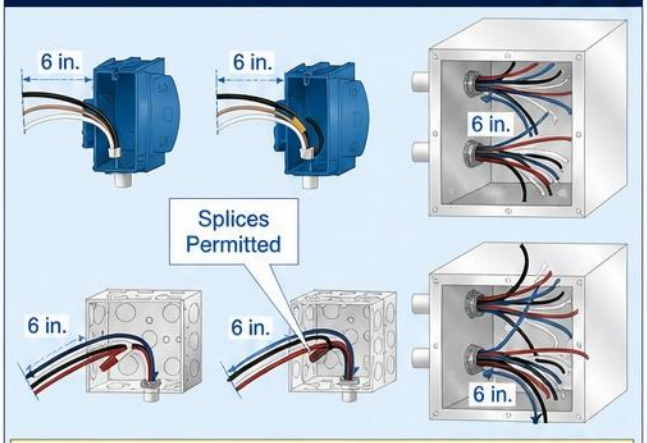
(A) General. At least 6 in. of spliced or unspliced conductor measured from the point in the box where the conductors emerge from the raceway or cable sheath must be left at each outlet. **Figure 300–71**

(B) Openings Smaller Than 8 in. Boxes with openings of less than 8 in. at any dimension must have:

(1) At least 6 in. of conductor measured from the point where the conductors emerge from the raceway or cable sheath

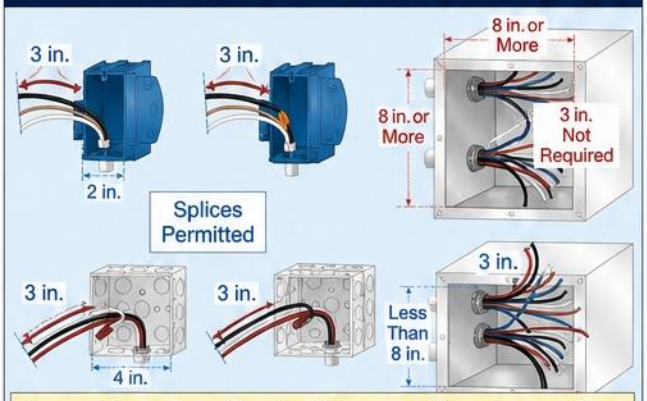
(2) At least 3 in. of conductor outside the box **Figure 300–72**

Figure 300–71 Conductor Length at Boxes At Least 6 in. 300.16(A)



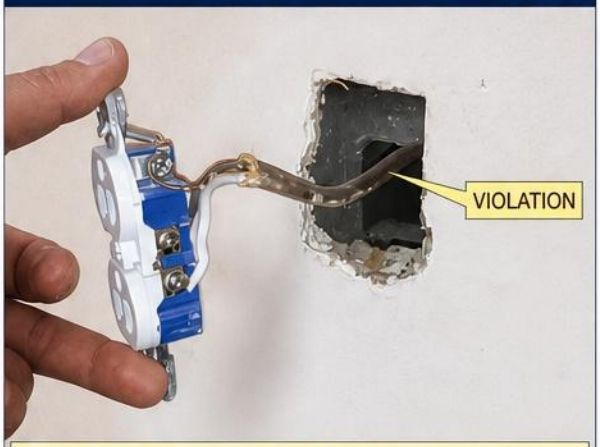
At least 6 in. of spliced or unspliced conductor, measured from the point in the box where the conductors emerge from the raceway or cable sheath, must be left at each outlet.

Figure 300–72 Conductor Length at Boxes Openings Smaller Than 8 in. 300.16(B)



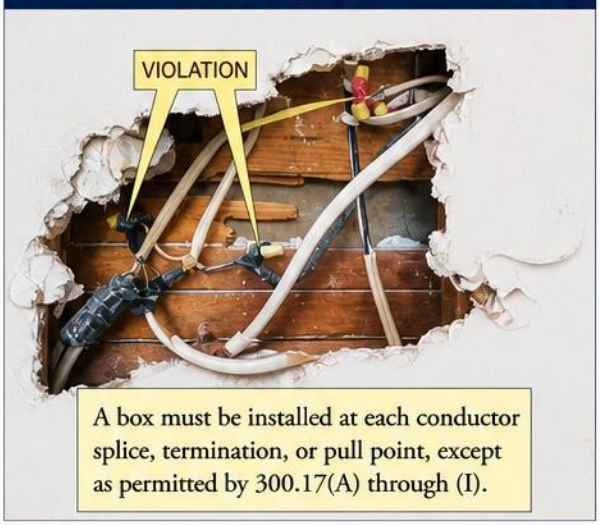
Boxes with openings of less than 8 in. at any dimension must have:
(1) At least 6 in. of conductor, measured from the point where the conductors emerge from the raceway or cable sheath.
(2) At least 3 in. of conductor outside the box.

Figure 300–73 Boxes and Fittings Conductor Termination Point 300.17



A box must be installed at each conductor splice, termination, or pull point, except as permitted by 300.17(A) through (I).

Figure 300–74 Boxes and Fittings Conductor Splice Point 300.17



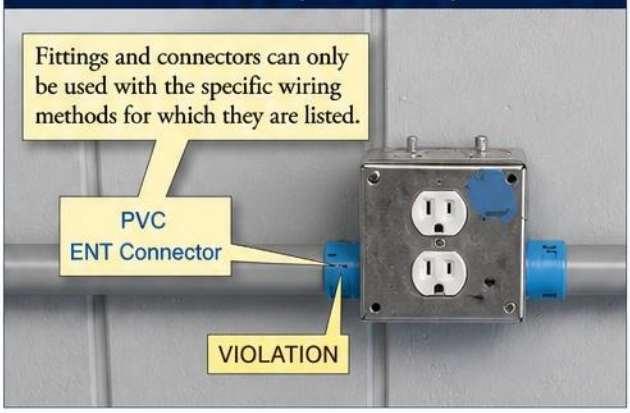
A box must be installed at each conductor splice, termination, or pull point, except as permitted by 300.17(A) through (I).

300.17 Boxes or Fittings, Splices and Terminations

A box must be installed at each conductor splice point or conductor termination point, except as permitted by 300.17(A) through (I). Figure 300–73 a Figure 300–74

Fittings and connectors can only be used with the wiring methods for which they are listed. Figure 300–75

Figure 300–75 Fittings and Connectors Listed for Specific Raceway 300.17

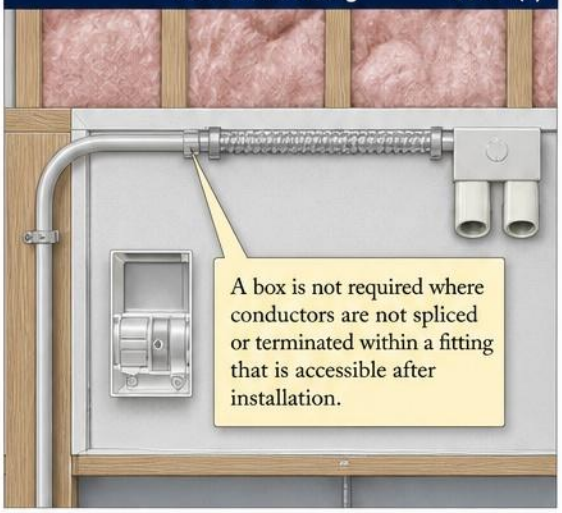


AUTHOR'S COMMENT

- NM cable connectors are not allowed to be used with AC cable.
- EMT fittings are not allowed to be used with RMC or IMC, unless specifically listed for the purpose.
- PVC couplings and connectors are permitted to be installed on ENT if the proper glue is used in accordance with the manufacturer's instructions [110.3(B)]. See 362.48.

(F) Fitting. A box is not required where conductors are not spliced or terminated within a fitting that is accessible after installation. Figures 300–76

Figure 300–76 Boxes Not Required—Accessible Fitting 300.17(F)



No box is needed when conductors are not spliced or terminated inside an accessible fitting.

(G) Underground Conductor and Cable Splices. Underground UF or USE conductors are permitted to be spliced with a splicing device listed for direct burial. Figures 300–77 and 300–78

(H) Insulated Devices. A box is not required for insulated devices supplied by nonmetallic-sheathed cable, installed in accordance with 334.40(B). Figure 300–79

Figure 300–77 Boxes Not Required—Underground Splices 300.17(G)

Figure 300–78 Boxes Not Required—Underground Splices 300.17(G)

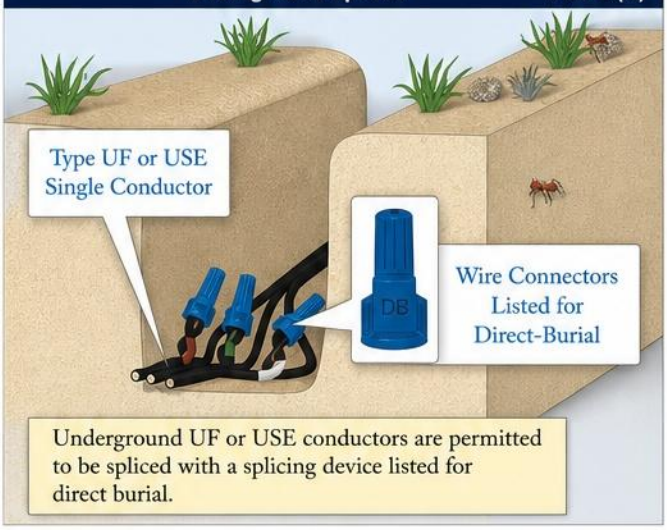
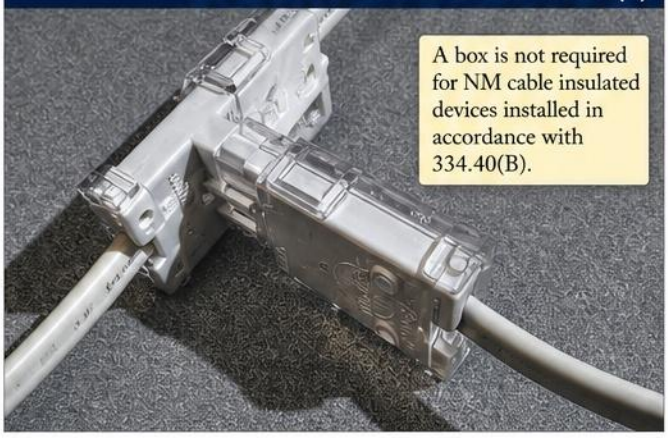


Figure 300–79 Boxes Not Required—NM Cable Interconnector Device 300.17(H)



300.19 Number and Size of Conductors in a Raceway

(A) Raceway Fill. The total number of conductors in any raceway shall not be more than the allowable percentage fill specified in Chapter 9, Table 1.

Author's Comment:

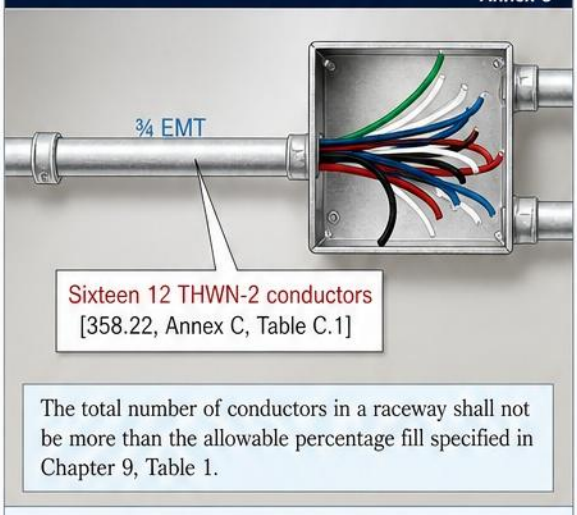
- If all conductors in a raceway have the same size, insulation type, quantity, or raceway size, refer to Annex C, see Note (1) of Chapter 9.

EMT Annex C Table Example

Question: How many 12 AWG, THWN-2 conductors can be installed in ¾ EMT? ▶ Figure 300–80

(a) 10 (b) 12 (c) 14 (d) 16

Figure 300–80 EMT Annex C Table Example — 300.19(A) Annex C



The total number of conductors in a raceway shall not be more than the allowable percentage fill specified in Chapter 9, Table 1.

Answer: *(d) 16 [Annex C, Table C.1]*

FMC Annex C Table Example

Question: How many 6 AWG, THWN-2 conductors can be installed in 1 FMC?

(a) 2 conductors (b) 4 conductors
(c) 6 conductors (d) 8 conductors

Answer: *(c) 6 conductors [Annex C, Table C.3]*

LFNC Annex C Table Example

Question: How many 8 AWG, THHN conductors can be installed in ¾ LFNC-B?

(a) 2 conductors (b) 4 conductors
(c) 6 conductors (d) 8 conductors

Answer: *(c) 6 conductors [Annex C, Table C.6]*

Author's Comment:

- When different size conductors are installed in a raceway, the conductor fill is limited to the percentages in Table 1 and Note (6) of Chapter 9. ▶ Figure 300–81

Figure 300–81 Raceway Percentage Fill Limitation Chapter 9, Table 1 — 300.19(A)

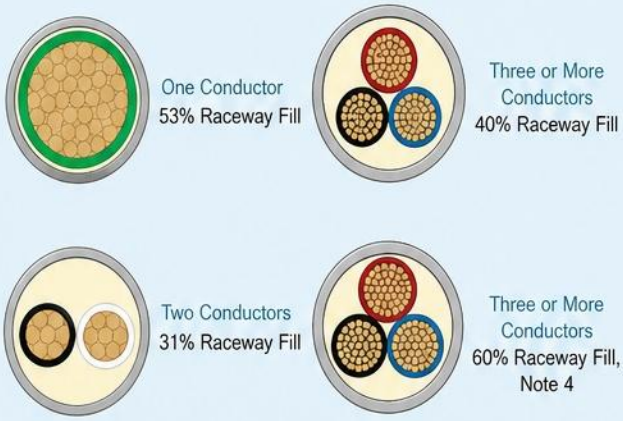


Table 1 of Chapter 9 specifies the maximum percent of the cross-sectional area of a raceway permitted for the installation of conductors.

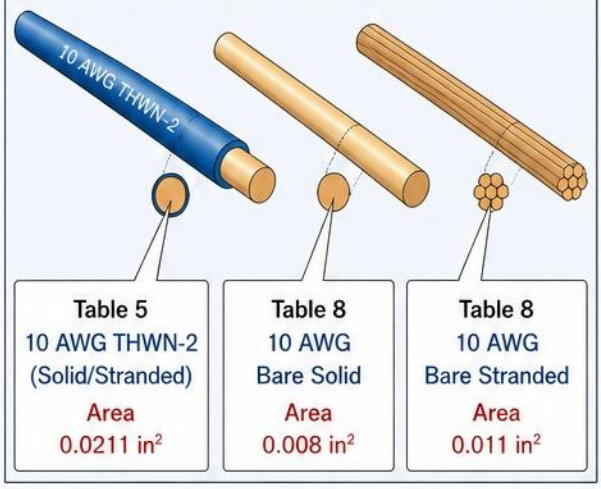
Chapter 9, Table 1

Number	Percent Fill
1 Conductor	53%
2 Conductors	31%
3 or More Conductors	40%

AUTHOR'S COMMENT

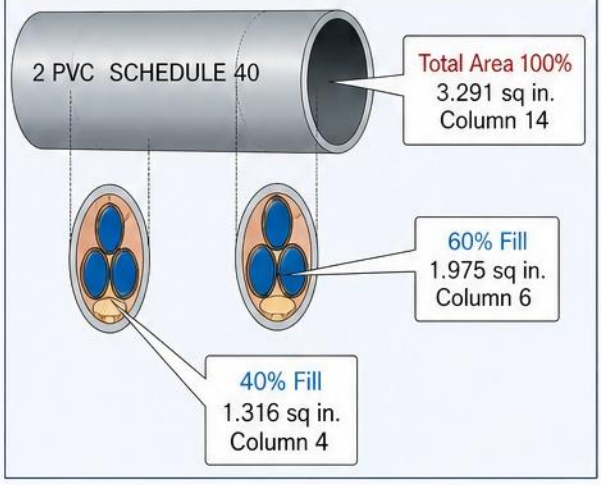
- Follow these steps for sizing raceways:
  - **Step 1.** First determine the total area of the conductors in the raceway. Use Chapter 9, Table 5 for insulated conductors; and use Chapter 9, Table 8 for bare conductors.

Figure 300–82 300.19(A)
Conductor Cross-Sectional Area
Chapter 9, Tables 5 and 8



  - **Step 2.** Select the raceway from Chapter 9, Table 4 in accordance with the percent fill listed in Chapter 9, Table 1.

Figure 300–83 300.19(A)
Raceway Cross-Sectional Area
Chapter 9, Table 4



CHAPTER 9, TABLE 4 AND TABLE 5 EXAMPLE

Question: *What size Schedule 40 PVC is required for the following conductors?* ▶ **Figure 300–84**

- *3–500 kcmil THWN-2*
- *1–250 kcmil THWN-2*
- *1–3 AWG THWN-2*

(a) Trade size 1 in. *(b) Trade size 2 in.*
(c) Trade size 3 in. *(d) Trade size 4 in.*

Figure 300–84 300.19(A)
Number and Size of Conductors, Raceway Fill
300.19(A) Chapter 9 Tables 4 and 5 Example

Step 1. Determine the conductor area, Chapter 9, Table 5.

500 kcmil = 0.7073 in² × 3 conductors	=	2.1219 in²
250 kcmil = 0.3970 in² × 1 conductor	=	0.3970 in²
3 AWG = 0.0973 in² × 1 conductor	=	0.0973 in²
Total area of the conductors	=	2.6162 in²

Step 2. Size the raceway at 40% fill, Chapter 9, Table 4.
Trade Size 3 PVC at 40 percent fill = 2.907 in²

Solution:

Step 1: *Determine the total area needed for the conductors [Chapter 9, Table 5].*

500 kcmil THWN-2	*0.7073 in.² × 3*	*2.1219 in.²*
250 kcmil THWN-2	*0.3970 in.² × 1*	*0.3970 in.²*
3 AWG THWN-2	*0.0973 in.² × 1*	*+0.0973 in.²*
Total Area of Conductors		*2.6162 in.²*

Step 2: *Select the raceway at 40 percent fill [Chapter 9, Table 1 and Table Note (6), and Table 4].*

Use 3 in, schedule 40 PVC because there are 2.907 sq in. of conductor fill at 40 percent.

Answer: *(c) Trade size 3 in.*

300.20 Raceway Installations

(A) Complete Runs. Raceways must be mechanically completed between the pulling points before conductors are installed—except as follows: ▸Figure 300–85

Figure 300–85 Complete Run of Raceway Prior to Conductor or Cable Installation 300.20(A)

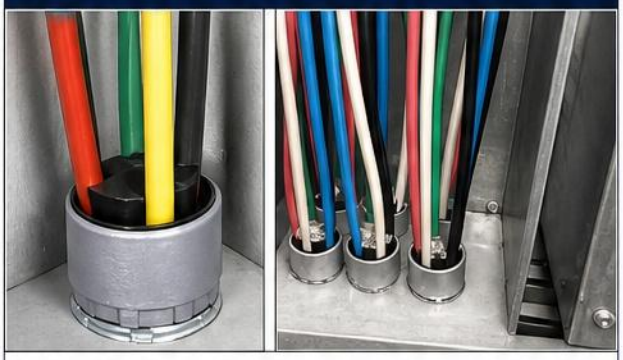
Raceways must be mechanically completed between the pulling points before conductors or cables are installed.

(4) Where required to facilitate the installation of utilization equipment

300.21 Supporting Conductors in Vertical Raceways

(A) Spacing Intervals. If the vertical rise of a raceway exceeds the values of Table 300.21(A), each conductor must be supported at the top or as close to the top as practical. Intermediate support is required in increments not exceeding the values of Table 300.21(A).

Figure 300–86 Supporting Conductors in Vertical Raceways 300.21(A)



Each conductor in vertical raceways must be supported at the top or as close to the top as practical. in increments not exceeding the values of Table 300.21(A).

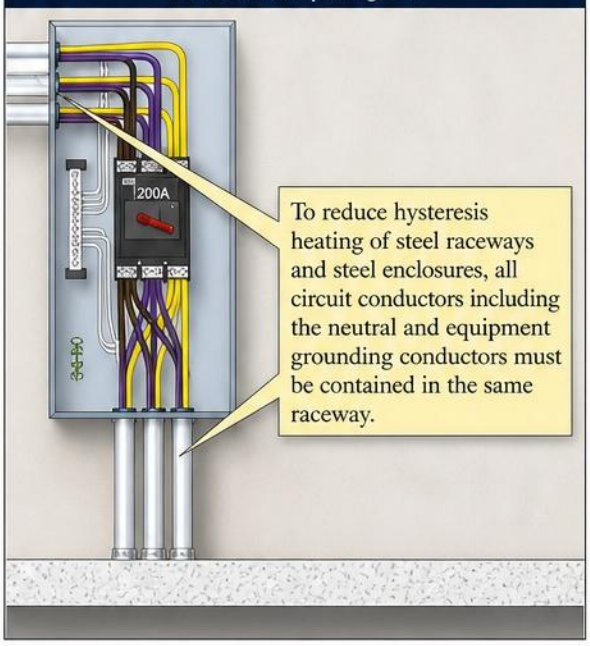
Author's Comment:

▸ A great deal of weight accumulates in long vertical runs of conductors and can cause them to drop out of the raceway (sometimes called "runaway") if the vertical conductors are not properly secured. There have been cases where conductors in a vertical raceway were released from the pulling "basket" or "grip" (at the top) without being secured. The weight of the conductors and gravity took over, accelerating the conductors down and out of the raceway, and injuring those at the bottom of the installation.

300.22 Reducing Hysteresis Heating

(A) Conductors Grouped Together. To reduce hysteresis heating of steel raceways and steel enclosures, all circuit conductors including the neutral and equipment grounding conductors must be contained in the same raceway. ▸Figure 300–87 ▸Figure 300–88

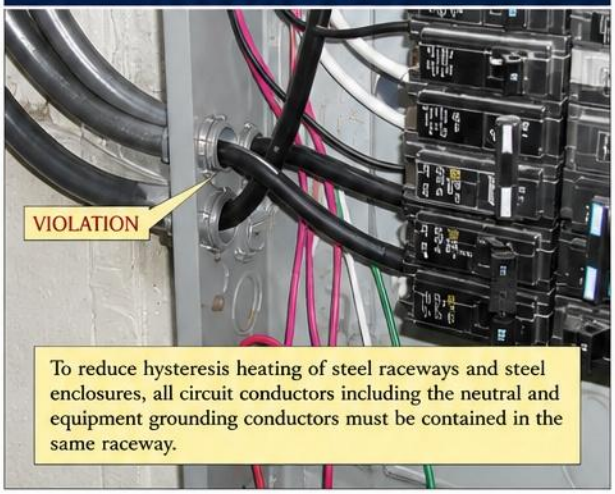
Figure 300–87 Reducing Hysteresis Heating Conductors Grouped Together 300.22(A)



Author's Comment:

▸ The following sections require all conductors of the circuit, (including the neutral and equipment grounding conductors) to be grouped together in the same raceway [300.5(B), 300.7(I), 376.20, 310.10(G), and 392.20(C)].

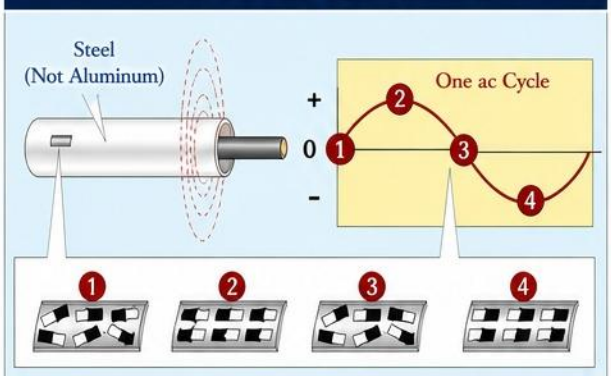
Figure 300–88 Reducing Hysteresis Heating—Conductors Grouped Together **300.22(A)**



To reduce hysteresis heating of steel raceways and steel enclosures, all circuit conductors including the neutral and equipment grounding conductors must be contained in the same raceway.

- When alternating current flows through a conductor, a pulsating or varying magnetic field is created around the conductor. This magnetic field is constantly expanding and contracting with the amplitude of the alternating current. In the United States, the frequency is 60 cycles per second (Hz). Since alternating current reverses polarity 120 times per second, the magnetic field that surrounds the conductor also reverses direction 120 times per second. This expanding and collapsing magnetic field induces eddy currents in the steel parts surrounding the conductors. This causes them to heat up due to hysteresis heating.
- The steel molecules align to the polarity of the magnetic field, and when it reverses, the steel molecules reverse their polarity as well. This back-and-forth alignment of the molecules heats up the metal.

Figure 300–89 Reducing Hysteresis Heating—Conductors Grouped Together (Comment) **300.22(A)**

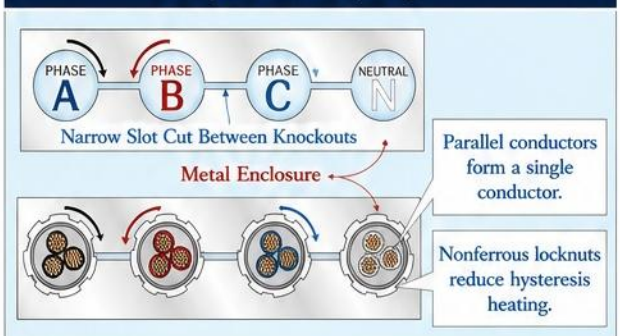


Ferrous metal (steel and iron) molecules align to the polarity of the magnetic field, and when the field reverses the molecules reverse their polarity. This back-and-forth alignment of the molecules heats up ferrous metal parts.

- When conductors of the same circuit are installed in the same raceway, the magnetic fields of the different conductors tend to cancel each other out, resulting in a reduced magnetic field around the conductors. The smaller magnetic field reduces induced currents in steel raceways or enclosures, which reduces the hysteresis heating of the metal raceway or enclosure.

(B) Single Conductors. Where a single conductor or a parallel set of conductors enters an enclosure, the hysteresis heating effects on the metal enclosure must be reduced by cutting slots between the individual holes through which the conductors pass, or by passing the conductors through the same wall opening.

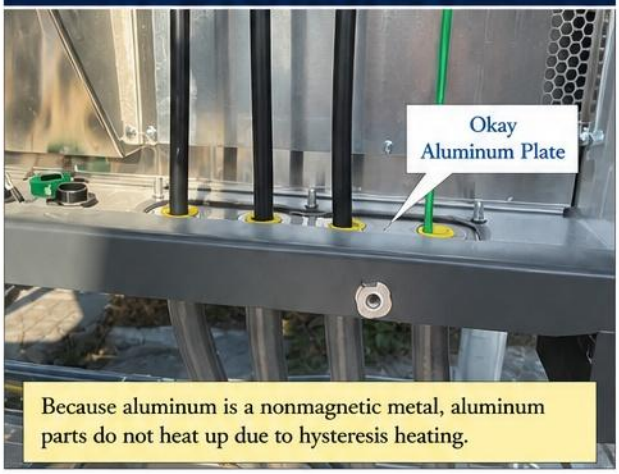
Figure 300–90 Reducing Hysteresis Heating—Cutting Slots Between Openings **300.22(B)**



Where a single conductor or a parallel set of conductors enters an enclosure, the hysteresis heating effects on the metal enclosure must be reduced by cutting slots between the individual holes through which the conductors pass.

Note: Because aluminum is a nonmagnetic metal, aluminum parts do not heat up due to hysteresis heating.

Figure 300–91 Reducing Hysteresis Heating—Conductors Through Same Opening **300.22(B) Note**



Because aluminum is a nonmagnetic metal, aluminum parts do not heat up due to hysteresis heating.

300.23 Spread of Fire or Products of Combustion

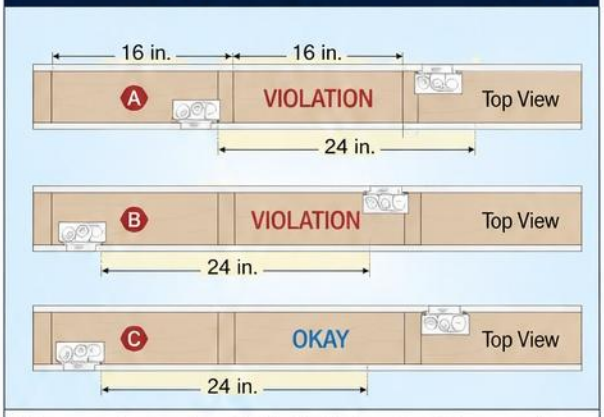
Electrical circuits and equipment must be installed in such a way that the spread of fire or products of combustion will not be substantially increased. Openings around electrical penetrations into or through fire-resistant-rated walls, partitions, floors, or ceilings must be firestopped using approved methods to maintain the fire-resistance rating. ▶Figure 300–92 and ▶Figure 300–93

Note: Directories published by testing laboratories contain installation restrictions necessary to maintain the fire-resistive rating of assemblies. Building codes have restrictions on electrical penetrations located on opposite sides of a fire-resistance-rated wall (boxes). For example, outlet boxes must have a minimum 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 300–94 and ▶Figure 300–95

Figure 300–92 Openings Around Electrical Penetrations Fire-Stopped Using Approved Methods 300.23

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

Figure 300–94 Opening Around Electrical Penetrations Boxes in Fire-Rated Walls 300.23 Note



Three 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 300–92 Openings Around Electrical Penetrations Fire-Stopped Using Approved Methods 300.23

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

Figure 300–95 Openings Around Electrical Penetrations Fire-Resistant Puddy Pads 300.23 Note

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."

Author's Comment

- Firestopping materials are listed for the specific types of wiring methods and fire-rated assembly they penetrate. For example, MC cable will have a different fire penetration detail when passing through a fire wall than will EMT.

AUTHOR'S COMMENT:

Enclosures used in fire-resistive-rated assemblies must be specified for the intended purpose. When steel boxes are installed, they must be fastened to the framing member because cut-in style boxes are not allowed. "Putty pads" may be installed on the outside of the box, but numerous manufacturers now list inserts for the interiors of boxes. Firestopping materials are identified for the particular types of wiring methods and for the construction of the assembly being penetrated. ▶ **Figure 300–96**

Figure 300–96 Opening Around Electrical Penetrations Firestopping Listed Assembly **300.23 Comment**

Firestopping materials are identified for the particular types of wiring methods and for the construction of the assembly being penetrated.

300.24 Total Raceway Bends

The combined degree of all bends in any run of conduit or tubing must not exceed 360 degrees between pull points.

300.25 Wiring in Ducts and Plenum Spaces

(A) Ducts Used for Dust or Vapor. Wiring methods are not permitted in ducts that transport dust or flammable vapors. ▶ **Figure 300–97**

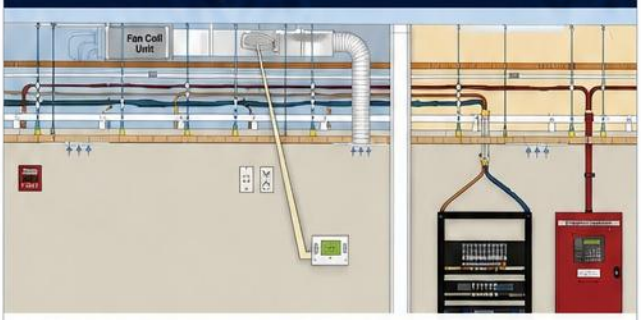
(B) Ducts Fabricated for Environmental Air.

Wiring Method Permitted. Wiring methods are only permitted in a duct fabricated to transport dust, loose stock, or flammable vapors—if the equipment and wiring method is necessary for the direct action upon (or sensing of) the contained air. ▶ **Figure 300–98** and ▶ **Figure 300–99**

Figure 300–97 Ducts Used for Dust or Vapor Wiring Methods Are Not Permitted **300.25(A)**

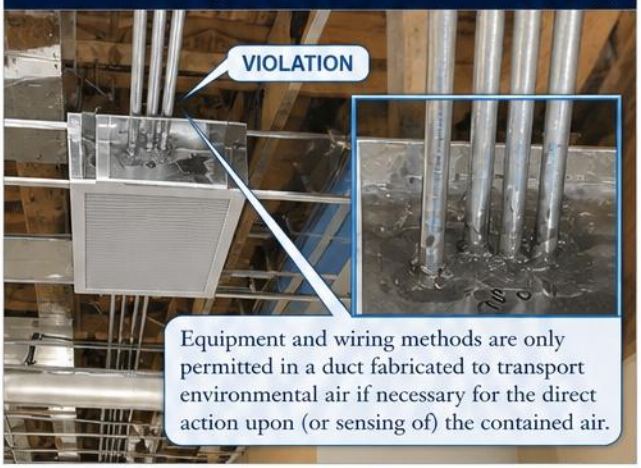
Wiring methods are not permitted in ducts that transport dust or flammable vapors.

Figure 300–98 Ducts Used for Environmental Air Wiring Methods **300.25(B)**



Wiring methods are only permitted in a duct fabricated to transport environmental air if necessary for the direct action upon (or sensing of) the contained air.

Figure 300–98 Ducts Used for Environmental Air Wiring Methods Permitted **300.25(B)**

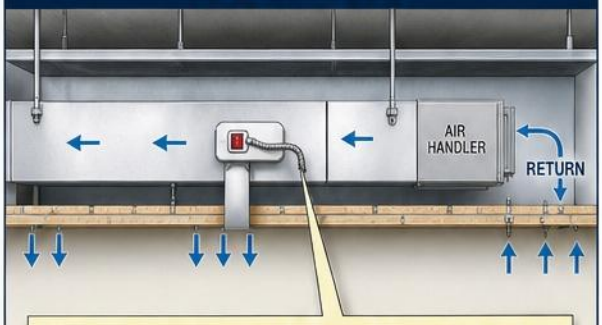


Equipment and wiring methods are only permitted in a duct fabricated to transport environmental air if necessary for the direct action upon (or sensing of) the contained air.

Wiring Methods Permitted. MC cable without an overall nonmetallic covering and metal raceways can be installed in ducts fabricated to transport environmental air. Flexible metal conduit (not exceeding 4 ft) can be used to connect physically adjustable equipment and devices within the fabricated duct. ▸ Figure 300–100

Figure 300–100 300.25(B)

Ducts Fabricated for Environmental Air
Wiring Methods Permitted



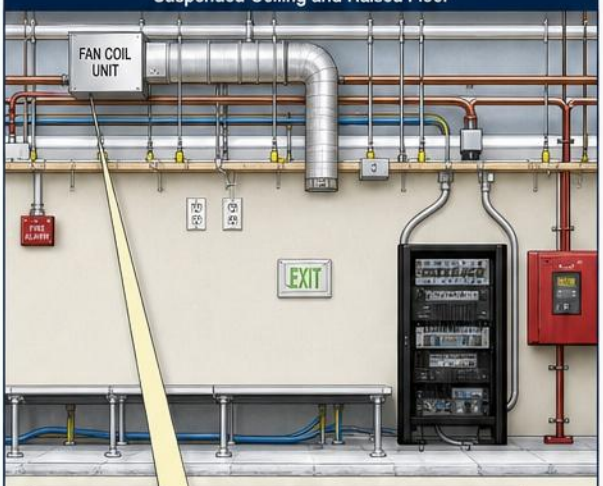
MC cable without an overall nonmetallic covering and metal raceways can be installed in ducts fabricated to transport environmental air. Flexible metal conduit (not exceeding 4 ft) can be used to connect physically adjustable equipment and devices within the fabricated duct.

(C) Plenum Spaces for Environmental Air. Wiring methods in plenum spaces must comply with (1) through (3) as follows:

Note 1: The spaces above a suspended ceiling and below a raised floor used for environmental air is considered a plenum space. ▸ Figure 300–101

Figure 300–101 300.25(C) Note 1

Plenum Spaces for Environmental Air
Suspended Ceiling and Raised Floor



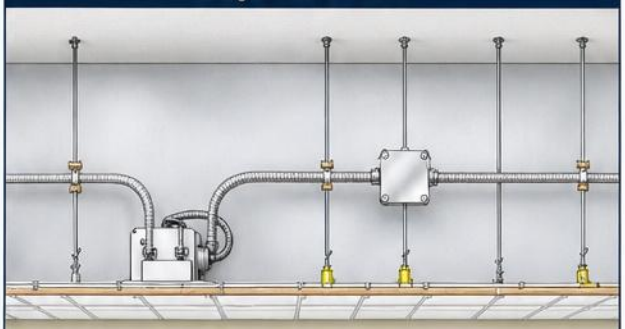
The spaces above a suspended ceiling and below a raised floor used for environmental air is considered a plenum space.

(1) Wiring Methods.

(a) Wiring methods are permitted in plenum spaces as follows: ▸ Figure 300–102

Figure 300–102 300.25(C)(1)(a)

Plenum Spaces for Environmental Air
Wiring Methods Permitted



Wiring methods permitted in plenum spaces:

(2) Rigid metal conduit
(3) Intermediate metal conduit
(4) Electrical metallic tubing
(6) Flexible metal conduit
(8) MC cable without a nonmetallic cover
(9) AC cable

(2) Rigid metal conduit

(3) Intermediate metal conduit

(4) Electrical metallic tubing

(6) Flexible metal conduit

(8) MC cable without a nonmetallic cover

(9) AC cable

(b) Other metal raceways such as surface metal raceways or metal wireways

(c) Cable ties for securing and supporting cables must be listed for use in a plenum space ▸ Figure 300–103

Figure 300–103 300.25(C)(1)(c)

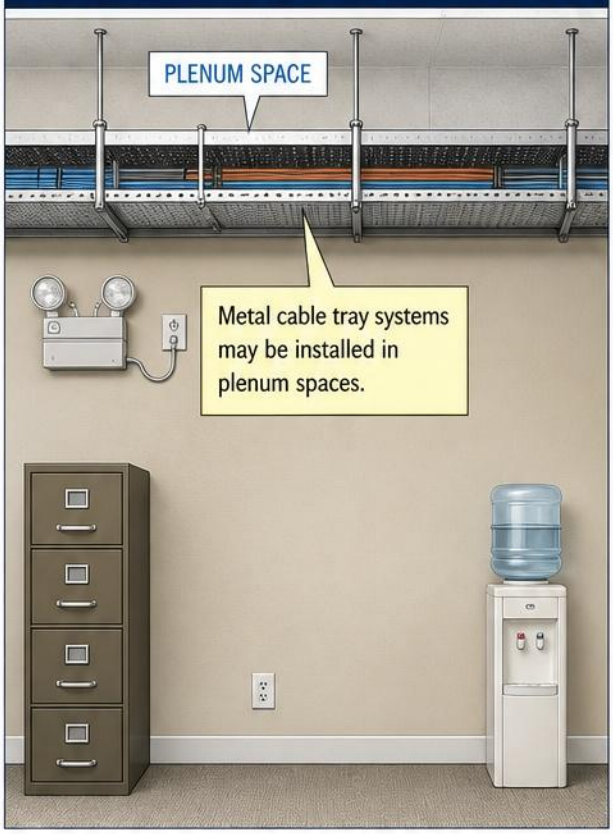
Plenum Spaces for Environmental Air
Listed Cable Ties

Cable ties for securing and supporting cables and power-limited plenum rated cables must be listed for use in a plenum space.

(2) Cable Tray Systems.

(a) Metal Cable Tray Systems. Metal cable tray systems may be installed in plenum spaces. **Figure 300–104**

Figure 300–104 Metal Cable Tray in Plenum Space 300.25(C)(2)(a)



Metal cable tray systems are permitted for installation within plenum spaces.

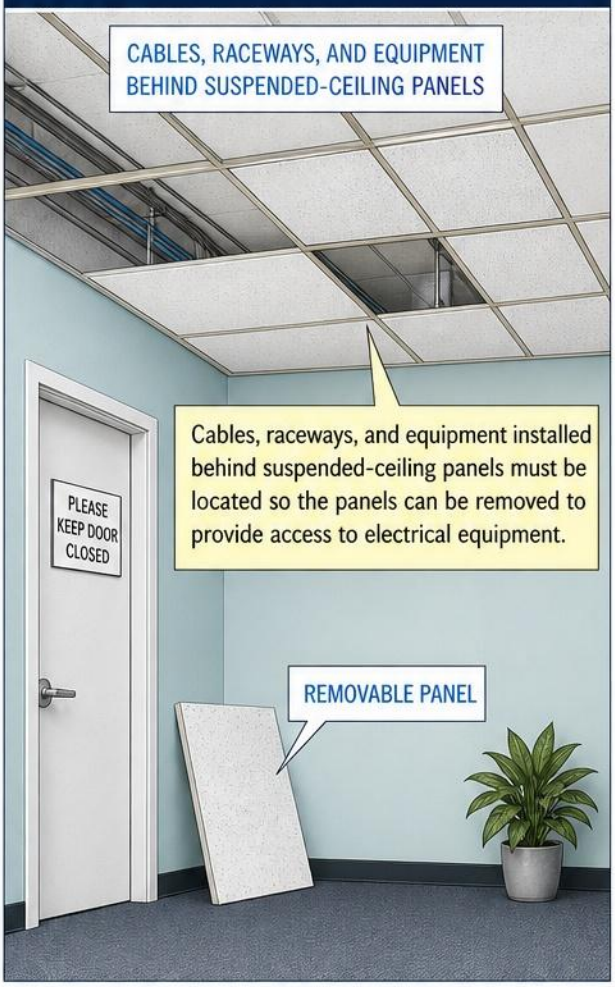
AUTHOR'S COMMENT

Examples of electrical equipment allowed in plenum spaces include air handlers, junction boxes, and dry-type transformers. However, transformers are not allowed to be rated over 50 kVA when installed in hollow spaces [450.13(B)].

300.26 PANELS DESIGNED TO ALLOW ACCESS

Cables, raceways, and equipment installed behind suspended-ceiling panels must be located so the panels can be removed to provide access to electrical equipment. **Figure 300–105**

Figure 300–105 Removable Panels for Access 300.26



Install cables, raceways, and equipment above suspended ceilings so panels can be removed to access electrical equipment.

ARTICLE 210
BRANCH CIRCUITS

210.4 Multiwire Branch Circuits

A multiwire branch circuit supplies two or more utilization equipment enclosures or outlets, or both, from the same branch-circuiting means, where all ungrounded conductors have a common disconnecting means.

210.4(A) General

Multiwire branch circuits shall consist of two or more ungrounded conductors, a grounded conductor, and an equipment grounding conductor.

210.4(B) Disconnecting Means

A multiwire branch circuit shall have a means to simultaneously disconnect all ungrounded conductors at the origin of the branch circuit.

210.4(C) Conductor Terminations

All ungrounded conductors of a multiwire branch circuit shall be terminated on the same multi-pole circuit breaker or group of circuit breakers that are mechanically joined together.

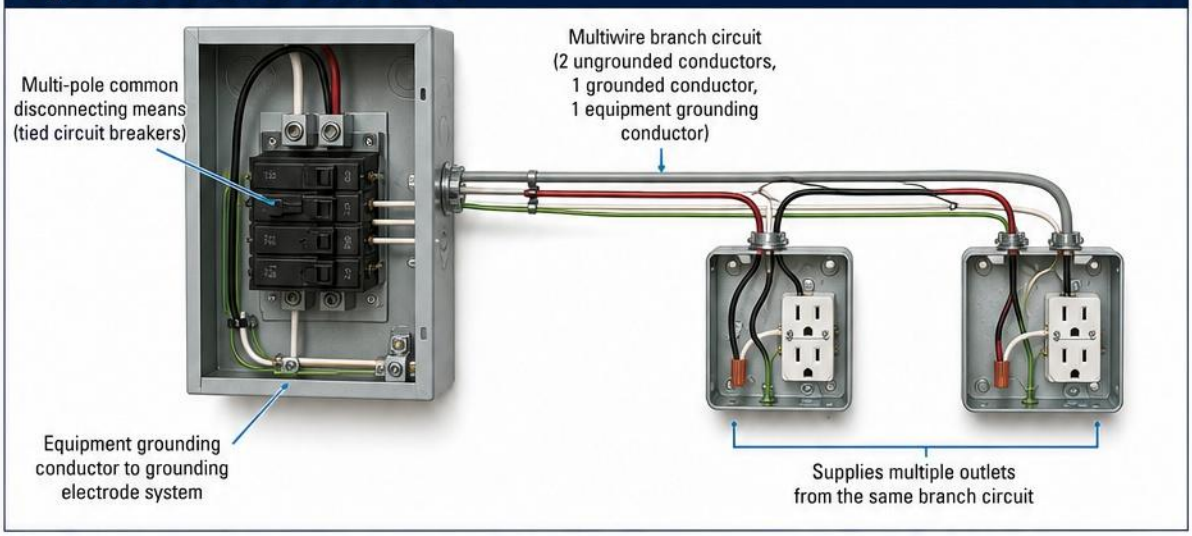
210.4(D) Identification

The disconnecting means for multiwire branch circuits shall be identified by markings to indicate that the circuit supplies multiple branches or circuits.

210.4(E) Grounded Conductor

The grounded conductor of a multiwire branch circuit shall be installed so that it carries only the unbalanced current.

Figure 210.4 Multiwire Branch Circuit — NEC® 210.4



A multiwire branch circuit provides power to multiple outlets using two or more ungrounded conductors that share a common grounded conductor and equipment grounding conductor, all disconnected simultaneously at the origin of the circuit.

ARTICLE 310

Conductors for General Wiring

Introduction to Article 310—Conductors for General Wiring

Article 310 sets forth general requirements and permitted uses for conductors—including insulation types, identification markings, and ampacity ratings. Article 310 does not apply to conductors that are part of flexible cords, fixture wires, or conductors that are an integral part of equipment [90.7 and 310.1]. A special section also provides guidance for sizing service and feeder conductors in single-family dwellings and individual units of multifamily dwellings.

Understanding Article 310 is key to ensuring safe, *Code*-compliant conductor installations.

Part I. General

310.1 Scope

Article 310 contains the general requirements and permitted uses for conductors, conductor insulation markings, and ampacity ratings.

Figure 310–1 310.1 Scope

Article 310 sets forth the general requirements and permitted uses for conductors, conductor insulation markings, and ampacity ratings.

310.2 Listing Requirements

The following must be listed:

(1) Insulated conductors

(2) Copper-clad aluminum conductor material

Part II. Construction Specifications

310.4 Conductor Construction and Application

Table 310.4(1) provides information on conductor insulation properties such as letter type, maximum operating temperature, application, insulation, and outer cover properties.

Figure 310–2 Conductor Construction and Application Types of Insulation Ratings 310.4

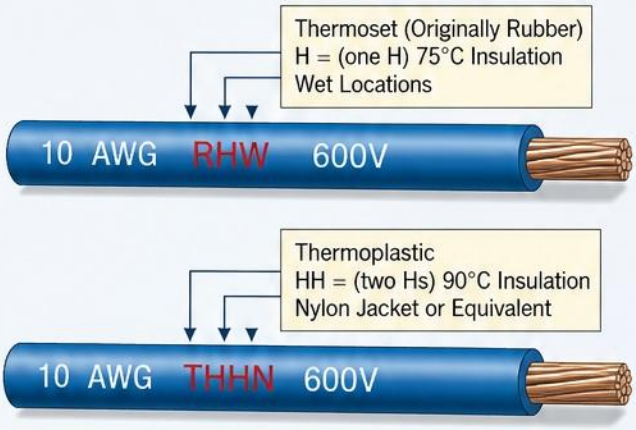


Table 310.4(1) provides information on conductor insulation properties such as letter type, maximum operating temperature, application, insulation, and outer cover properties.

Author's Comment:

The following explains the lettering on conductor insulation [Table 310.4(1)]:

- **No H** 60°C insulation rating
- **H** 75°C insulation rating
- **HH** 90°C insulation rating permitted in dry locations
- **-2** 90°C insulation rating permitted in wet locations
- **N** Nylon outer cover
- **T** Thermoplastic insulation
- **U** Underground
- **W** Permitted in wet or damp locations
- **X** Thermoset insulation
- **R** Rubber insulation

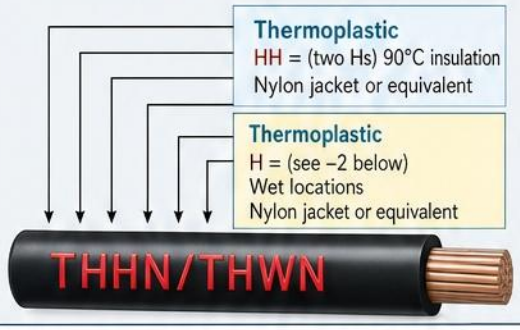
Table 310.4(1) Conductor Applications and Insulations

Type Letter	Column 2 Insulation	Column 3 Max. Operating Temperature	Column 4 Application	Column 5 Sizes Available AWG or kcmil	Column 6 Outer Covering
RHH	Flame-retardant thermoset	90°C	Dry and damp locations	16 AWG—2000 kcmil	Moisture-resistant, flame-retardant, nonmetallic
RHW	Flame-retardant, moisture-resistant thermoset	75°C	Dry and wet locations	16 AWG—2000 kcmil	Moisture-resistant, flame-retardant, nonmetallic
RHW-2	Flame-retardant, moisture-resistant thermoset	90°C	Dry and wet locations	16 AWG—2000 kcmil	Moisture-resistant, flame-retardant, nonmetallic
THHN	Flame-retardant, heat-resistant thermoplastic	90°C	Dry and damp locations	16 AWG—1000 kcmil	Nylon jacket or equivalent
THHW	Flame-retardant, moisture- and heat-resistant thermoplastic	75°C 90°C	Dry and wet locations	16 AWG—1000 kcmil	None
THW	Flame-retardant, moisture- and heat-resistant thermoplastic	75°C	Dry, damp, and wet locations	16 AWG—2000 kcmil	None
THW-2	Flame-retardant, moisture- and heat-resistant thermoplastic	90°C	Dry, damp, and wet locations	16 AWG—1000 kcmil	None
THWN	Flame-retardant, moisture- and heat-resistant thermoplastic	75°C	Dry, damp, and wet locations	16 AWG—1000 kcmil	Nylon jacket or equivalent
THWN-2	Flame-retardant, moisture- and heat-resistant thermoplastic	90°C	Dry, damp, and wet locations	16 AWG—1000 kcmil	Nylon jacket or equivalent
TW	Flame-retardant, moisture-resistant thermoplastic	60°C	Dry, damp, and wet locations	16 AWG—2000 kcmil	None
USE	Heat- and moisture-resistant	75°C	See Article 338	16 AWG—2000 kcmil	Moisture-resistant nonmetallic
USE-2	Heat- and moisture-resistant	90°C	See Article 338	16 AWG—2000 kcmil	Moisture-resistant nonmetallic

AUTHOR'S COMMENT

- It is common to encounter conductors that have more than one insulation rating (for example, THHN/THWN). These conductors are suitable for use in dry locations at the THHN 90°C ampacity rating. If the conductor is installed in a wet location, the THWN ampacity rating of 75°C from Table 310.16 must be used. Figure 310–3.

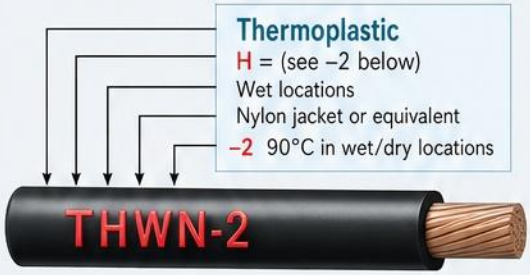
Figure 310–3 Multiple Insulation Ratings NEC 310.5



It is common to see conductors with multiple insulation ratings. THHN/THWN may be used in a dry location at the THHN 90°C ampacity, or in a wet location using the THWN ampacity rating of 75°C from Table 310.16.

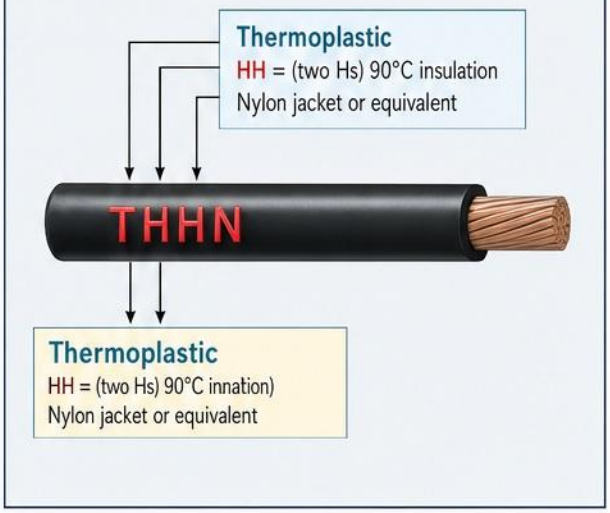
- When a "–2" appears at the end of an insulation type (such as THWN-2), the conductor is rated for a maximum operating temperature of 90°C and is suitable for installation in either dry or wet locations. Figure 310–4.

Figure 310–4 –2 Suffix in Insulation Type NEC 310.5



When a "–2" is part of the insulation type (such as THWN-2), the conductor is rated for a maximum operating temperature of 90°C and is suitable for use in either dry or wet locations.

Figure 310–5 Conductor Insulation Example NEC 310.5



(a) Thermoplastic insulation
(b) Suitable for dry or damp locations
(c) Maximum operating temperature of 90°C
(d) All of these

Answer: *(d) All of these*

310.5 CONDUCTORS, MINIMUM SIZE AND MATERIAL

(A) Minimum Size Conductor. The minimum size conductor is 16 AWG copper, 14 AWG copper-clad aluminum, or 12 AWG aluminum, except as permitted elsewhere in this *Code*.

AUTHOR'S COMMENT

- Some believe that 12 AWG copper is the smallest size conductor allowed for commercial or industrial installations. Although that is not accurate based on *NEC* rules, local code requirements may dictate otherwise.

(B) Conductor Material. Conductors must be copper, aluminum, or copper-clad aluminum as follows:

(1) The 8, 10, and 12 AWG solid aluminum conductors must be manufactured from an AA-8000 series electrical grade aluminum alloy.

(2) The 8 AWG through 1000 kcmil stranded aluminum conductors must be constructed of an AA-8000 series electrical grade aluminum alloy.
See Figure 310–6 and Figure 310–7.

Figure 310–6 Conductor Material – Aluminum 310.5(B)(1) and (2)

Figure 310–7 Conductor Material – Aluminum 310.5(B)(1) and (2)

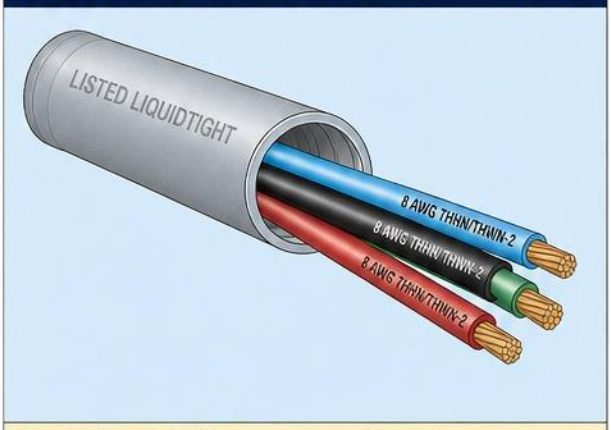
(3) Copper in copper-clad aluminum conductors must form a minimum 10 percent of the cross-sectional area, and the aluminum core must be made of an AA-8000 series electrical grade aluminum alloy.
See Figure 310–8.

(C) Stranded Conductors. Conductors 8 AWG and larger installed in a raceway must be stranded, unless specifically permitted or required elsewhere in this Code to be solid.
See Figure 310–9.

Figure 310–8 Copper-Clad Aluminum Conductors 310.5(B)(3)

Copper in copper-clad aluminum conductors must constitute at least 10% of the cross-sectional area, and the aluminum core must be made of an AA-8000 series electrical grade aluminum alloy.

Figure 310–9 Stranded Conductors in Raceway 310.5(C)



Conductors 8 AWG and larger installed in a raceway must be stranded, unless specifically permitted or required elsewhere in this Code to be solid.

Author's Comment:

A grounding electrode conductor is an example of where a solid conductor 8 AWG and larger can be installed in a raceway when it is required to be protected from physical damage [250.64(B)].

310.6 CONDUCTOR IDENTIFICATION

(A) Conductors Not Exceeding 1000V.

(1) Neutral Conductor. Insulated neutral conductors must be identified white or gray in accordance with 200.7.

(2) Equipment grounding conductor. Insulated equipment grounding conductors must be marked green or marked green with one or more yellow stripes in accordance with 250.119.

(3) Identification of phase conductors.

(a) General. Phase conductors must be identified by a color that is distinguishable from neutral conductors [200.7] and equipment grounding conductors [250.119].

Figure 310–10 Identification of Phase Conductors 310.6(A)(3)(a)

Phase conductors must be identified by a color that is distinguishable from neutral conductors and equipment grounding conductors.

(b) Branch circuit. Where premises wiring is supplied from more than one nominal voltage system, branch-circuit phase conductors must be identified in accordance with 210.5(C).

(c) Feeders. Where premises wiring is supplied from more than one nominal voltage system, feeder phase conductors must be identified in accordance with 215.12(C).

Author's Comment

- Although the *NEC* does not require a specific color code for phase conductors, electricians often use the following color system:
  - 120/240V, single-phase—black, red, and white
  - 208Y/120V, three-phase—black, red, blue, and white
  - 240V/120V, three-phase (high-leg)—black, orange, blue, and white
  - 480Y/277V, three-phase—brown, orange, yellow, and gray; or brown, purple, yellow, and gray

Figure 310–11 Conductor Identification Practices 310.6(A)(3) Comment

Although the *NEC* does not require a specific color code for phase conductors, electricians often use the following for power and lighting conductor identification:

- 120/240V, single-phase—black, red, and white
- 208Y/120V, three-phase—black, red, blue, and white
- 240V/120V, three-phase (high-leg)—black, orange, blue, and white
- 480Y/277V, three-phase—brown, orange, yellow, and gray; or brown, purple, yellow, and gray

Part III. Installation

310.10 Uses Permitted

Conductors described in Table 310.4(1) are permitted for use in any of the wiring methods covered in Chapter 3.

(A) Dry locations. Conductors used in dry locations can be any of the types identified in Table 310.4.

(C) Wet locations. Conductors in wet locations must be listed for wet locations (such as THWN-2 or XHHW-2). Cables in wet locations must be listed for wet locations (such as UF or USE).

Author's Comment

- The letter "W" found on the insulation types indicates it is suitable for wet locations.

(D) Conductors exposed to direct sunlight. Conductors exposed to the rays of the sun must be:

(1) Insulated and listed as being sunlight resistant.

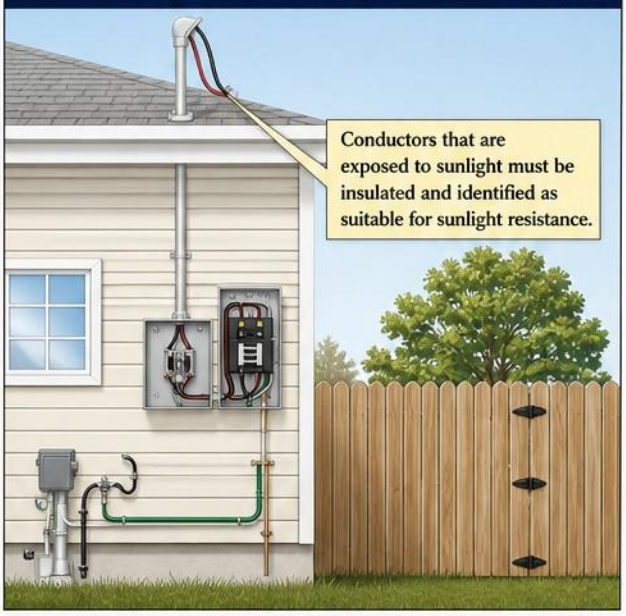
(3) Bare

(E) Direct-burial conductors. Conductors used for direct-burial applications must be of a type identified for such use.

Author's Comment

- Single-conductor UF cable is permitted for direct burial, see 340.10(1) and single-conductor USE cable is permitted for direct burial, see 338.10(B)(4)(b)(2).

Figure 310–12 Conductors and Cables Exposed to Direct Sunlight 310.10(D)(1)

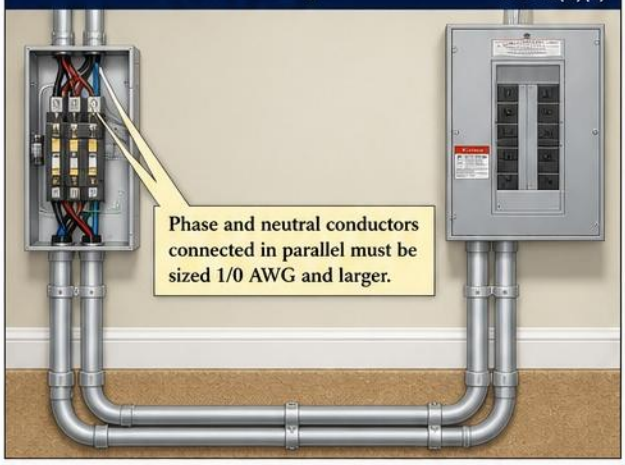


Conductors exposed to sunlight must have insulation rated for sunlight resistance and be identified for such use.

(G) Conductors Connected in Parallel.

(1) 1/0 AWG and Larger Conductors. Phase, neutral, and equipment grounding conductors are permitted to be connected in parallel (electrically joined at both ends). Phase and neutral conductors connected in parallel must be sized 1/0 AWG and larger.

Figure 310–13 Conductors Connected in Parallel 1/0 AWG and Larger 310.10(G)(1)



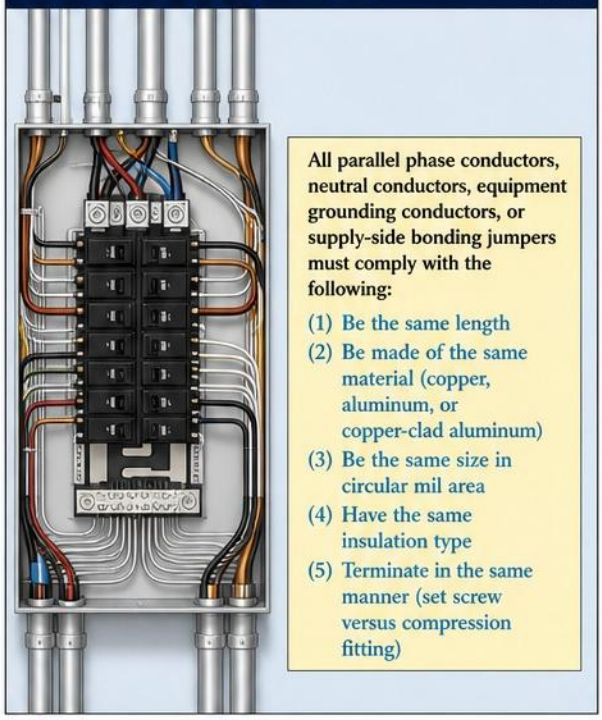
Phase and neutral conductors may be paralleled at both ends when sized 1/0 AWG or larger.

Author's Comment:

When conductors are installed in parallel (electrically joined at both ends), the current flow will be evenly distributed between the individual parallel conductors.

(2) Conductor and Installation Characteristics. All parallel phase conductors, neutral conductors, equipment grounding conductors, and supply-side bonding jumpers must comply with the following:

Figure 310–14 Conductors Connected in Parallel Installation Characteristics 310.10(G)(2)



(1) All conductors must be the same length.

(2) All conductors must be made of the same material (copper, aluminum, or copper-clad aluminum).

(3) All conductors must have the same size in circular mil area.

(4) All conductors must use the same type of insulation.

(5) All conductors must terminate in the same manner (set screw versus compression fitting).

(3) Separate Raceways and Cables.

(a) Raceways and Cables. The raceways or cables for parallel circuits must have the same number of conductors and the raceways or cables must have the same electrical characteristics (metallic versus nonmetallic).

(b) Conductors. Conductors composing one paralleled set are not required to have the same physical characteristics as those of another paralleled set.

(4) Conductor Ampacity Correction or Adjustment. Conductors in parallel must comply with 310.15(B) and (C).

Figure 310–15 Conductors Connected in Parallel Separate Raceways and Cables *310.10(G)(3)(a)*

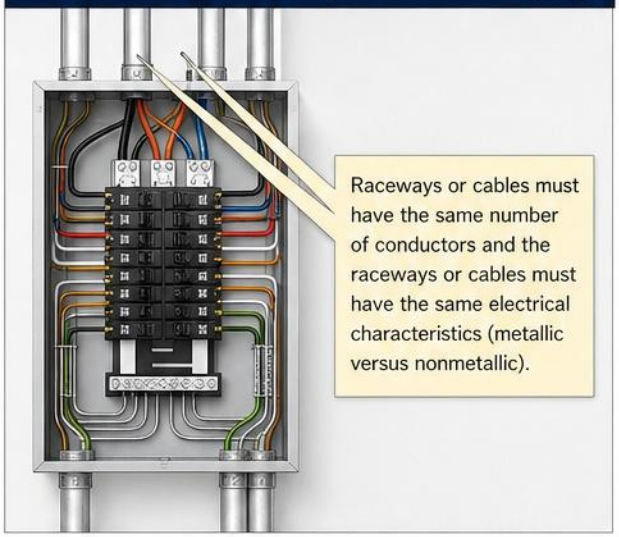


Figure 310–17 Conductors Connected in Parallel Four or More Current-Carrying Conductors *310.10(G)(4) Comment*

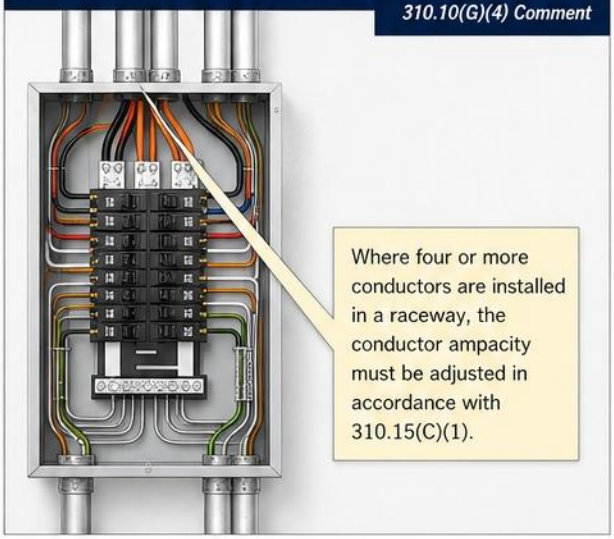


Figure 310–16 Conductors Connected in Parallel Physical Characteristics *310.10(G)(3)(b)*

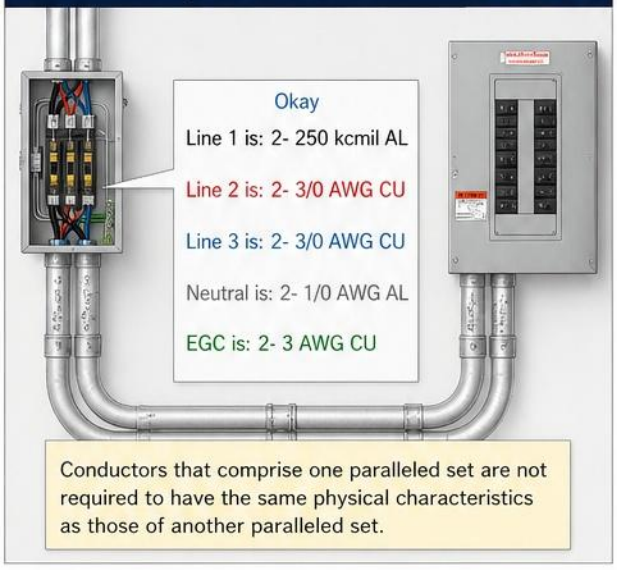
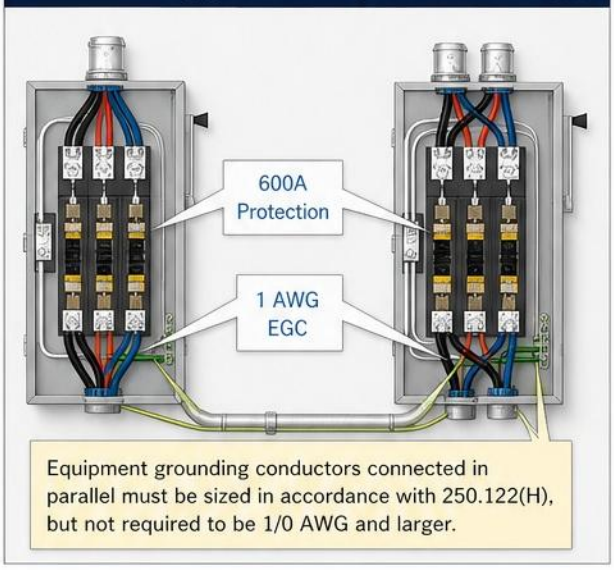


Figure 310–18 Conductors Connected in Parallel Equipment Grounding Conductors *310.10(G)(5)*



Author's Comment:

- Where conductors are in an ambient temperature greater than 86°F, the conductor ampacity (based on the 90°C column of Table 310.16) must be corrected in accordance with 310.15(B)(1).
- Where four or more current-carrying conductors are in a raceway or cable, the conductor ampacity (based on the 90°C column of Table 310.16) must be adjusted in accordance with 310.15(C)(1). Figure 310–17

(5) Equipment Grounding Conductors. Equipment grounding conductors connected in parallel must be sized in accordance with 250.122(H), but they are not required to be 1/0 AWG and larger. Figure 310–18

(6) Bonding Jumpers. Supply-side bonding jumpers must be sized in accordance with 250.102(C) and load-side bonding jumpers must be sized in accordance with 250.102(D), but they are not required to be 1/0 AWG and larger.

310.12 DWELLING SERVICES AND FEEDERS

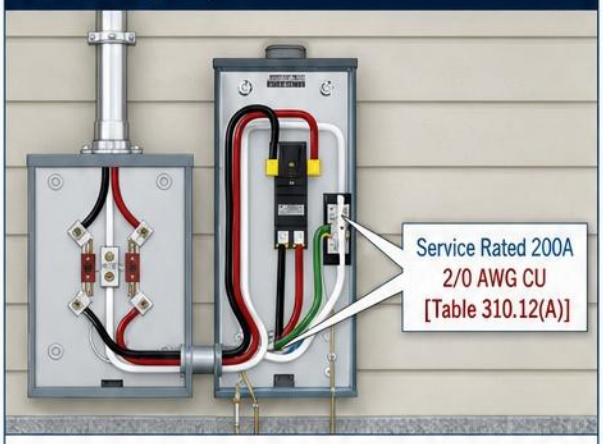
(A) Services. For a service rated 100A through 400A, service conductors or cables rated 75°C or greater supplying the entire load associated with a one-family dwelling unit can be sized in accordance with Table 310.12(A).

▶ Dwelling Unit Service Conductor Size [310.12(A)] Example

Question: *What is the minimum size copper service conductor for a single-family dwelling unit with a service disconnected 200A?* Figure 310–19

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

Figure 310–19: Dwelling Unit Service Conductor Sizing Example 1 310.12(A)



Service conductors or cables rated 75°C or greater supplying the entire load associated with a one-family dwelling unit can be sized in accordance with Table 310.12(A).

Answer: *(b) 2/0 AWG [Table 310.12(A)]*

Author's Comment:

- Table 310.12(A) cannot be used to size service conductors for two-family or multifamily dwelling buildings. Figure 310–20 and Figure 310–21

Figure 310–20: Dwelling Unit Service Conductor Sizing—Two-Family Dwelling Comment 310.12(A)

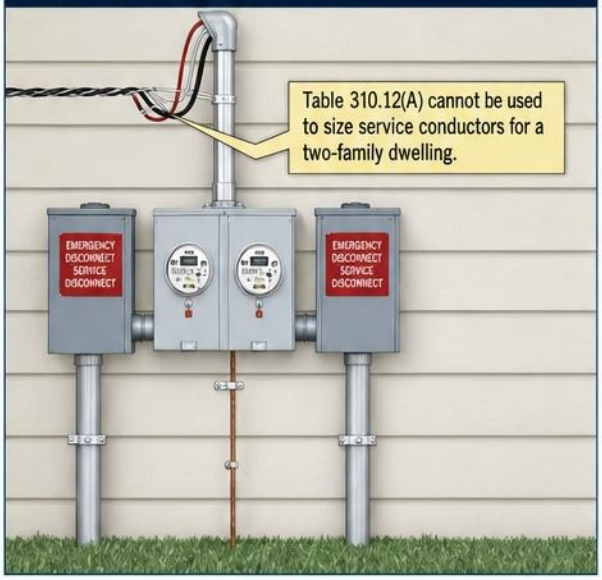
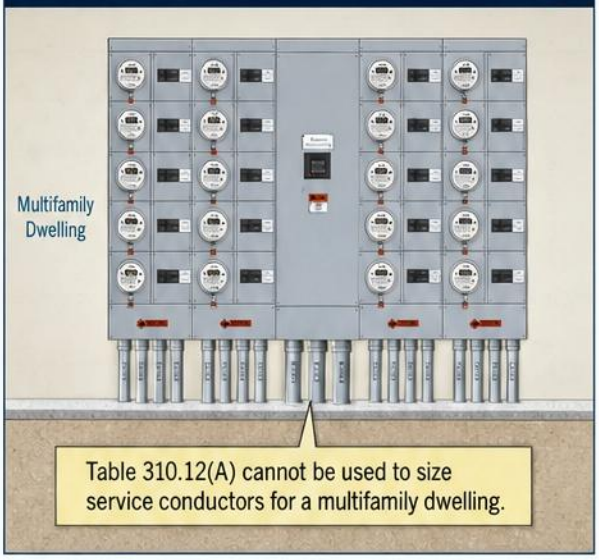


Figure 310–21: Dwelling Unit Service Conductor Sizing—Multifamily Dwelling 310.12(A)



(B) Feeders. For a feeder rated 100A through 400A, feeder conductors or cables rated 75°C or greater supplying the entire load associated with a one-family dwelling or individual dwelling unit (in a two-family dwelling and multifamily dwelling) can be sized in accordance with Table 310.12(A). Figure 310–22, Figure 310–23, and Figure 310–24

Figure 310–22: Dwelling Unit Feeder Conductor Sizing—One-Family Dwelling 310.12(B)

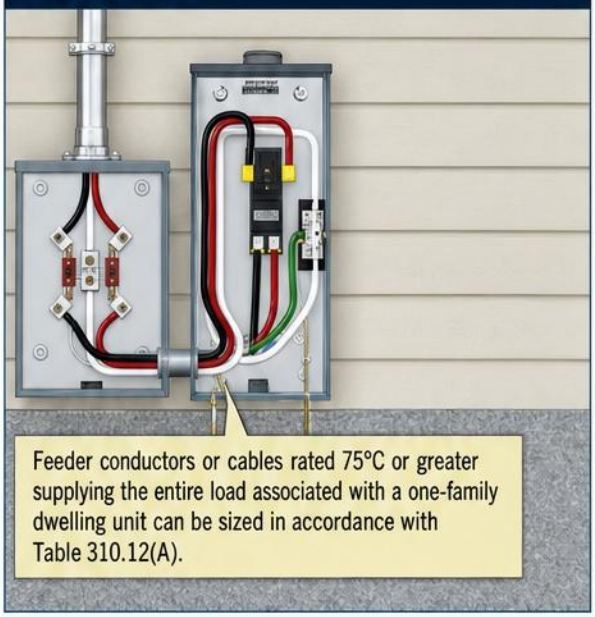
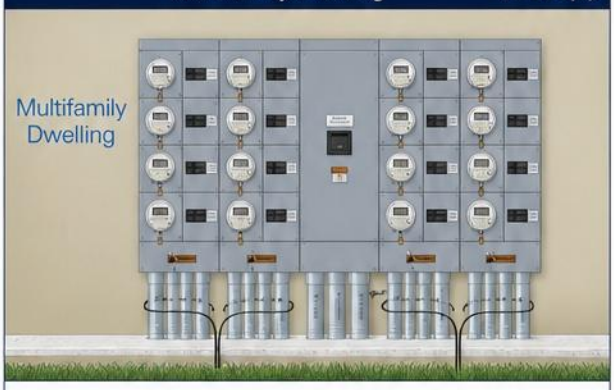


Figure 310–23 Dwelling Unit Feeder Conductor Sizing Two-Family Dwelling 310.12(B)

Feeder conductors or cables rated 75°C or greater supplying the entire load associated with an individual dwelling unit in a two-family dwelling can be sized in accordance with Table 310.12(A).

Figure 310–24 Dwelling Unit Feeder Conductor Sizing Multifamily Dwelling 310.12(B)



Feeder conductors or cables rated 75°C or greater supplying the entire load associated with an individual dwelling unit in a multifamily dwelling can be sized in accordance with Table 310.12(A).

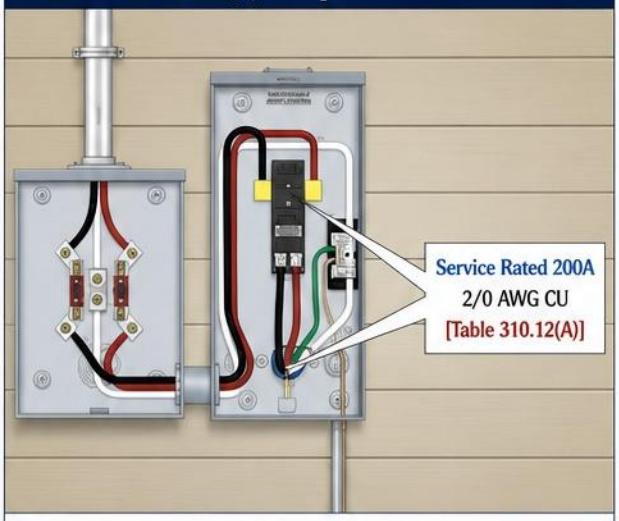
Dwelling Unit Feeder Conductor Size [310.12(B)] Example

Question: *What is the minimum size copper feeder conductors for a single-family dwelling unit that has overcurrent protection of 200A and the feeder conductors carry the entire load of the dwelling unit?*

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

Answer: *(b) 2/0 AWG [Table 310.12(A)]*

Figure 310–25 Dwelling Unit Feeder Conductor Sizing 310.12(B) Example



Feeder conductors or cables rated 75°C or greater supplying the entire load associated with an individual dwelling unit can be sized in accordance with Table 310.12(A).

(C) Feeder Conductors Not Greater Than Service Conductors.

In no case is the feeder conductor for an individual dwelling unit required to have an ampacity greater than the service, as specified in 310.12(A) or (B).

Feeder conductors are not required to be larger than the service conductor.

▶ Figure 310–26

Figure 310–26 Dwelling Unit Feeder Conductor Sizing Not Larger Than Service Conductors 310.12(C)

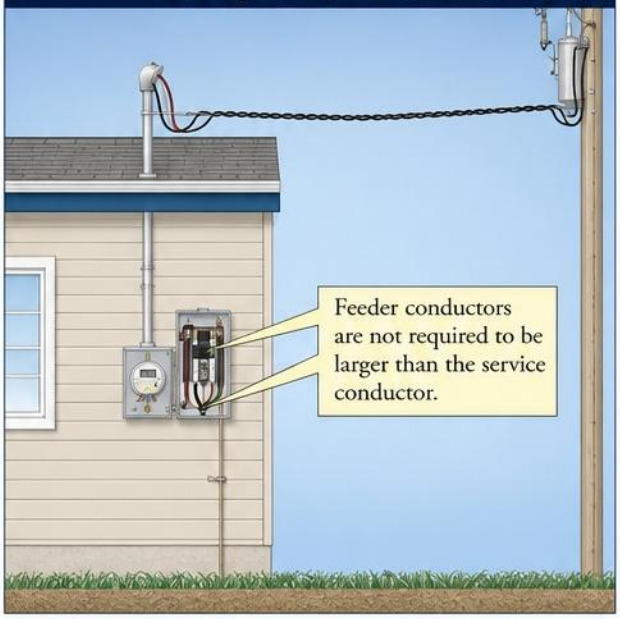


Table 310.12(A) Single-Phase Dwelling Services and Feeders

Service or Feeder Rating	Copper	Aluminum or Copper-Clad Aluminum
100A	4 AWG	2 AWG
110A	3 AWG	1 AWG
125A	2 AWG	1/0 AWG
150A	1 AWG	2/0 AWG
175A	1/0 AWG	3/0 AWG
200A	2/0 AWG	4/0 AWG
225A	3/0 AWG	250 kcmil
250A	4/0 AWG	300 kcmil
300A	250 kcmil	350 kcmil
350A	350 kcmil	500 kcmil
400A	400 kcmil	600 kcmil

310.14 Ampacities for Conductors

(A) General Requirements.

(1) Tables or Engineering Supervision. The allowable current (ampacity) for conductors shall be established using the *NEC* tables as corrected and adjusted in accordance with 310.15, or under engineering supervision as provided in 310.14(B).

(2) Lower Rating Conductor Ampacity. Where more than one conductor ampacity applies to a given circuit length due to temperature correction [Table 310.15(B)(1)(1)] or adjustment factors [Table 310.15(C)(1)], the smallest (lowest) conductor ampacity shall be used for the entire circuit. Figure 310–27

Example: *Where a conductor has different ampacities because of ambient temperature correction [310.15(B)] or adjustment factors [310.15(C)], the higher ampacity is permitted for the entire circuit only if the lower ampacity does not exceed the lesser of:*

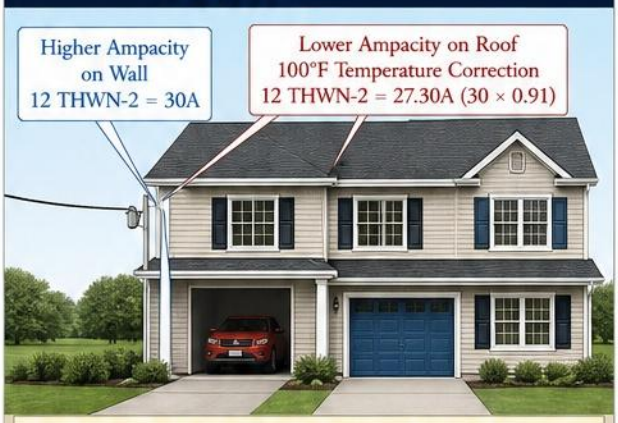
(1) 10 ft of the total circuit

(2) 10 percent of the total circuit ▸Figure 310–28

Figure 310–27 Conductor Ampacity, Lower Selection 310.14(A)(2)

Where more than one conductor ampacity applies to a given circuit length because of temperature correction or adjustment factors, the lowest conductor ampacity applies to the total circuit.

Figure 310–28 Conductor Ampacity, Higher Selection 310.14(A)(2) Ex



Where a conductor has different ampacities because of correction or adjustment factors, the higher ampacity is permitted for the entire circuit if the lower ampacity does not exceed the lesser of:
(1) 10 ft of the total circuit
(2) 10% of the total circuit.

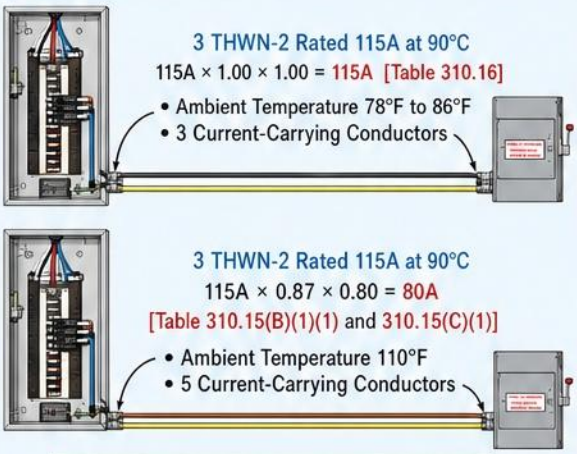
310.15 Ampacity Tables

(A) General. Ampacities for conductors are contained in Table 310.16.

Ampacity. The maximum current, in amperes, that a conductor can carry continuously under its conditions of use without exceeding its temperature rating. ▸Figure 310–29

Temperature ampacity correction [310.15(B)(1)] and ampacity adjustment factors [310.15(C)(1)] are applied to the ampacities listed in Table 310.16 based on the conductor's insulation temperature rating.

Figure 310–29 Ampacity Article 100 Definition 310.15(A)

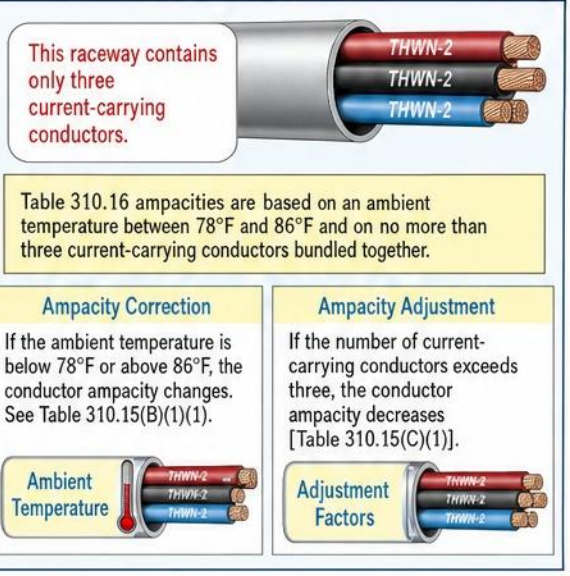


The maximum current, in amperes, a conductor can carry continuously under its conditions of use without exceeding its temperature rating.

Author's Comment:

The Table 310.16 ampacity must be corrected when the ambient temperature is not between 78°F and 86°F and must be adjusted when more than three current-carrying conductors are bundled together. The temperature correction multiplier [310.15(B)(1)] and adjustment multiplier [310.15(C)(1)] are applied to the conductor ampacity based on the temperature rating of the conductor insulation in Table 310.16 (typically in the 90°C column). See **Figure 310–30**.

Figure 310–30 Conductor Ampacity Tables *310.15(A) Comment* 310.15(A)



(B) CONDUCTOR AMPACITY CORRECTION

(1) General. Where the ambient temperature is greater than 86°F or less than 78°F, the conductor ampacities contained in Table 310.16 in the 90°C column must be corrected in accordance with Table 310.15(B)(1)(1). See **Figure 310–31**.

Figure 310–31 Conductor Ampacity Correction Ambient Temperature 310.15(B)(1)

Where the ambient temperature is greater than 86°F the conductor ampacities contained in Table 310.16 in the 90°C column must be corrected in accordance with Table 310.15(B)(1)(1).

Author's Comment:

Conductor ampacity reduction is required when the ambient temperature is greater than 86°F. This is because heat generated by the current flow in the conductor plus the added ambient temperature can exceed the conductor insulation temperature rating. See **Figure 310–32**.

Figure 310–32 Conductor Ampacity Correction Ambient Temperature Formula 310.15(B)(1)

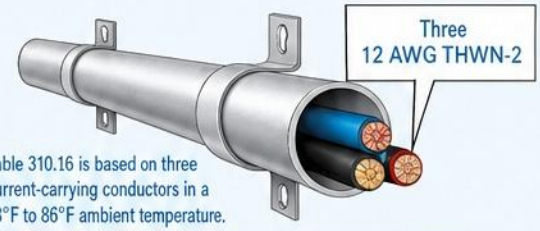


Table 310.16 is based on three current-carrying conductors in a 78°F to 86°F ambient temperature.

Ambient Temperature 78°F to 86°F (30°C)	Ambient Temperature 87°F to 95°F
90°C Table Ampacity Correction Factor = 100% (1.00)	90°C Table Ampacity Correction Factor = 96% (0.96)
30 Table Amps × 1.00 Ampacity = 30A	30 Table Amps × 0.96 Ampacity = 28.80A

Table 310.15(B)(1)(1) Ambient Temperature Correction Factors Based on 30°C (86°F) and 90°C Insulation

Ambient Temperature °F	Ambient Temperature °C	Correction Factor 90°C Conductors
50°F or less	10°C or less	1.15
51–59°F	11–15°C	1.12
60–68°F	16–20°C	1.08
69–77°F	21–25°C	1.04
78–86°F	26–30°C	1.00
87–95°F	31–35°C	0.96
96–104°F	36–40°C	0.91
105–113°F	41–45°C	0.87
114–122°F	46–50°C	0.82

Corrected conductor ampacity is determined by applying an ambient temperature correction factor.

Corrected Ampacity = Table 310.16 Ampacity × Ambient Correction Factor

Example 1 — Ambient Temperature Correction [310.15(B)(1)(1)]

Question: What is the ampacity of a 12 AWG, THWN-2 copper conductor in an ambient temperature of 50°F?

(a) 30.50*A* (b) 32.50*A* (c) 34.50*A* (d) 36.50*A*

Solution:

The conductor ampacity for 12 AWG, THWN-2 is 30A at 90°C [Table 310.16].

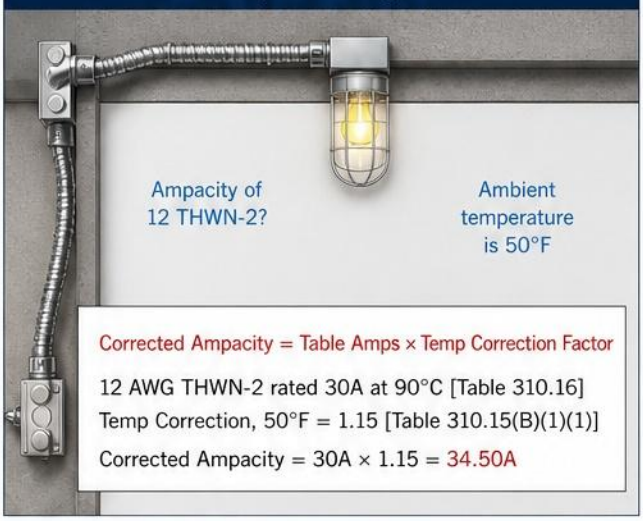
The correction factor for a 90°C conductor in an ambient temperature of 50°F is 1.15 [Table 310.15(B)(1)(1)].

Corrected Ampacity = 30A × 115%
Corrected Ampacity = 34.50A

Note: Ampacity increases when the ambient temperature is less than 86°F.

Answer: *(c) 34.50A*

Figure 310–33 Conductor Ampacity Correction — Ambient Temperature Example 1 NEC 310.15(B)(1)(1)



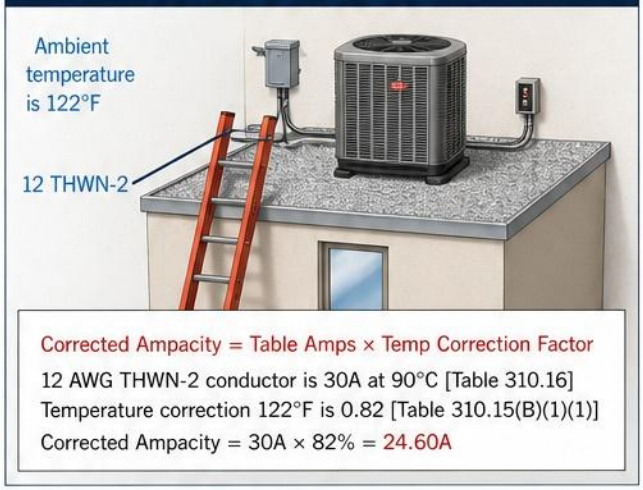
Ampacity is increased when the ambient temperature is below 86°F.

Example 2 — Ambient Temperature Correction [310.15(B)(1)(1)]

Question: What is the ampacity of a 6 AWG, THWN-2 copper conductor in an ambient temperature of 122°F?

(a) 59.50*A* (b) 60.50*A* (c) 61.50*A* (d) 62.50*A*

Figure 310–34 Conductor Ampacity Correction — Ambient Temperature Example 2 NEC 310.15(B)(1)(1)



Ampacity is reduced when the ambient temperature is above 86°F.

Solution:

The conductor ampacity for 6 AWG, THWN-2 conductor is 75A at 90°C [Table 310.16].

The correction factor for a 90°C conductor in an ambient temperature of 122°F is 0.82 [Table 310.15(B)(1)(1)].

Corrected Ampacity = 75A × 82%
Corrected Ampacity = 61.50*A*

Answer: *(c) 61.50A*

(2) Raceways and Cables Exposed to Sunlight on Rooftops. Raceways or cables that are subjected to direct sunlight and located less than ¾ in. above the roof, at a temperature of 60°F (33°C) must be adjusted to the outdoor ambient temperature to determine the ambient temperature correction in accordance with Table 310.15(B)(1)(1).

Figure 310–35 Raceways Exposed to Sunlight on Rooftops 310.15(B)(2)

Raceways that are exposed to sunlight and located less than ¾ in. above the roof must be adjusted to an outdoor ambient temperature of 60°F for the purpose of determining the conductor ampacity correction.

AUTHOR'S COMMENT

- The temperature adder is required because the air inside raceways and cables that are in direct sunlight becomes much hotter than the surrounding air.

CONDUCTOR AMPACITY TEMPERATURE ROOFTOP ADDER [310.15(B)(2)] EXAMPLE

Question: *A 6 AWG, THWN-2 copper conductor is installed in a raceway ½ in. above the roof in an ambient temperature of 90°F. What is its ampacity?*

(a) 38A (b) 40A (c) 42A (d) 44A

Solution:

Corrected Temperature = 90°F + 60°F adder [310.15(B)(2)]

Corrected Temperature = 150°F

The temperature correction factor for 150°F = 0.58 [Table 310.15(B)(1)(1)]

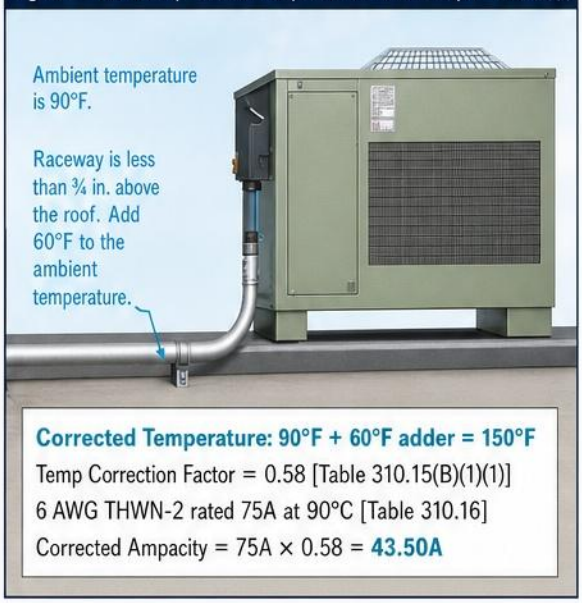
A 6 AWG, THWN-2 conductor is rated 75A at 90°C [Table 310.16]

Corrected Ampacity = 75A × 58%

Corrected Ampacity = 43.50A, rounded to 44A

Answer: *(d) 44A*

Figure 310–36 Rooftop Conductor Temperature Correction Example 310.15(B)(2)



Ex: *XHHW-2 insulated conductors are not subject to the rooftop temperature correction adder.*

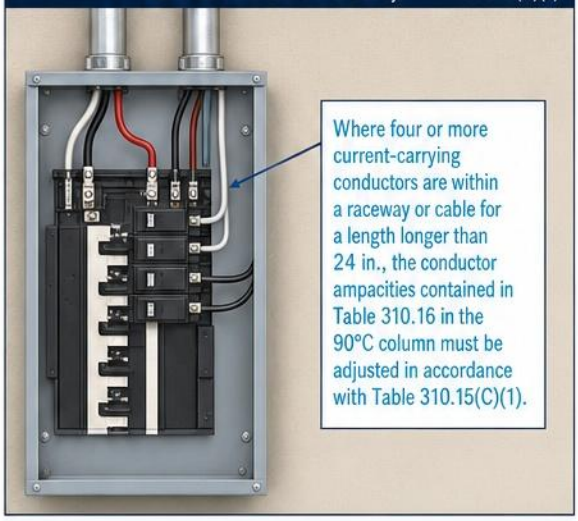
Note 1: The *ASHRAE Handbook—Fundamentals* (www.ashrae.org) is a reliable source for ambient temperatures in various locations.

(C) CONDUCTOR AMPACITY ADJUSTMENT

(1) Four or More Current-Carrying Conductors.

Conductors Within Raceways or Cables. Where four or more current-carrying conductors are contained within a raceway or cable for a length longer than 24 in., the conductor ampacities contained in Table 310.16 in the 90°C column must be adjusted in accordance with Table 310.15(C)(1).

Figure 310–37 Conductor Ampacity Adjustment — Four or More Conductors in Raceways 310.15(C)(1)



Conductors Not Within Raceways or Cables. If four or more current-carrying conductors are not contained within a raceway or cable for a length greater than 24 in., the conductor ampacities listed in Table 310.16 in the 90°C column must be adjusted in accordance with Table 310.15(C)(1).

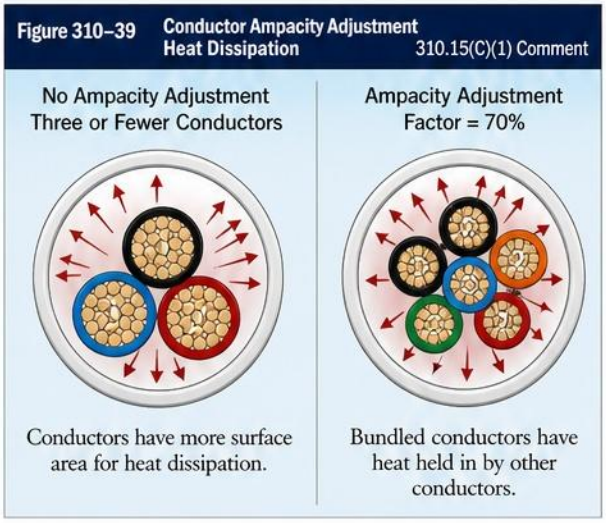
Figure 310–38 Conductors Not Within Raceways or Cables 310.15(C)(1)

Open conductors in equipment not contained in a raceway for more than 24 in. require an ampacity adjustment.

Author's Comment:

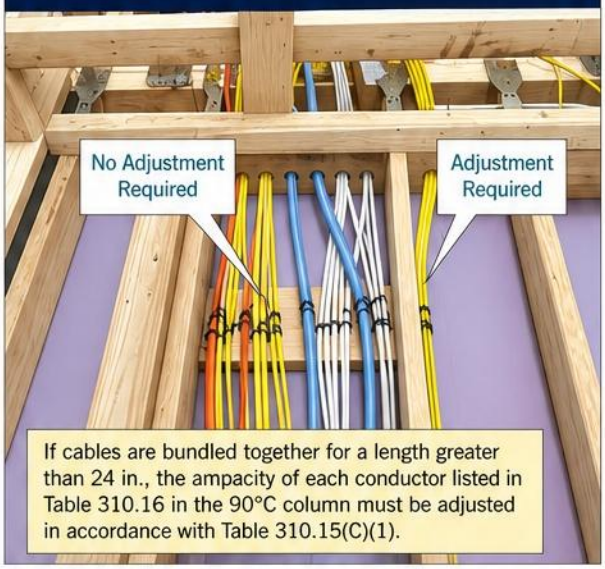
- An ampacity reduction is required when four or more current-carrying conductors are bundled together because heat produced by current flow cannot dissipate as quickly when fewer current-carrying conductors are present.

Figure 310–39 Conductor Ampacity Adjustment Heat Dissipation 310.15(C)(1) Comment



Cables Bundled Together. If cables are bundled together for a length greater than 24 in., the ampacity of each conductor listed in Table 310.16 in the 90°C column must be adjusted in accordance with Table 310.15(C)(1).

Figure 310–40 Cables Bundled Together 310.15(C)(1)



Cables bundled together for more than 24 in. require an ampacity adjustment.

Author's Comment:

- The neutral conductor is considered a current-carrying conductor for the purposes of conductor ampacity adjustment [310.15(C)(1)] under the conditions specified in 310.15(E)(1).
- Equipment grounding conductors are never considered current carrying. See 310.15(F).

Table 310.15(C)(1) Conductor Ampacity Adjustment for More Than Three Current-Carrying Conductors

Number of Conductors[1]	Adjustment
4–6	80%
7–9	70%
10–20	50%
21–30	45%
31–40	40%
41 and above	35%

[1] *Does not include conductors that cannot be energized at the same time.*

CONDUCTOR AMPACITY ADJUSTMENT [310.15(C)(1)] – EXAMPLE 1

Question: What is the adjusted ampacity of four current-carrying 12 AWG, THWN-2 copper conductors in a raceway longer than 24 in.?

(a) 20A (b) 24A (c) 28A (d) 32A

Figure 310-41 **310.15(C)(1)**

Conductor Ampacity Adjustment for Four or More Current-Carrying Conductors – Table 310.15(C)(1) Example 1

12 AWG THWN-2 rated 30A at 90°C [Table 310.16]
Adjusted ampacity = 30A × 80% [Table 310.15(C)(1)]
Adjusted ampacity = 24A

Solution:

Adjusted ampacity = Table 310.16 ampacity × Bundled Ampacity Adjustment Factor from Table 310.15(C)(1)

12 AWG, THWN-2 is rated 30A at 90°C [Table 310.16].

The adjustment factor for four current-carrying conductors is 80 percent [Table 310.15(C)(1)].

Adjusted ampacity = 30A × 80%
Adjusted ampacity = 24A

Answer: (b) 24A

CONDUCTOR AMPACITY ADJUSTMENT [310.15(C)(1)] – EXAMPLE 2

Question: What is the adjusted ampacity of eight current-carrying 12 AWG, THWN-2 copper conductors in a raceway longer than 24 in.?

(a) 18A (b) 21A (c) 24A (d) 27A

Figure 310-42 **310.15(C)(1)**

Conductor Ampacity Adjustment for Four or More Current-Carrying Conductors – Table 310.15(C)(1) Example 2

12 AWG THWN-2 rated 30A at 90°C [Table 310.16]
Adjusted ampacity = 30A × 70% [Table 310.15(C)(1)]
Adjusted ampacity = 21A

Solution:

Adjusted ampacity = Table 310.16 ampacity × Bundled Ampacity Adjustment Factor from Table 310.15(C)(1)

12 AWG, THWN-2 is rated 30A at 90°C [Table 310.16].

The adjustment factor for eight current-carrying conductors is 70 percent [Table 310.15(C)(1)].

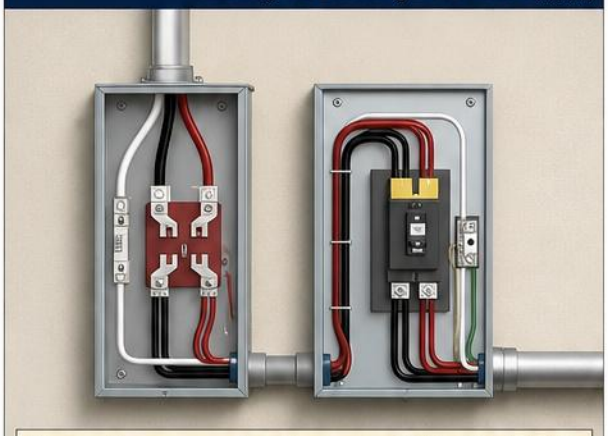
Adjusted ampacity = 30A × 70%
Adjusted ampacity = 21A

Answer: (b) 21A

(a) Where conductors are in cable trays, 392.80 applies.

(b) In raceways not exceeding 24 in., conductor ampacity adjustment from Table 310.15(C)(1) does not apply ▸ **Figure 310–43**

Figure 310–43 | Conductor Ampacity Adjustment Raceway Not Exceeding 24 in. 310.15(C)(1)(b)



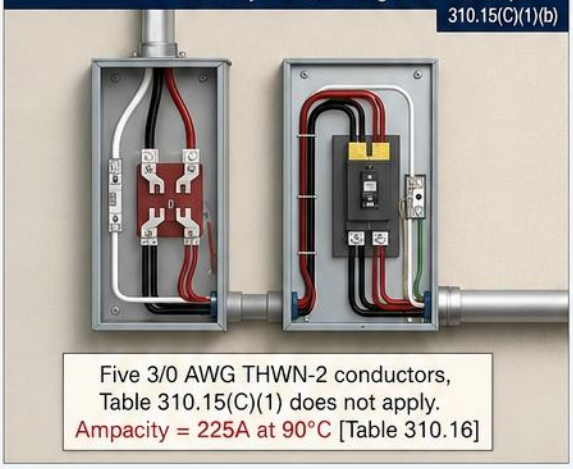
The conductor ampacity adjustment of Table 310.15(C)(1) does not apply to conductors in raceways not exceeding 24 in. in length.

▶ CONDUCTOR AMPACITY ADJUSTMENT—RACEWAY NOT EXCEEDING 24 IN. EXAMPLE

Question: What is the ampacity of five 3/0 AWG, THWN-2 copper conductors in a raceway that does not exceed 24 in. in length? ▸ **Figure 310–44**

(a) 175A *(b) 195A* *(c) 205A* *(d) 225A*

Figure 310–44 | Conductor Ampacity Adjustment Raceway Not Exceeding 24 in. Example 310.15(C)(1)(b)



Solution:

3/0 AWG, THWN-2 is rated 225A at 90°C [Table 310.16].

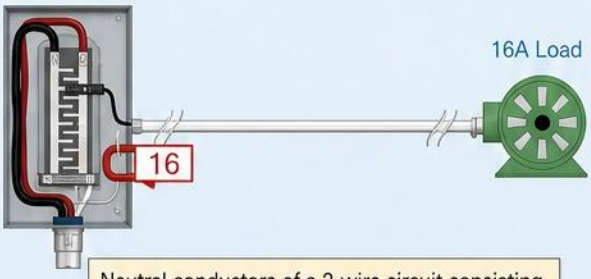
Answer: *(d) 225A*

(E) Neutral Conductor. When applying 310.15(C), neutrals are considered current-carrying or considered not current-carrying in accordance with the following:

(1) Considered Current Carrying. A neutral conductor is considered a current-carrying conductor for ampacity adjustments in accordance with Table 310.15(C)(1) for the following circuits:

(1) 2-wire circuit consisting of one phase and one neutral conductor ▸ **Figure 310–45**

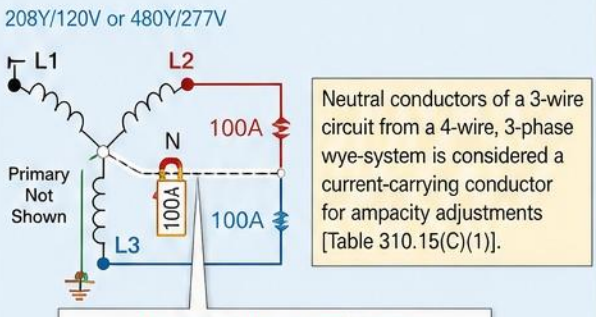
Figure 310–45 | Neutral Conductor, 2-Wire Circuit Considered Current Carrying 310.15(E)(1)(1)



Neutral conductors of a 2-wire circuit consisting of one phase and one neutral conductor is considered a current-carrying conductor for ampacity adjustments [Table 310.15(C)(1)].

(2) 3-wire circuit from a 4-wire, three-phase wye-connected system ▸ **Figure 310–46**

Figure 310–45 | Neutral Conductor, 3-Wire from 4-Wire Wye Considered Current Carrying 310.15(E)(1)(2)



Neutral conductors of a 3-wire circuit from a 4-wire, 3-phase wye-system is considered a current-carrying conductor for ampacity adjustments [Table 310.15(C)(1)].

Determine the neutral current.

$$I_{NEUTRAL} = \sqrt{(L_2^2 + L_3^2) - (L_2 \times L_3)}$$

$$I_{NEUTRAL} = \sqrt{(100^2 + 100^2) - (100 \times 100)}$$

$$I_{NEUTRAL} = 100A$$

Unbalanced 3-Wire Wye Secondary Neutral Current Formula:

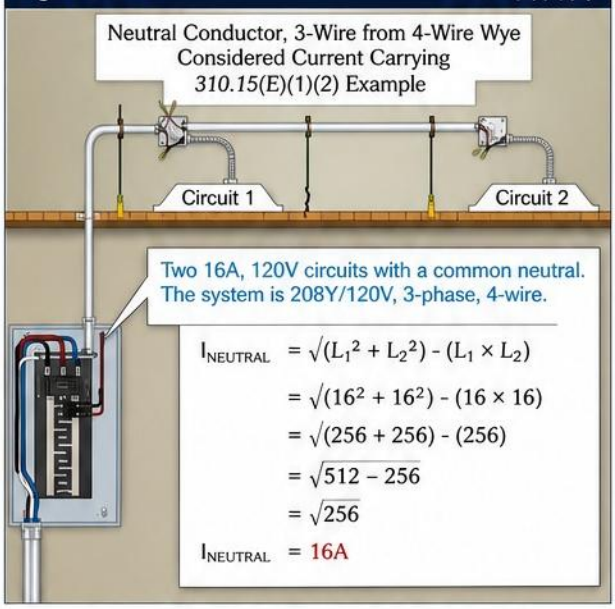
$$I_{Neutral} = \sqrt{[(I_{Line1})^2 + (I_{Line2})^2 - (I_{Line1} \times I_{Line2})]}$$

▶ Neutral Conductor Current Carrying [310.15(E)(1)(2)] Example

Question: Determine the neutral current for two 16A, 120V circuits in a 208Y/120V, three-phase, 4-wire, wye-connected system. ▶ **Figure 310–47**

(a) 8A *(b)* 16A *(c)* 24A *(d)* 32A

Figure 310–47 **310.15(E)(1)(2)**



The neutral conductor must be sized for the calculated unbalanced current.

Solution:

$$I_{NEUTRAL} = \sqrt{(I_{LINE1}{}^2 + I_{LINE2}{}^2) - (I_{LINE1} \times I_{LINE2})}$$
$$I_{NEUTRAL} = \sqrt{(16^2 + 16^2) - (16 \times 16)}$$
$$I_{NEUTRAL} = \sqrt{(512 - 256)}$$
$$I_{NEUTRAL} = \sqrt{256}$$
$$I_{NEUTRAL} = 16A$$

Answer: *(b) 16A*

(3) A 4-wire, three-phase, wye circuit in which most of the line-to-neutral loads consist of *nonlinear* loads. ▶ **Figure 310–48**

> **Nonlinear Load.** A load for which the current waveform does not follow the shape of the voltage waveform.

Figure 310–48 **310.15(E)(1)(3)**

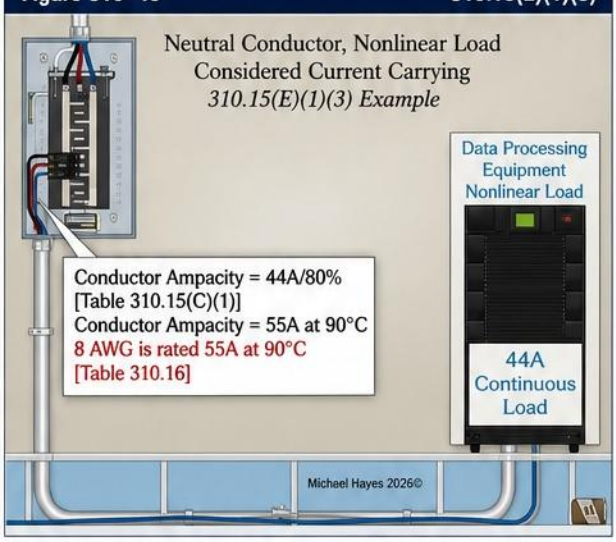
Nonlinear loads can cause additional current in the neutral conductor.

▶ Neutral Conductor Nonlinear Load [310.15(E)(1)(3)] Example

Question: What size conductor is required for a circuit supplying a 44A nonlinear load where the equipment is rated for 75°C conductor? ▶ **Figure 310–49**

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

Figure 310–49 **310.15(E)(1)(3)**



Use Table 310.15(C)(1) to adjust ampacity for the neutral conductor.

Solution:

Conductor ampacity at 90°C = Actual load / Adjustment

Actual Load = 44A

Adjustment [Table 310.15(C)(1)] = 80% (four current-carrying conductors)

Conductor Ampacity at 90°C Column = 44A/80%

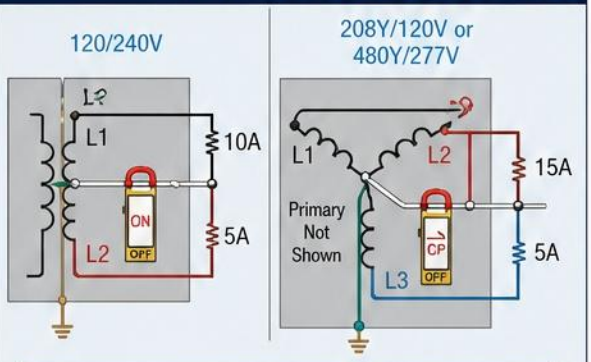
Conductor Ampacity at 90°C Column = 55A

8 AWG copper is rated 55A at 90°C based on Table 310.16.

Answer: *(b) 8 AWG*

(2) Not Considered Current Carrying. For circuits not covered in 310.15(E)(1), a neutral conductor that carries only the unbalanced current from other conductors of the same circuit is not required to be counted when applying ampacity adjustment provisions of 310.15(C)(1).

Figure 310-50 Neutral Conductor, Linear Loads Not Considered Current Carrying 310.15(E)(2)



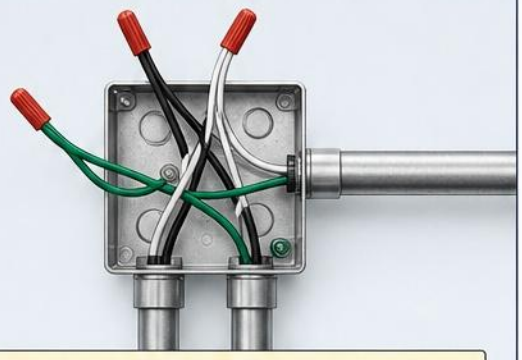
For circuits not covered in 310.15(E)(1), a neutral conductor that carries only the unbalanced current from the same circuit is not required to be counted when applying ampacity adjustment of 310.15(C)(1).

Author's Comment:

- The neutral conductor of a 3-wire, 120/240V circuit, or a 4-wire 208Y/120V or 480Y/277V circuit is not considered a current-carrying conductor for ampacity adjustments in accordance with Table 310.15(C)(1).
- The neutral conductor of a 2-wire circuit supplied from a 3-wire, single-phase, 120/240V system, or a 4-wire, three-phase, 208Y/120V or 480Y/277V system, is considered a current-carrying conductor for the application of conductor ampacity adjustments in accordance with Table 310.15(C)(1).

(F) Grounding and Bonding Conductor. Equipment grounding and bonding conductors are not considered current carrying for ampacity adjustments in accordance with Table 310.15(C)(1).

Figure 310-51 Equipment Grounding and Bonding Conductor Not Considered Current Carrying 310.15(F)



Equipment grounding and bonding conductors are not considered current carrying for conductor ampacity adjustments per Table 310.15(C)(1).

310.16 Insulated Conductors

Conductor ampacity is based on the following conditions: Figure 310-52.

Figure 310-52 Ampacities of Insulated Conductors 310.16

Table 310.16 is based on the following:
(1) Conductors are rated 0V through 2000V.
(2) Conductors are rated 60°C, 75°C, or 90°C.
(3) Conductors are installed in an ambient temperature between 78° - 86°F.
(4) Not more than three current-carrying conductors.

(1) Conductors are rated 0V through 2000V

(2) Conductors are rated 60°C, 75°C, or 90°C

(3) Conductors in an ambient temperature between 78–86°F

(4) There are not more than three current-carrying conductors

TABLE 310.16 AMPACITIES OF INSULATED CONDUCTORS WITH NOT MORE THAN THREE CURRENT-CARRYING CONDUCTORS IN RACEWAY, CABLE, OR EARTH (DIRECTLY BURIED)

Size AWG kcmil	COPPER							ALUMINUM						Size AWG kcmil
	60°C (140°F)		75°C (167°F)		90°C (194°F)			60°C (140°F)		75°C (167°F)		90°C (194°F)		
	TW	UF	RHW THHW THW XHHW	THHW THWN USE	RHH THHW USE-2	RHW-2 THW-2 XHHW	THHN THWN-2 XHHW-2	TW	UF	RHW THW THWN	THHW USE XHHW	THHN THWN-2 XHHW	THW-2 THHW XHHW-2	
	Copper							Aluminum or Copper-Clad Aluminum						
16[1]	10		15[2]		20[2]									16[1]
14[1]	15		20		25			10[3]		15[2,3]		20[2,3]		14[1]
12[1]	20		25		30			15		20		25		12[1]
10[1]	30		35		40			25		30		35		10[1]
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

NOTES:

1. Refer to 310.15(B) for ampacity correction factors when the ambient temperature differs from 30°C (86°F).
2. Refer to 310.15(C)(1) for ampacity adjustment factors when more than three current-carrying conductors are present.
3. See 240.4(D) for overcurrent protection of small conductors.
4. These ampacities apply only to copper-clad aluminum conductors.
5. These ampacities may be used solely for adjustment or correction.

Article 408 Switchboards, Switchgear, and Panelboards

408.1 Scope

This article covers switchboards, switchgear, and panelboards that are used to distribute electrical energy.

408.2 Definitions

Switchboard. A single panel or assembly of panels with one or more main overcurrent devices, designed for assembly with or without meters, and including their accessories, such as buses, instrument transformers, and control devices.

Switchgear. A general term that covers both switchboards and panelboards. It denotes a type of electric power equipment that is used for switching, protecting, and controlling electrical power.

Panelboard. A single panel without a main overcurrent device, or a combination assembly of panels, each having only branch overcurrent devices and including their accessories.

408.3 General

Switchboards, switchgear, and panelboards must be listed and labeled. They must be suitable for the application and environment in which they are used.

The working space in front of switchboards, switchgear, and panelboards must comply with 110.26.

Live parts of switchboards, switchgear, and panelboards operating at more than 1000 volts, nominal, or at 1000 volts, nominal, or less to ground, must be guarded by enclosures or by other means.

408.4 Switchboards and Switchgear

Switchboards and switchgear rated 1000 volts, nominal, or less must have a main disconnecting means.

Switchboards and switchgear rated more than 1000 volts, nominal, must have a main disconnecting means unless all of the circuit conductors are provided with overcurrent protection and a disconnecting means.

Figure 408.4 Switchboards and Switchgear *NEC 408.4*

Switchboards and switchgear must have a main disconnecting means as required by 408.4.

ARTICLE 312

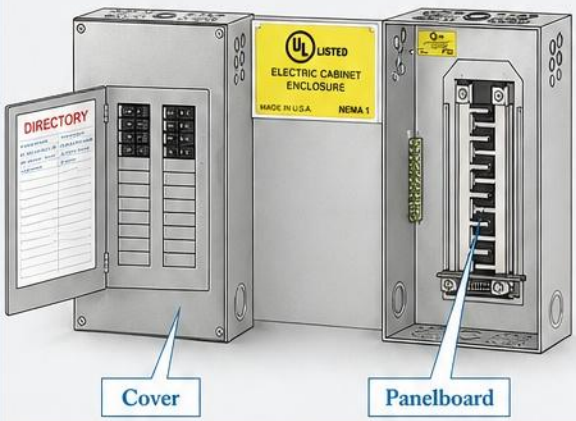
Cabinets and Meter Socket Enclosures

Introduction to Article 312—Cabinets and Meter Socket Enclosures

Article 312 sets forth the requirements for installing and constructing cabinets that contain panelboards and meter socket enclosures. These provisions apply specifically to enclosures that house electrical equipment including panelboards, fusible or nonfusible disconnects, and circuit breaker enclosures. The intent of this article is to ensure that such enclosures are appropriate for the environment, provide adequate conductor bending space, and include rules for splices, taps, and feed-through conductors.

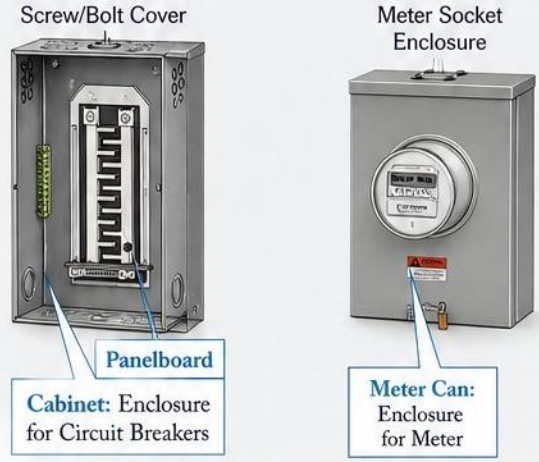
Cabinet. An enclosure mounted on or recessed into a surface, furnished with a frame, and designed so that a door can be installed on hinges. **See Figure 312–1.**

Figure 312–1 Cabinet NEC 100



A surface-mounted or flush-mounted enclosure furnished with a frame in which a door can be hung on hinges.

Figure 312–2 Cabinets and Meter Socket Enclosures NEC 312.1



Article 312 sets forth the requirements for installing cabinets that contain panelboards and meter socket enclosures.

Part I. General

312.1 Scope

This article sets forth the requirements for installing cabinets that contain panelboards and meter socket enclosures. **See Figure 312–2.**

312.2 Listing Requirements

Nonmetallic cabinets must be either listed or submitted for approval before installation.

312.4 Damp or Wet Locations

(A) Weatherproof Enclosures. Cabinets that contain panelboards and meter socket enclosures and are to be installed in damp or wet locations shall be *weatherproof.*

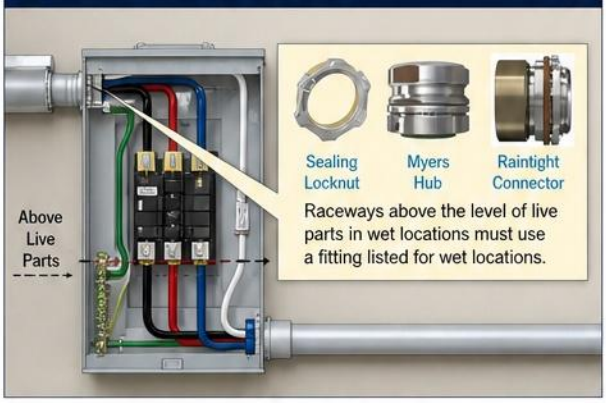
Weatherproof: Constructed or protected so exposure to the weather will not interfere with successful operation.

AUTHOR'S COMMENT:

- According to Table 110.28, Note 1, any NEMA Type 3 enclosure is identified as rainproof, raintight, or watertight, and is considered weatherproof and suitable to be in a damp or wet location.

(B) Raceways or Cables Above Live Parts. Raceways or cables entering a cabinet or meter socket enclosure above the level of live parts in wet locations must use a fitting listed for wet locations. See Figure 312–3 and Figure 312–4.

Figure 312–3 Raceways Above Live Parts 312.4(B)



Raceways or cables entering above the level of live parts in wet locations must use a fitting listed for wet locations.

Figure 312–4 Cables Above Live Parts 312.4(B)

Cables entering above the level of live parts in wet locations must use a fitting listed for wet locations.

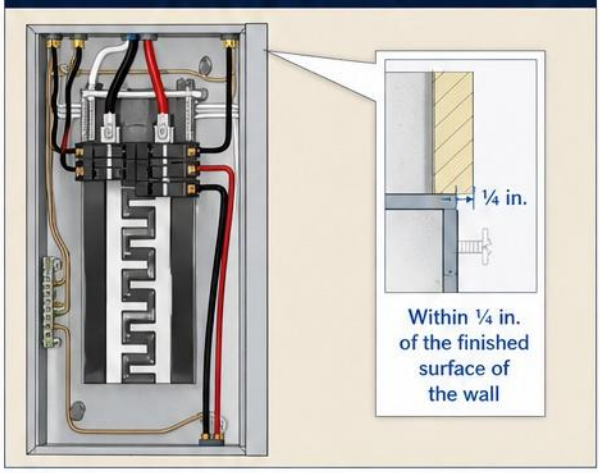
AUTHOR'S COMMENT:

- In accordance with *UL Guide Information DWTT*, sealing locknuts (inside or outside the enclosure), conduit hubs, and connectors listed for a wet location will meet this requirement.

312.5 Position in Walls

Noncombustible Materials. Cabinets in walls of noncombustible surfaces (plaster, drywall, or plasterboard) must have the front edge of the enclosure set back no more than ¼ in. from the finished surface. See Figure 312–5.

Figure 312–5 Position in Walls — Noncombustible Materials 312.5



Cabinets in walls of noncombustible surfaces (plaster, drywall, or plasterboard) must have the front edge of the enclosure set back no more than ¼ in. from the finished surface.

Combustible Materials. Cabinets in walls constructed of wood or other combustible surfaces must have the enclosure front edge flush with the finished surface or project outward. See Figure 312–6.

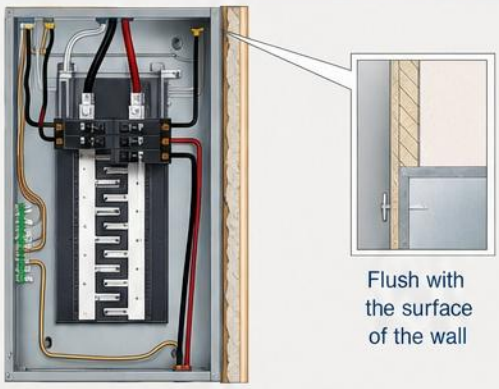
312.7 Repairing Gaps in Noncombustible Surfaces

Cabinets in noncombustible surfaces (plaster, drywall, or plasterboard) must not have a gap of more than 1/8 in. around the enclosure. See Figure 312–7.

312.8 Cable Termination to Enclosures

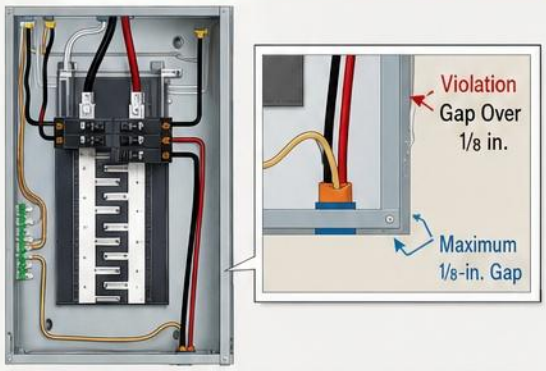
(C) Cable Termination. Cable wiring methods must be secured to the cabinet or meter socket enclosure. See Figure 312–8, Figure 312–9, and Figure 312–10.

Figure 312–6 Cabinets, Position in Walls 312.5



Electrical cabinets installed in walls framed with wood or other combustible materials must have the front edge of the enclosure even with the finished surface of the wall or be mounted to project outward from the finished surface.

Figure 312–7 Cabinets, Gaps in Noncombustible Surfaces 312.7



Electrical cabinets installed in noncombustible surfaces (plaster, drywall, or plasterboard) must not have any opening greater than 1/8 in. around the enclosure.

Figure 312–8 Cabinets and Meter Socket Enclosures, Cable Termination 312.8(C)

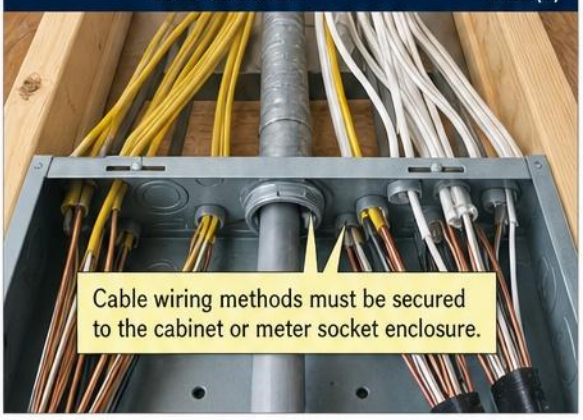


Figure 312–9 Cabinets and Meter Socket Enclosures, Cable Termination 312.8(C)

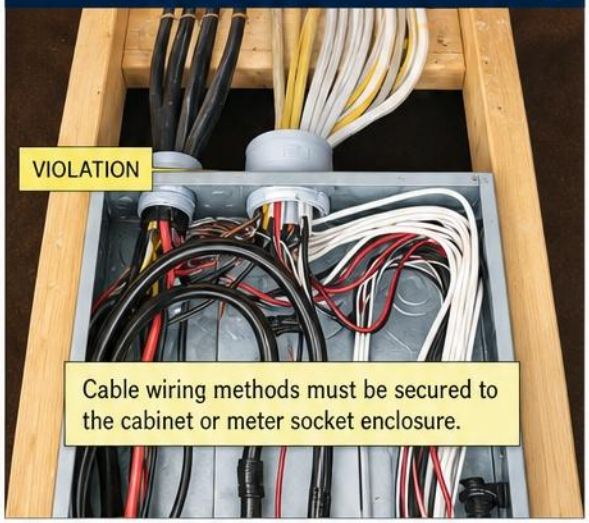
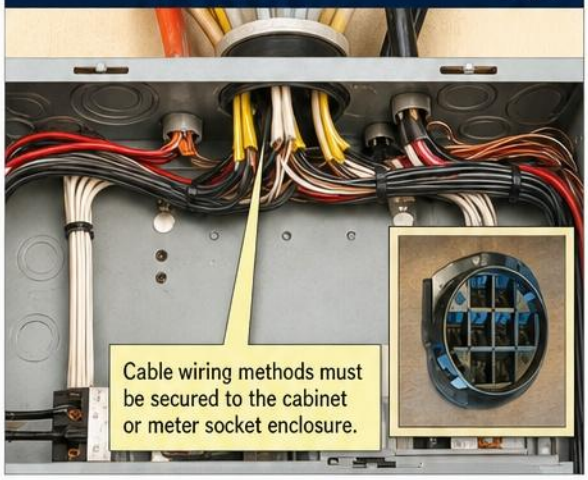


Figure 312–10 Cabinets and Meter Socket Enclosures, Cable Termination 312.8(C)

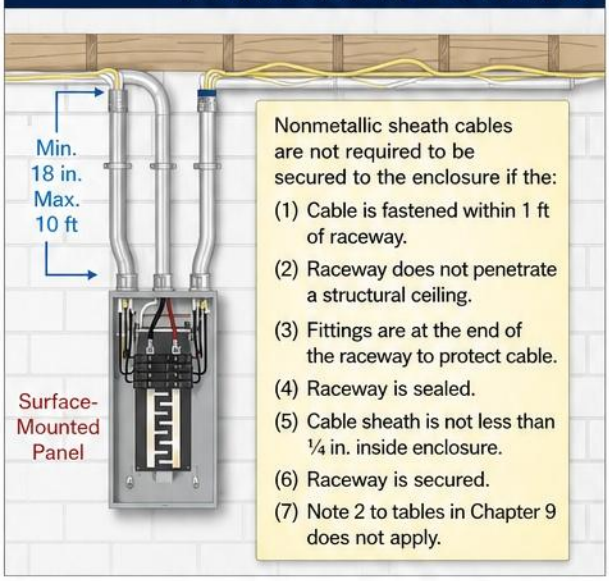


AUTHOR'S COMMENT:

- *In accordance with UL Guide Information PXUV, NM cable clamps or cable connectors are only suitable for a single NM cable, unless that clamp or connector is identified for more than one cable. Some NM cable clamps are listed for two or more NM cables within a single fitting.*

Ex 1: NM cables are not required to be secured to the cabinet and meter socket enclosure if the cables enter the top of a surface-mounted enclosure through a nonflexible raceway not less than 18 in. or more than 10 ft long, if all the following conditions are met: Figure 312–11

Figure 312–11 Cabinets and Meter Socket Enclosures Cable Termination, Raceway Sleeve 312.8(C) Ex 1



Illustrates a surface-mounted panel with NM cables entering through a raceway. Security and sealing requirements are met under 312.8(C) Exception 1.

(1) Each cable is fastened within 12 in. of the raceway.

(2) The raceway does not penetrate a structural ceiling.

(3) Fittings are provided on the raceway to protect the cables from abrasion.

(4) The raceway is sealed.

(5) *Each cable sheath extends into the enclosure beyond the fitting not less than ¼ in.*

(6) The raceway is properly secured.

(7) *Where installed as conduit or tubing, Chapter 9, Table 1 Notes 5 and 9 apply. Note 2 to the tables in Chapter 9 does not apply to this condition.*

Ex 3: Cables installed in a complete raceway system in accordance with 300.14 are not required to be secured to enclosures.

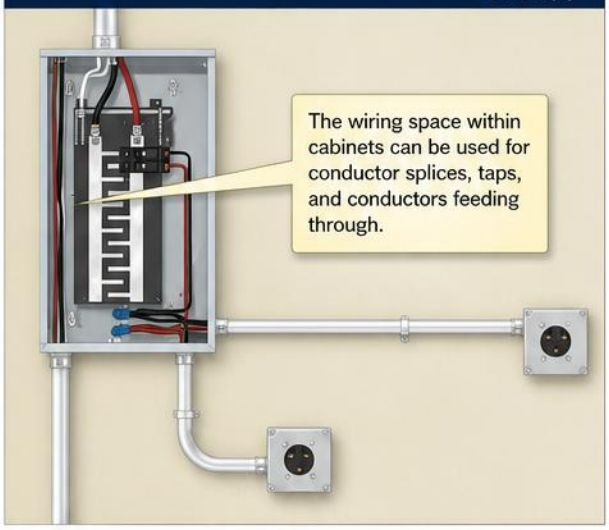
312.11 Overcurrent Protective Device and Switch Enclosures

Enclosures containing overcurrent protective devices and switch enclosures are permitted to contain wiring and other equipment as follows:

(A) Splices, Taps, and Feed-Through Conductors. The wiring space within cabinets can be used for conductor splices, taps, and conductors feeding through where all the conditions are met: Figure 312–12

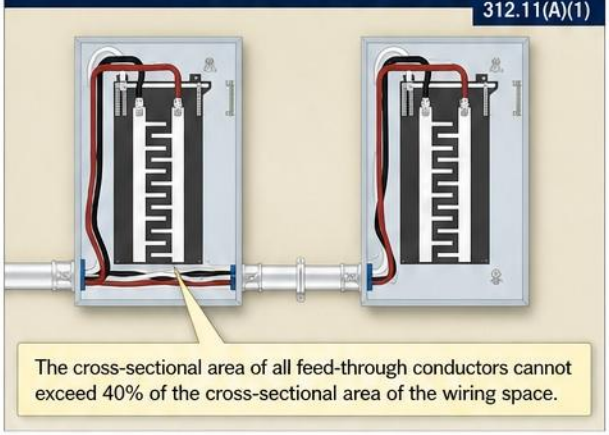
(1) Cross-sectional area of all conductors cannot exceed 40 percent of the cross-sectional area of that wiring space Figure 312–13

Figure 312–12 Overcurrent Protective Device and Switch Enclosures Splices, Taps, and Feed-Through 312.11(A)



Shows that splices, taps, and feed-through conductors are permitted within the wiring space of overcurrent protective device and switch enclosures.

Figure 312–13 Overcurrent Protective Device and Switch Enclosures Feed-Through Conductors 312.11(A)(1)

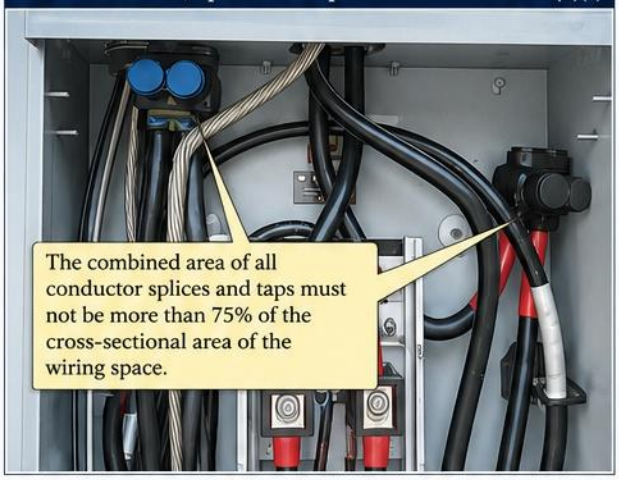


Depicts two enclosures connected with feed-through conductors. The total cross-sectional area of those conductors is limited to 40% of the wiring space cross-sectional area.

(2) Cross-sectional area of all conductors, splices, and taps cannot exceed 75 percent of the cross-sectional area of that wiring space Figure 312–14 and Figure 312–15

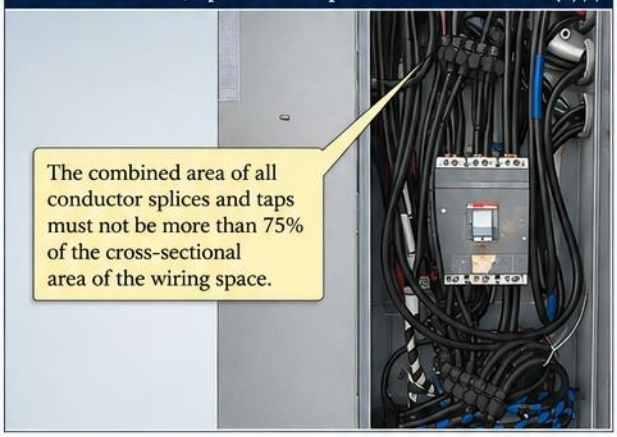
(4) Where conductors feed through cabinets and cutout boxes, a warning label of sufficient durability to withstand the environment cannot be handwritten and must be permanently affixed to the equipment in accordance with 110.21(B); the warning label must identify the location of the disconnecting means for the feed-through conductors Figure 312–16

Figure 312–14 Overcurrent Protective Device and Switch Enclosures, Splices and Taps 312.11(A)(2)



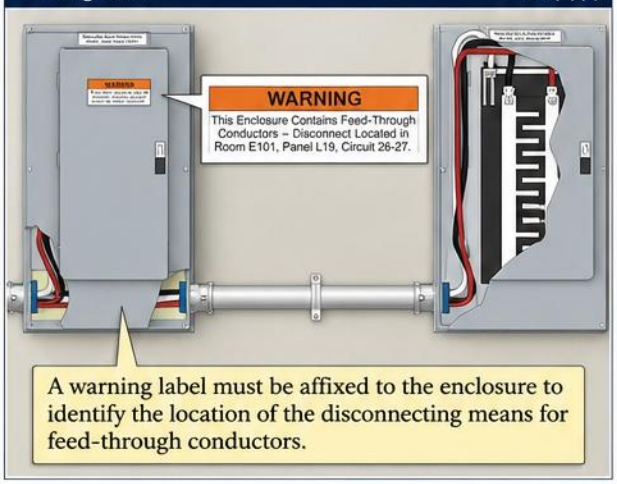
The total area of all splices and taps is within 75% of the cross-sectional area of the wiring space.

Figure 312–15 Overcurrent Protective Device and Switch Enclosures, Splices and Taps 312.11(A)(2)



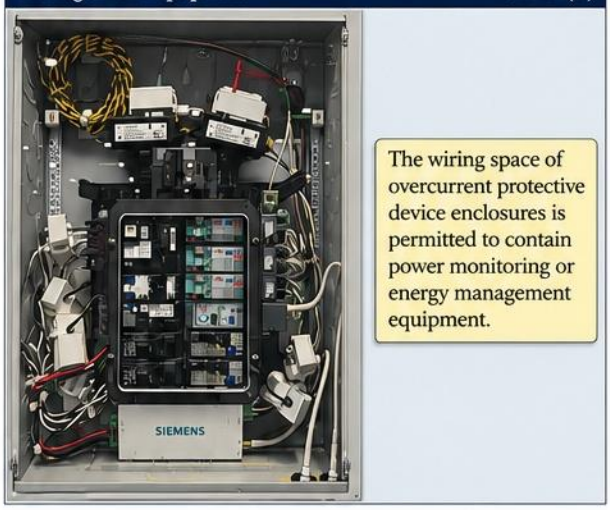
The total area of all splices and taps exceeds 75% of the cross-sectional area of the wiring space.

Figure 312–16 Overcurrent Protective Device and Switch Enclosures, Feed-Through Conductors, Warning Label 312.11(A)(4)



(B) Power Monitoring or Energy Management Equipment. The wiring space of overcurrent protective device enclosures is permitted to contain power monitoring or energy management equipment where all the following conditions are met: **Figure 312–17**

Figure 312–17 Overcurrent Protective Device and Switch Enclosures, Energy Monitoring or Management Equipment 312.11(B)



(1) Identification. Power monitoring or energy management equipment is recognized either as a field-installable accessory listed as part of the listed equipment, or as a listed kit that has been evaluated for field installation in such enclosures.

(2) Area. The total area of all conductors, splices, taps, and equipment in any cross-section of the wiring space must not be greater than 75 percent of the cross-sectional area of that space.

312.13 Screws or Other Fasteners

Screws installed in the field to secure a cover to a cabinet must be as provided by or specified by the manufacturer, or must comply with all of the following:

(1) Screws must be machine type with blunt ends.

(2) Other fasteners WITH blunt ends.

(3) Screws or other fasteners must not project into the enclosure more than ¼ in., unless the end is protected by a listing method.

Exception to (3): *Screws or other fasteners are permitted to project into the enclosure not more than 7/16 in., if the enclosure wall thickness is ⅜ in. or more.*

Notes

ARTICLE 100 DEFINITIONS

In Article 100, the *National Electrical Code*® (*NEC*®) defines bonding as "the permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed."

Bonding is used in electrical systems to establish an effective ground-fault current path and to reduce voltage that may be imposed on metal parts.

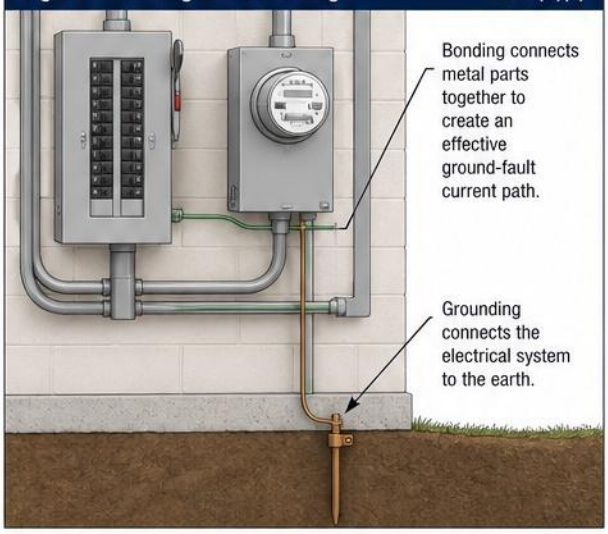
The NEC uses the terms "bonding" and "grounding" in different ways. Bonding refers to the intentional connecting of metal parts that are not intended to carry current. Grounding refers to the connecting of the electrical system to the earth.

An effective ground-fault current path begins with bonding. Low-impedance bonding connections reduce voltage potential on non–current-carrying metal parts. Grounding at the service supplies the final connection to earth. We'll look at bonding in more detail in the next section.

BONDING AND GROUNDING

Whereas bonding creates an effective ground-fault current path between metal parts, grounding connects the electrical system to the earth. Figure 1 illustrates the different functions of bonding and grounding.

Figure 1 Bonding and Grounding 250.4(A)(1)



Bonding connects non–current-carrying metal parts together to provide a low-impedance path for ground-fault current. Grounding connects the electrical system to the earth.

BONDING EQUIPMENT

Bonding equipment is used to connect metal parts together to create an effective ground-fault current path. Equipment bonding jumpers and bonding conductors make these connections.

In general, equipment bonding jumpers are used to bond non–current-carrying metal parts to equipment enclosures. Equipment bonding conductors are used to connect non–current-carrying metal parts to the system bonding jumper or the grounded service conductor at the service.

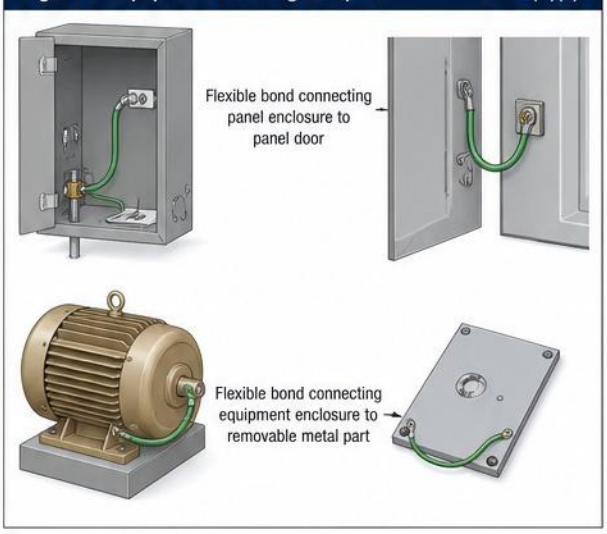
Equipment bonding jumpers are required for the enclosures of all electrical equipment. They are also required for certain enclosure doors, panels, and removable metal parts that may become energized.

Equipment bonding conductors are required for metal raceways, reinforcing steel, fixed metal ladders, piping systems, and other metal parts.

EQUIPMENT BONDING JUMPERS

Equipment bonding jumpers connect the enclosures of electrical equipment to create an effective ground-fault current path. Figure 2 shows typical equipment bonding jumpers.

Figure 2 Equipment Bonding Jumpers 250.4(A)(1)



Equipment bonding jumpers connect equipment enclosures and certain removable metal parts to the equipment enclosure to create an effective ground-fault current path.

ARTICLE

314 Boxes, Conduit Bodies, and Handhole Enclosures

Introduction to Article 314—Boxes, Conduit Bodies, and Handhole Enclosures

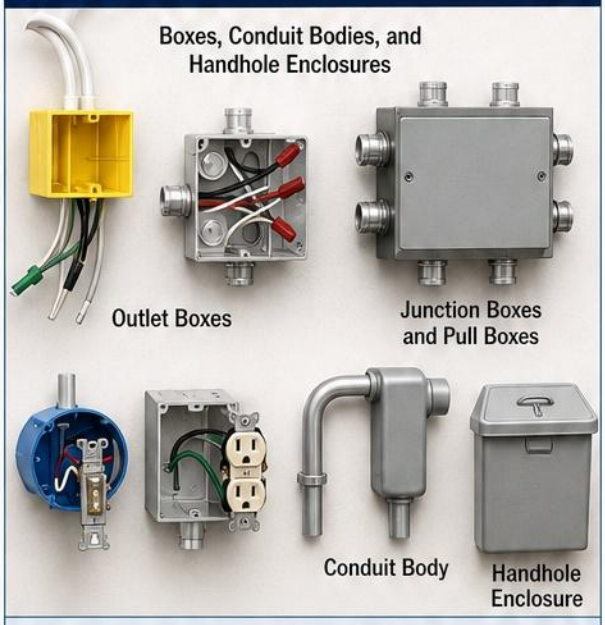
Article 314 sets forth the requirements for outlet boxes, device boxes, pull boxes, junction boxes, conduit bodies, and handhole enclosures. The rules in this article address outlet box sizing, securing and supporting of boxes, junction and pull box sizing, and accessibility of boxes. Understanding these requirements will help ensure safe installations that reduce the risk of overheating, mechanical damage, or electrical faults within boxes.

Part I. General

314.1 Scope

This article establishes requirements for outlet boxes, pull and junction boxes, conduit bodies, handhole enclosures, and fittings used to connect raceways and cables to boxes or conduit bodies. Figure 314–1

Figure 314–1 Scope 314.1



Article 314 sets forth requirements for outlet boxes, pull and junction boxes, conduit bodies, handhole enclosures, and fittings used to connect raceways and cables to boxes or conduit bodies.

314.2 Listing Requirements

The following equipment must be listed:

(A) **Extenders.** Extenders for device boxes.

(B) **Drain Fittings.** Drain fittings larger than ¼ in.

(C) **Floor Boxes.**

(1) **General.** Floor boxes and floor covers.

(2) **Show Windows.** Show window assembly receptacles and covers.

(D) **Outlet Boxes for Ceiling-Suspended (Paddle) Fans.** Outlet boxes used to provide mechanical support for ceiling-suspended (paddle) fans.

(F) **Underground Boxes and Handhole Enclosures.** Underground boxes and handhole enclosures that are permitted to be covered by gravel, light aggregate, or noncohesive granulated soil.

(H) **Boxes and Conduit Bodies.**

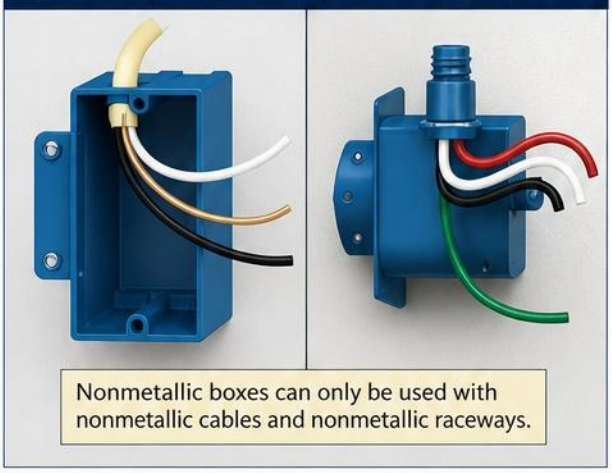
(1) **Different Materials.** Covers made from different materials than boxes or conduit bodies.

(2) **Metal Covers.** Metal covers of thinner construction than boxes or conduit bodies on which they are installed.

314.5 Nonmetallic Boxes

Nonmetallic boxes can only be used with nonmetallic cables and nonmetallic raceways. ▸**Figure 314–2**

Figure 314–2 Nonmetallic Boxes with Nonmetallic Wiring Method 314.5



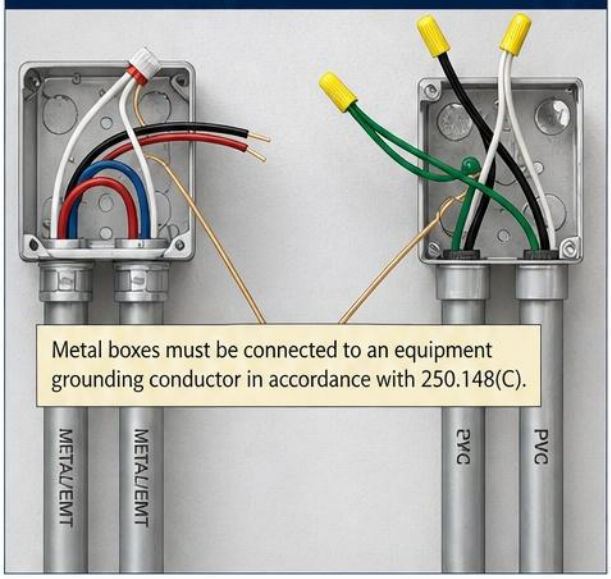
Example: Nonmetallic boxes are permitted to be installed with metal conduit or metal armored cable bonded in accordance with 250.109(B). ▸Figure 314–3

Figure 314–3 Nonmetallic Boxes with Metal Wiring Methods 314.5 Ex

314.6 Metal Boxes

Metal boxes must be connected to the circuit equipment grounding conductor in accordance with 250.148(C). ▸Figure 314–4

Figure 314–4 Metal Boxes Connected to an EGC 314.6



314.7 Screws or Other Fasteners

Screws or other fasteners installed in the field that enter a wiring space must be as provided by the manufacturer, or specified by the manufacturer, or comply with the following:

(1) Screws must be machine type with blunt ends

(2) Other fasteners must have blunt ends

(3) Screws attaching a cover must extend no more than ⅜ in.

(4) Screws or other fasteners, other than in (1), penetrating a cover must extend to no more than ⅛ in.

(5) Screws or other fasteners penetrating a wall of a box exceeding 100 cu in. must extend no more than ¼ in.—or no more than ⅜ in. within ⅜ in. of an adjacent box wall

(6) Screws or other fasteners penetrating the wall of a box not exceeding 100 cu in. and not covered in 314.23(B)(1) must be made flush with the box interior

Ex 1 to (3) through (6): A screw can be longer if the end of the screw is protected with an approved means.

Part II. Installation

314.15 Wet Locations

(B) Listed. Boxes, conduit bodies, and fittings in a wet location must be listed for use in wet locations. ▸Figure 314–5 and ▸Figure 314–6

Figure 314–5 Wet Locations 314.15(B)

Boxes, conduit bodies, and fittings installed in a wet location must be listed for use in wet locations.

Figure 314–6 Wet Locations 314.15(B)

Boxes, conduit bodies, and fittings installed in a wet location must be listed for use in wet locations.

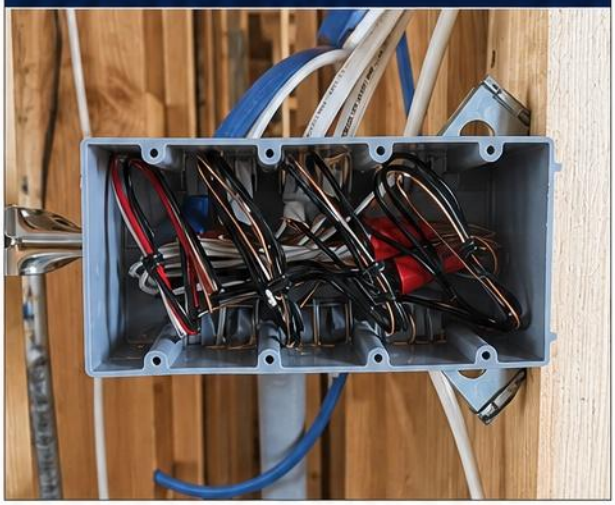
314.16 Outlet Box Sizing

Boxes containing conductors 6 AWG and smaller must be sized in accordance with 314.16(A) or (B). ▪ Figure 314–7

Author's Comment:

- When all the conductors in an outlet box are the same size (insulation does not matter), Table 314.16(A) can be used to determine the number of conductors permitted in the outlet box, or to determine the required outlet box size for the given number of conductors.

Figure 314–7 Box Fill Calculations 314.16



Boxes containing conductors 6 AWG and smaller must be sized in accordance with 314.16(A) or (B).

- If the outlet box contains switches, receptacles, luminaire studs, luminaire hickeys, cable clamps, or equipment grounding conductors, then allowance must be made for these items in accordance with 314.16(B).
- Boxes are sized to provide the space needed to safely accommodate conductors, devices, and fittings. ▪ Figure 314–8

Figure 314–8 Box Fill Calculations Comment 314.16

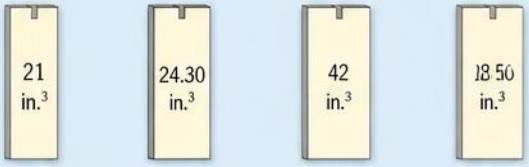
Boxes are sized to provide the space needed to accommodate conductors, devices, and fittings.

Boxes containing conductors 4 AWG or larger must be sized in accordance with 314.28, and handhole enclosures are sized in accordance with 314.30(A).

(A) Box Volume. The total volume of a box includes plaster rings, raised covers, and extension rings marked with their volumes in cubic inches or listed in Table 314.16(A). ▪ Figure 314–9

Figure 314–9. Box Fill Calculations— Assembled Parts 314.16(A)

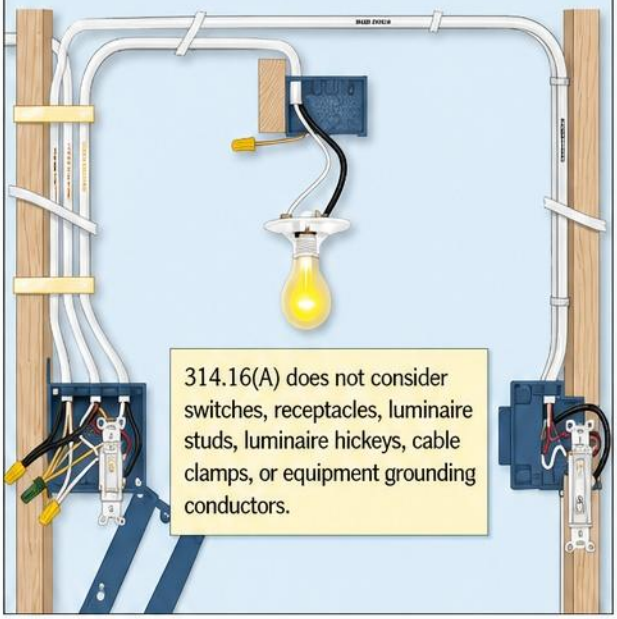
4 x 1½ in. Square Box | Box with Plaster Ring | Box with Extension Ring | Box with Raised Cover



21 in.³ | 24.30 in.³ | 42 in.³ | 28.50 in.³

The total volume of a box includes plaster rings, raised covers, and extension rings marked with their volumes in cubic inches or listed in Table 314.16(A).

Figure 314–10. Box Fill Calculations— Devices, Fittings, and EGCs 314.16(A) Comment



Author's Comment:

Table 314.16(A) volumes are based on the inside dimensions of the box. For example, the volume of a 4 in. × 4 in. × 1½ in. metal square box is 24 in.³, but Table 314.16(A) shows a volume of 21 in.³.

Table 314.16(A) Metal Boxes*

Box Trade Size		Minimum Volume in.³	Maximum Number of Conductors (arranged by AWG size)					
in.	Box Shape		18	16	14	12	10	8
(4 × 1¼)	round/octagonal	12.50	8	7	6	5	5	4
(4 × 1½)	round/octagonal	15.50	10	8	7	6	6	5
(4 × 2⅛)	round/octagonal	21.50	14	12	10	9	8	7
(4 × 1¼)	square	18.00	12	10	9	8	7	6
(4 × 1½)	square	21.00	14	12	10	9	8	7
(4 × 2⅛)	square	30.30	20	17	15	13	12	10
(4 11/16 × 1¼)	square	25.50	17	14	12	11	10	8
(4 11/16 × 1½)	square	29.50	19	16	14	13	11	9
(4 11/16 × 2⅛)	square	42.00	28	24	21	18	16	14

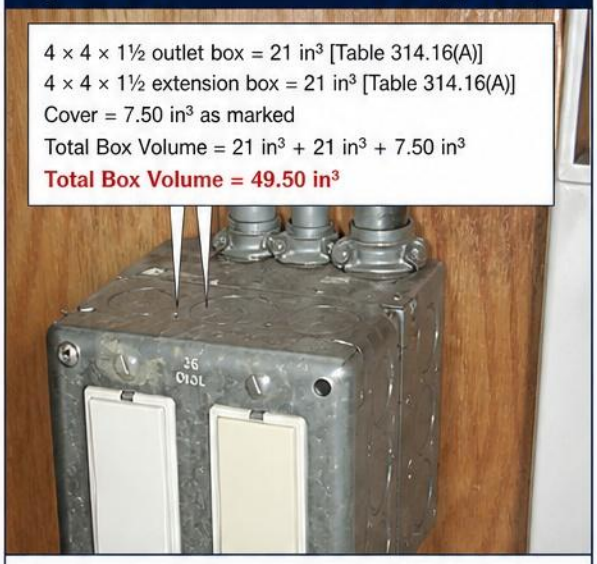
**Table 314.16(A) does not consider switches, receptacles, luminaire studs, luminaire hickeys, cable clamps, or equipment grounding conductors.*

BOX VOLUME [TABLE 314.16(A)] EXAMPLE 1

Question: What is the total box volume for a 4 in. × 4 in. × 1½ in. outlet box and a 4 in. × 4 in. × 1½ in. extension box with a domed cover marked with a 7.50 cu in. volume? Figure 314–11

(a) 44.50 cu in. (b) 46.50 cu in. (c) 47.50 cu in. (d) 49.50 cu in.

Figure 314–11 314.16(A) Example 1



The volumes from Table 314.16(A) are based on the inside dimensions of the box, not the outside dimensions.

Solution:

Volume of Outlet Box = 4 in. × 4 in. × 1½ in.

Volume of Outlet Box = 21 cu in. [Table 314.16(A)]

Volume of Extension Box = 4 in. × 4 in. × 1½ in.

Volume of Extension Box = 21 cu in. [Table 314.16(A)]

Cover Volume = 7.50 cu in. as marked

Total Box Volume = 21 cu in. + 21 cu in. + 7.50 cu in.

Total Box Volume = 49.50 cu in.

Note: Do not calculate the actual volume of a box contained in Table 314.16(A) because the table volume is based on the inside dimensions of the box—not the outside dimensions.

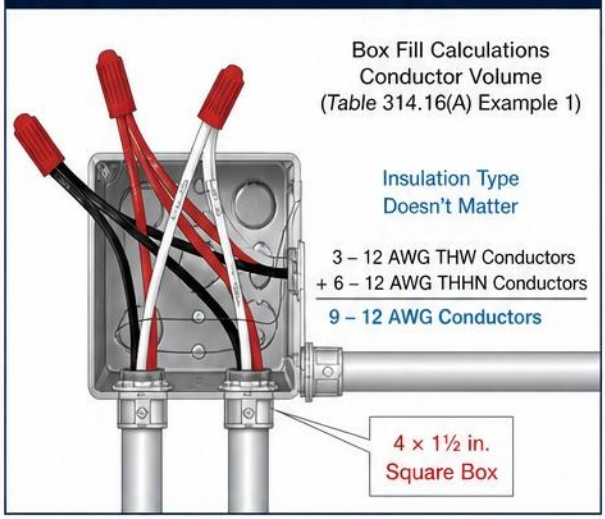
Answer: (d) 49.50 cu in.

BOX VOLUME [TABLE 314.16(A)] EXAMPLE 2

Question: Which 4-in. square outlet box is the smallest permitted for three 12 AWG, THW conductors and six 12 AWG, THHN conductors? Figure 314–12

(a) 4 in. × 1¼ in. square (b) 4 in. × 1½ in. square
(c) 4 in. × 2⅛ in. square (d) 4 in. × 2⅛ in. with extension

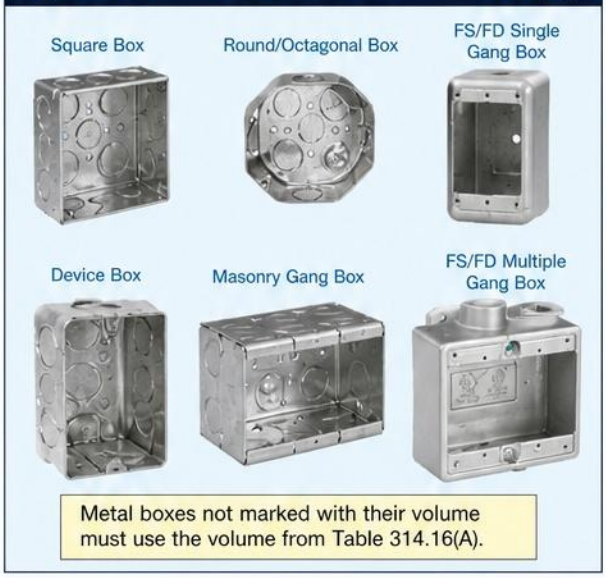
Figure 314–12 314.16(A) Example 2



Answer: *(b) 4 in. × 1½ in. square*

(1) Standard Boxes. Metal boxes not marked with their volume must use the volume from Table 314.16(A). Figure 314–13

Figure 314–13 Standard Metal Boxes 314.16(A)(1)



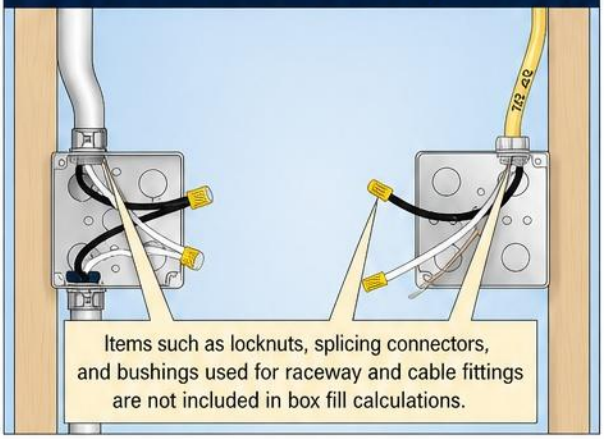
(2) Nonmetallic Boxes. The volume for nonmetallic boxes must be legibly marked on the box by the manufacturer. Figure 314–14

Figure 314–14 Outlet Box Sizing Nonmetallic Boxes 314.16(A)(2)

(B) Box Fill Calculations. The calculated conductor volumes determined by 314.16(B)(1) through (B)(6) are added together using Table 314.16(B)(4) to determine the total volume of the conductors, devices, and fittings.

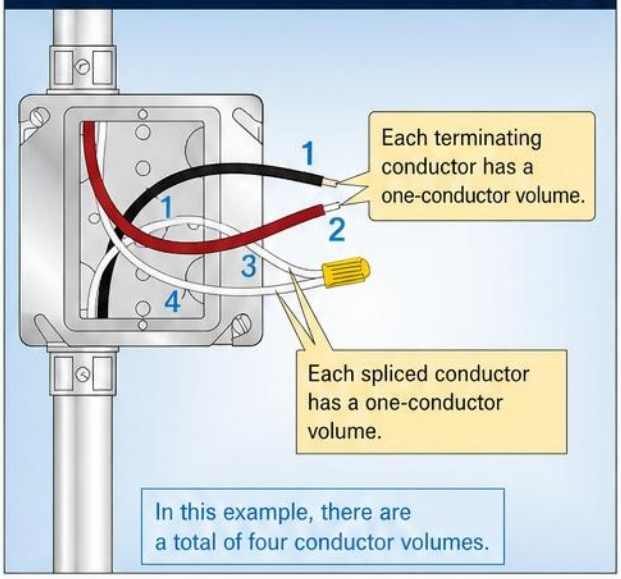
Raceway and cable fittings including locknuts, splicing connectors, and bushings are not counted for box fill calculations.

Figure 314–15 Box Fill Calculations Small Fittings 314.16(B)



(1) Conductor Volume. Each conductor that originates outside the box and terminates, or is spliced inside the box, counts as a single conductor volume as shown in Table 314.16(B)(4).

Figure 314–16 Box Fill Calculations Conductor Volume 314.16(B)(1)



Author's Comment:

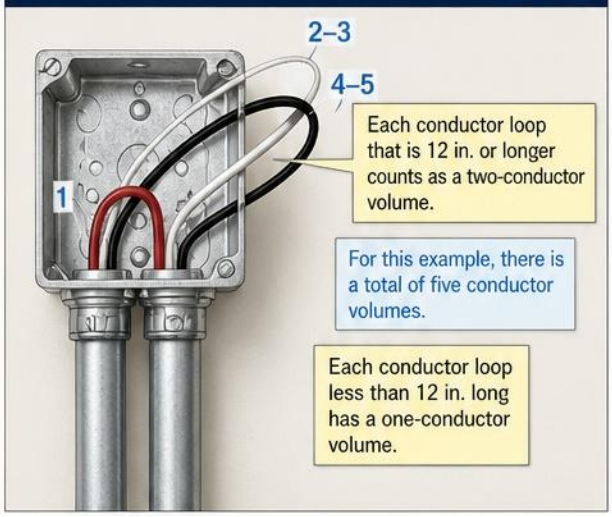
- Table 314.16(B)(1) lists the conductor cu in. volumes for 18 AWG through 6 AWG. For example, a 14 AWG conductor has a volume of 2 cu in., but if a box has four 14 AWG conductors, the total conductor volume is 8 cu in.
- Conductor insulation is not a factor for box fill calculations.

Table 314.16(B)(4)† Volume Allowance Required per Conductor

Conductor AWG Size	Free Space Required for Each Conductor (cu in.)
18	1.50
16	1.75
14	2.00
12	2.25
10	2.50
8	3.00
6	5.00

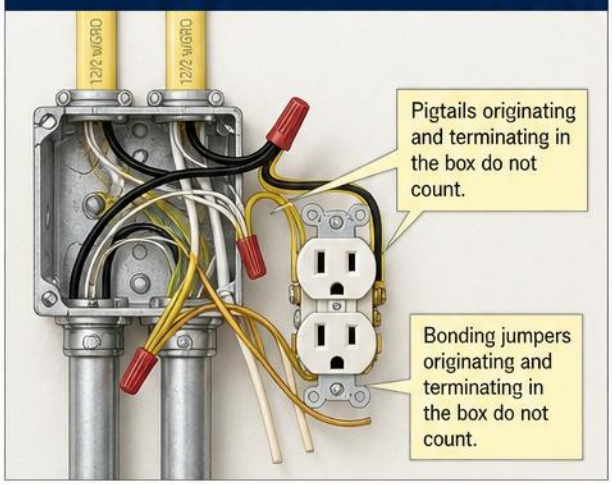
Each conductor loop in a box having a total length of less than 12 in. is considered a single conductor volume and each conductor loop in a box having a length of not less than 12 in. is considered as two conductor volumes in accordance with Table 314.16(B)(4).

Figure 314–17 Box Fill Calculations—Conductor Volume, Loop 314.16(B)(1)



Conductors that originate and terminate within the box (such as pigtails and bonding jumpers) are not counted as a conductor volume. Figure 314–18

Figure 314–18 Box Fill Calculations—Conductor Volume, Originates Inside Box 314.16(B)(1)



Ex: Equipment grounding conductors, circuit conductors, and not more than four fixture wires (smaller than 14 AWG) are not counted as a conductor volume if they enter the box from a domed luminaire or similar canopy (such as a ceiling paddle fan canopy). Figure 314–19

(2) Cable Clamp Volume. Internal cable clamps that are part of the outlet box are counted as a single conductor volume based on the largest conductor in the box in accordance with Table 314.16(B)(4). No allowance is required for a cable connector with its clamping means outside the box. Figure 314–20

Figure 314–19 Outlet Box Sizing—Fixture Wires 314.16(B)(1) Ex

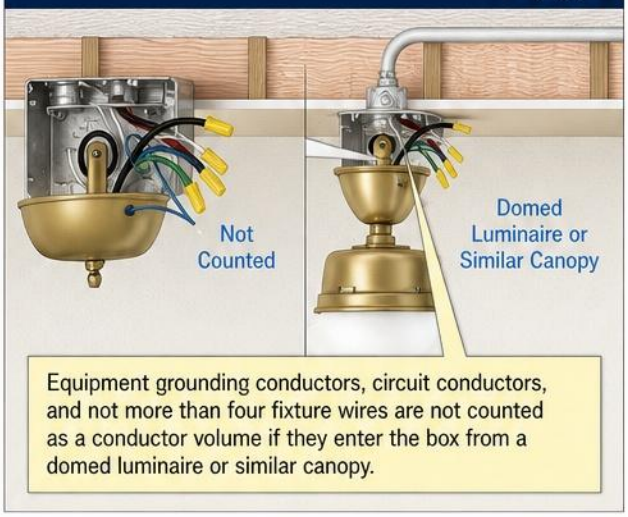
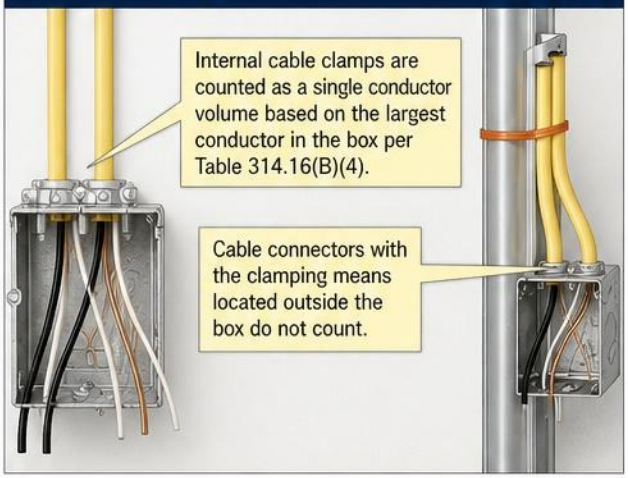


Figure 314–20 Box Fill Calculations—Internal Cable Clamp Volume 314.16(B)(2)



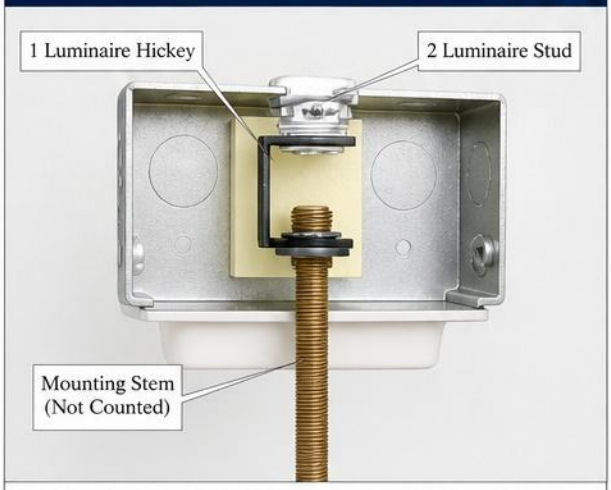
(3) Support Fitting Volume. Each luminaire stud or luminaire hickey counts as a single conductor volume based on the largest conductor that enters the box in accordance with Table 314.16(B)(4). Figure 314–21

(4) Device Yoke Volume. Each single-gang device yoke counts as two conductor volumes based on the largest conductor that terminates on the device in accordance with Table 314.16(B)(4). Figure 314–22

Author's Comment:

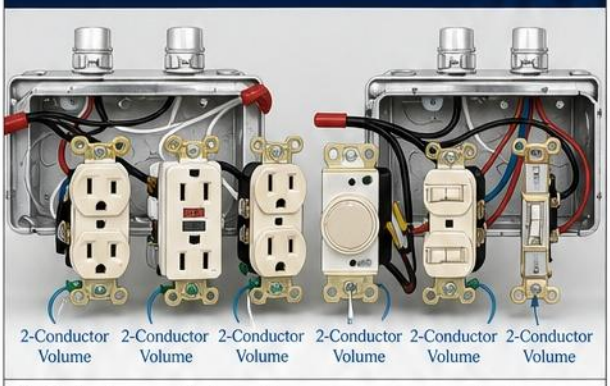
- A device yoke is the mounting structure for a receptacle, switch, switch with pilot light, switch/receptacle, and so forth. Figure 314–23

Figure 314–21 Box Fill Calculations—Fixture Stud or Hickey Fitting Volume 314.16(B)(3)



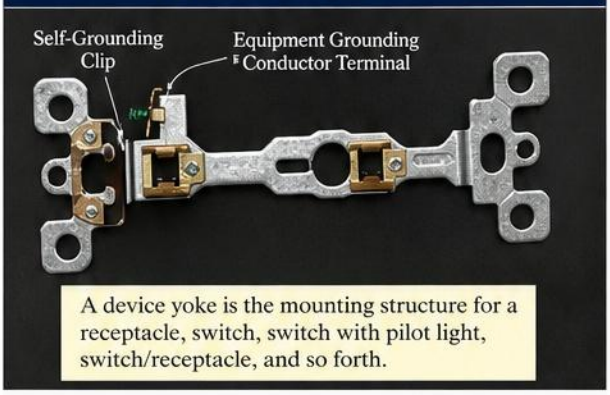
Each luminaire stud or hickey counts as a single conductor volume based on the largest conductor that enters the box per Table 314.16(B)(4).

Figure 314–22 Box Fill Calculations—Device Yoke Volume 314.16(B)(4)



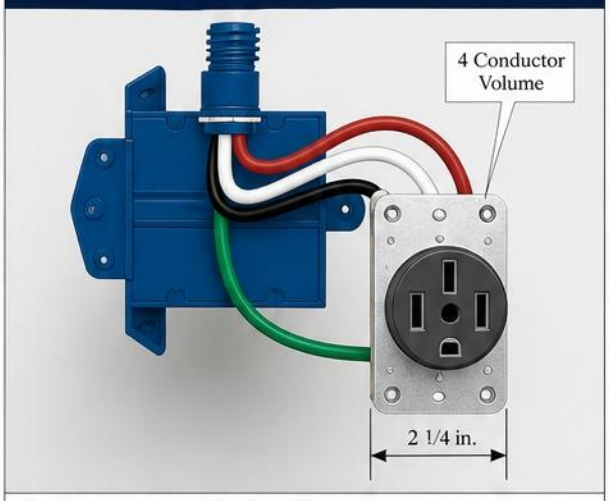
Each single-gang device yoke counts as a two-conductor volume, based on the largest conductor terminating on the device per Table 314.16(B)(4).

Figure 314–23 Box Fill Calculations—Device Yoke 314.16(B)(4) *Comment*



Each device yoke wider than 2 in. counts as a double conductor volume for each gang, based on the largest conductor that terminates on the device in accordance with Table 314.16(B)(4). Figure 314–24.

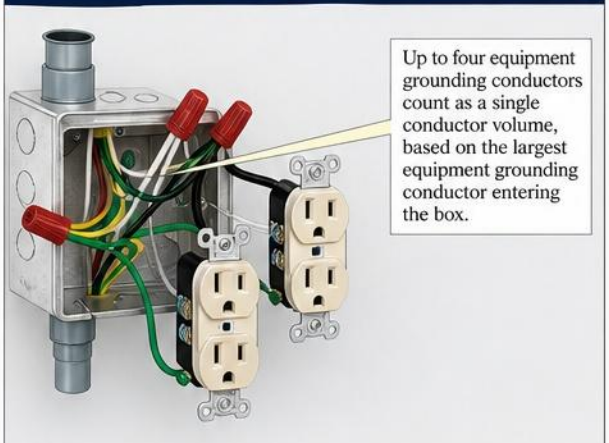
Figure 314–24 Box Fill Calculations—Device Yoke Wider Than 2 in. Volume 314.16(B)(4)



Each device yoke wider than 2 in. counts as a two-conductor volume for each gang required for mounting, based on the largest conductor that terminates on the device.

(5) Equipment Grounding Conductor Volume. Up to four equipment grounding conductors count as a single conductor volume based on the largest equipment grounding conductor entering the box in accordance with Table 314.16(B)(4). A 1/4 in. volume allowance must be made for each additional equipment grounding conductor that enters the box, based on the largest equipment grounding conductor entering the box. Figure 314–25.

Figure 314–25 Box Fill Calculations—Equipment Grounding Conductor Volume 314.16(B)(5)



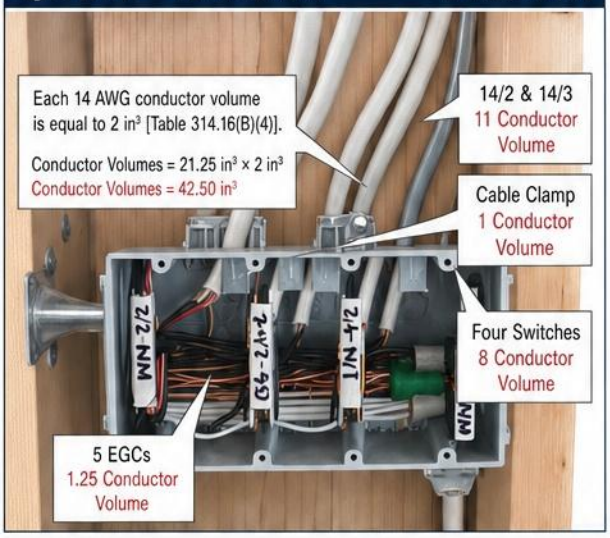
A 1/4 volume allowance must be made for each additional equipment grounding conductor that enters the box.

▶ Box Fill Volume [314.16(B)] Example

Question: *What is the volume fill for a 4-gang box containing four 14/2 NM cables and one 14/3 NM cable, three single-pole switches, and one three-way switch?* **Figure 314–26**

(a) 35.50 cu in. (b) 37.50 cu in. (c) 39.50 cu in. (d) 42.50 cu in.

Figure 314–26 • Box Fill Calculations 314.16(B) Example 2



Four 14/2 NM cables, one 14/3 NM cable, three single-pole switches, and one three-way switch in a 4-gang box. Callouts show individual conductor volume contributions.

Solution:

Four 14/2 NM Cables	*8–14 AWG conductor volumes*
One 14/3 NM Cable	*3–14 AWG conductor volumes*
Cable Clamps	*1–14 AWG conductor volume*
*Five EGCs**	*1.25–14 AWG conductor volumes*
Four Switches	*8–14 AWG conductor volumes*
Total	*21.25–14 AWG conductor volumes*

Each 14 AWG conductor volume is equal to 2 cu in. [Table 312.6(B)(4)].

**The first four EGCs count as one conductor volume, each additional count as ¼ of a conductor volume.*

Volume Fill = 21.25 conductor volumes × 2 cu in.
Volume Fill = 42.50 cu in.

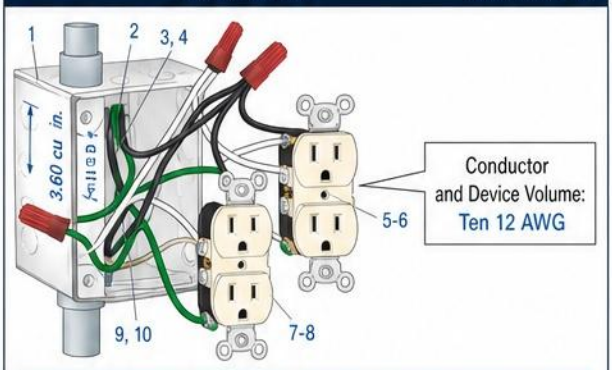
Answer: *(d) 42.50 cu in.*

▶ Number of Conductors [314.16(B)] Example

Question: *How many 14 AWG conductors can be pulled through a 4-in. square × 2⅛ in. deep box with a plaster ring marked 3.60 cu in.? The box contains two receptacles, five 12 AWG conductors, and two 12 AWG equipment grounding conductors.* **Figure 314–27**

(a) 4 conductors (b) 5 conductors
(c) 6 conductors (d) 7 conductors

Figure 314–27 • Box Fill Calculations Cubic Inch Volume 314.16(A) and 314.16(B) Example



Step 1: Volume of the box assembly [314.16(A)]:
21 cu in. Box + 3.60 cu in. plaster ring = 24.60 in³.

Step 2: Volume of the devices and conductors [Table 314.16(B)(4)]:
Ten—12 AWG × 2.25 in³ = 22.50 in³.

Step 3: Okay for 24.60 in³. box volume.

Solution:

Step 1: *Determine the volume of the box assembly [314.16(A)].*

Box Assembly Volume = Box 30.30 cu in. + 3.60 cu in. plaster ring
Box Assembly Volume = 33.90 cu in.

Step 2: *Determine the volume of the devices and conductors in the box.*

Two—receptacles	*4–12 AWG*
Five—12 AWG conductors	*5–12 AWG*
Two—12 AWG equipment grounding conductors	*1–12 AWG*
Total	*10–12 AWG*

Total Device Volume and Conductors = Ten—12 AWG × 2.25 cu in.
Total Device Volume and Conductors = 22.50 cu in.

Step 3: *Determine the remaining volume permitted for the 14 AWG conductors (volume of the box minus the volume of the conductors).*

Remaining Volume = 33.90 cu in. – 22.50 cu in.
Remaining Volume = 11.40 cu in.

Step 4: *Determine the number of 14 AWG conductors (at 2.00 cu in. each) permitted in the remaining volume of 11.40 cu in.*

14 AWG = 2.00 cu in. each [Table 312.6(B)(4)]
11.40 cu in./2.00 cu in. = 5 conductors

Five 14 AWG conductors can be pulled through.

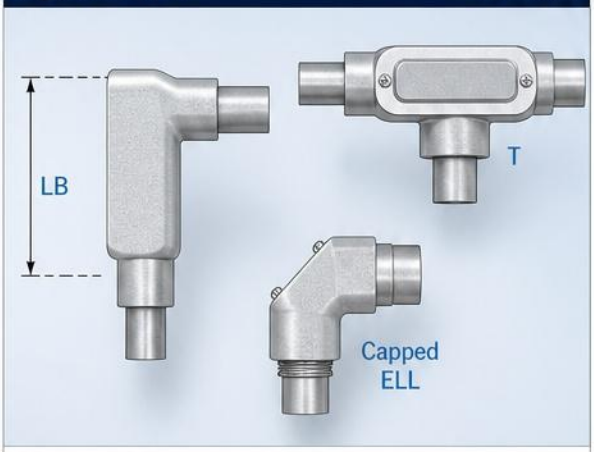
Answer: *(b) 5 conductors*

(C) Conduit Bodies.

(2) Splices. Only those *conduit bodies* that are durably and legibly marked by the manufacturer with their volume are permitted to contain splices. The maximum number of conductors in a conduit body containing splices is calculated in accordance with 314.16(B).

Conduit Body. A raceway fitting that provides access to conductors through a removable cover. Figure 314–28 and Figure 314–29.

Figure 314–28 314.16(B)



A raceway fitting that provides access to conductors through a removable cover.

Figure 314–29 314.16(B)

A raceway fitting that provides access to conductors through a removable cover.

▶ Splice in Conduit Bodies [314.16(C)] Example

Question: *What size LB is required for a two-wire 12 AWG conductor circuit that is spliced?*

(a) ½ in. (4.35 in.³) *(b) ¾ in. (7.30 in.³)*
(c) 1 in. (12.2 in.³) *(d) none of these*

Solution:

Determine the cubic inch volume for four 12 AWG conductors [Table 314.16(B)(4)].

Total Volume = 4 × 2.25 in.³
Total Volume = 9 in.³

Answer: *(c) 1 in. with a volume of 12.2 in.³*

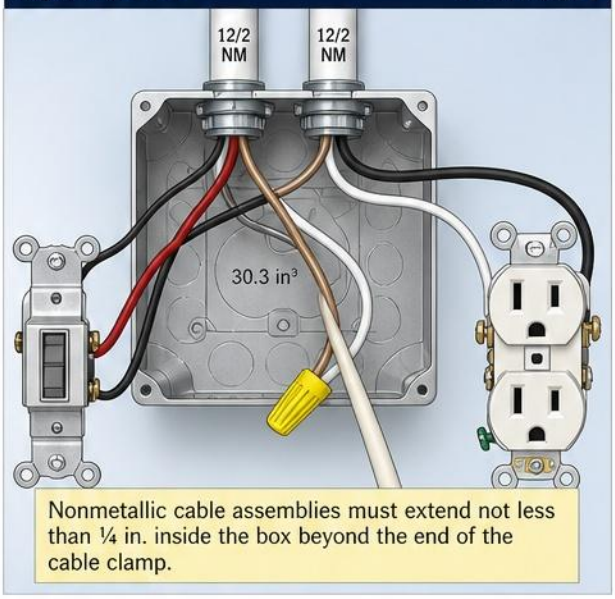
314.17 Cables That Enter Boxes

(B) Boxes. The installation of cables in boxes must comply with the following:

(2) Cables Entering Boxes Through Cable Clamps.

Extend into Box. Nonmetallic cable assemblies must extend not less than ¼ in. inside the box beyond the end of the cable clamp. Figure 314–30

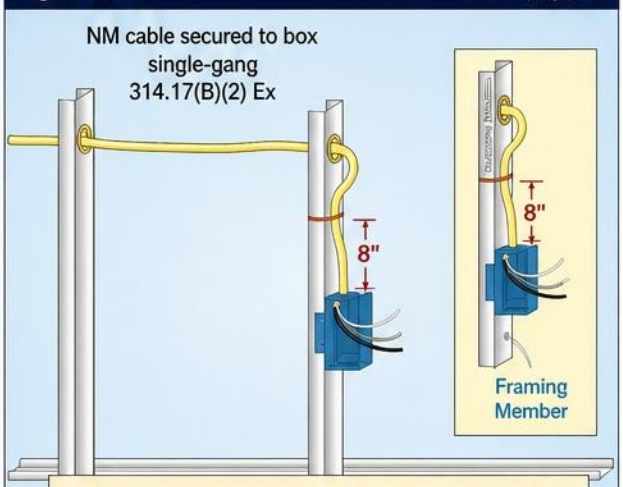
Figure 314–30 314.17(B)(2)



Secured to Box. NM cable must be secured to the box.

Ex: NM cable is not required to be secured to a single gang nonmetallic box (2¼ in. × 4 in.) if the cable is fastened within 8 in. of the box (measured along the sheath). Figure 314–31

Figure 314–31 314.17(B)(2) Ex



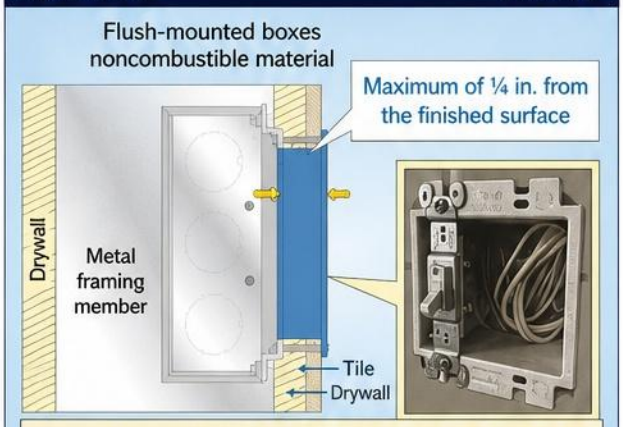
NM cable is not required to be secured to a single-gang nonmetallic box if the cable is fastened within 8 in. of the box measured along the sheath.

314.20 FLUSH-MOUNTED BOXES

(A) Noncombustible Material. Boxes made of noncombustible material must have the front edge of the box, plaster ring, extension ring, or listed extender set back no more than ¼ in. from the finished surface.

See Figure 314–32 and Figure 314–33.

Figure 314–32 314.20(A)



Boxes in noncombustible material must have the front edge of the box, plaster ring, extension ring, or listed extender set back no more than ¼ in. from the finished surface.

(B) Combustible Material. Boxes within a surface of wood or other combustible surface material must have the front edge of the box, plaster ring, extension ring, or listed extender reach to, or project out from, the finished surface.

See Figure 314–34 and Figure 314–35.

Figure 314–33 314.20(A)

Boxes in noncombustible material must have the front edge of the box, plaster ring, extension ring, or listed extender set back no more than ¼ in. from the finished surface.

Figure 314–34 314.20(B)

Boxes within a surface of wood or other combustible surface material must have the front edge of the box, plaster ring, extension ring, or listed extender reach to, or project out from, the finished surface.

Figure 314–35 314.20(B)

Boxes within a surface of wood or other combustible surface material must have the front edge of the box, plaster ring, extension ring, or listed extender reach to, or project out from, the finished surface.

AUTHOR'S COMMENT:

- Plaster and extension rings are available in a variety of depths to meet the above requirements.
- Final finished surfaces (such as backsplashes and tile) may require the use of listed extenders (plastic rings) to meet the requirements of this section.

Figure 314–36 Flush-Mounted Boxes *314.20 Comment*

When final finishes such as backsplashes and tile are used, listed extenders (plastic rings) may be necessary to satisfy this section's requirements.

314.21 Repairing Noncombustible Surfaces

Openings around boxes that are recessed in noncombustible finishes (for example, plaster, drywall, or plasterboard) must be repaired so that the gap at the box edge does not exceed 1/8 in. **Figure 314–37**

Figure 314–37 Boxes, Repairing Noncombustible Surfaces 314.21

Openings around boxes that are set into noncombustible surfaces must be repaired so that the gap at the box edge is no larger than 1/8 in.

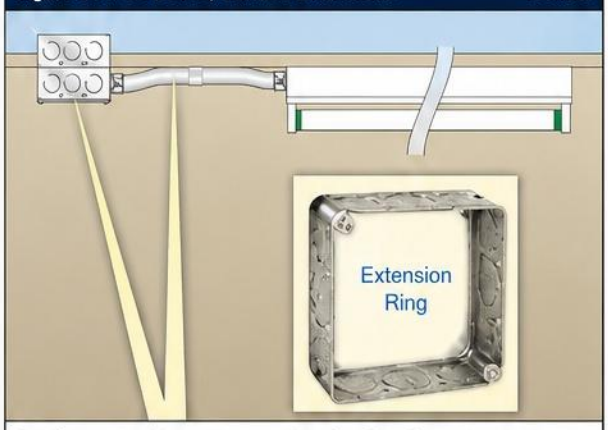
AUTHOR'S COMMENT:

- Other examples of noncombustible surfaces include ceramic wall tile, ceramic or marble floor tile, brick, cinder block, and other types of masonry or stone.

314.22 Surface Extensions

Surface extensions can only be made from one or more extension rings over a box. **Figure 314–38**

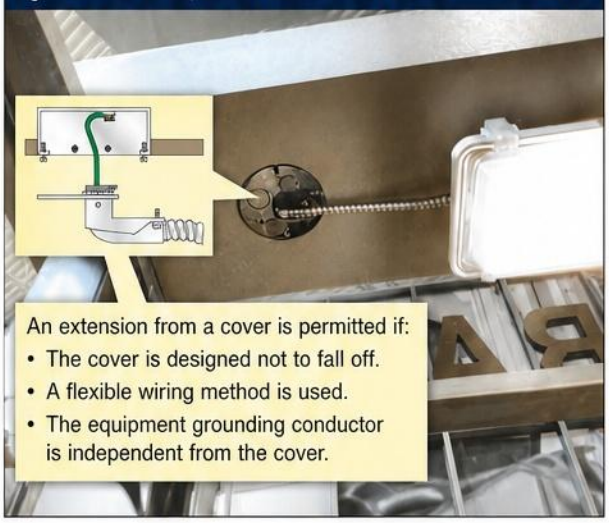
Figure 314–38 Boxes, Surface Extensions 314.22



Surface extensions are permitted only when one or more extension rings are installed over a box.

Example: A surface extension may be created from the cover of a box—if the cover is intended to fall off if it is mounted loosely. The surface extension wiring method must be flexible to allow removal of the cover, provide access to the inside of the box, and ensure that the equipment grounding continuity is not dependent on the connection between the box and the cover. **Figure 314–39**

Figure 314–39 Boxes, Surface Extension from a Cover 314.22 Ex



314.23 Supporting Enclosures

(A) Building Surface. An enclosure mounted on a building or other surface must be firmly and safely secured in place.

Figure 314–40 Supporting Enclosures Secured to Building Surface 314.23(A)

Enclosures mounted on a building or other surface must be firmly and safely secured in place.

(B) Structural Member or Grade. An enclosure supported from a structural member or from grade must be rigidly supported either directly or by using a metal, polymeric, or wood brace.

(2) Braces. Metal braces that protect against corrosion and are formed from metal not less than 0.02 in. thick uncoated.

Figure 314–41 Supporting Enclosures Secured to Metal Braces 314.23(B)(2)

Enclosures can be supported to metal braces protected against corrosion and formed from metal that is not less than 0.02 in. thick uncoated.

Wood braces having a cross-section not less than nominal 1 in. × 2 in. Wood braces in wet locations must be treated for the conditions.

Figure 314–42 Supporting Enclosures Secured to Wood Braces 314.23(B)(2)

Enclosures can be supported to wood braces having a cross section not less than nominal 1 in. × 2 in.

Figure 314–42 Supporting Enclosures Secured to Wood Braces 314.23(B)(2)

Enclosures can be supported to wood braces having a cross section not less than nominal 1 in. × 2 in.

Polymeric braces must be identified as being suitable for the use.

(C) Finished Surface. Enclosures secured to a finished surface (drywall, plaster walls, or ceilings) must be firmly secured by clamps or fittings identified for the purpose.

Figure 314–43 Supporting Enclosures Secured to Finished Surface 314.23(C)

Enclosures secured to a finished surface must be firmly secured by clamps or fittings identified for the purpose.

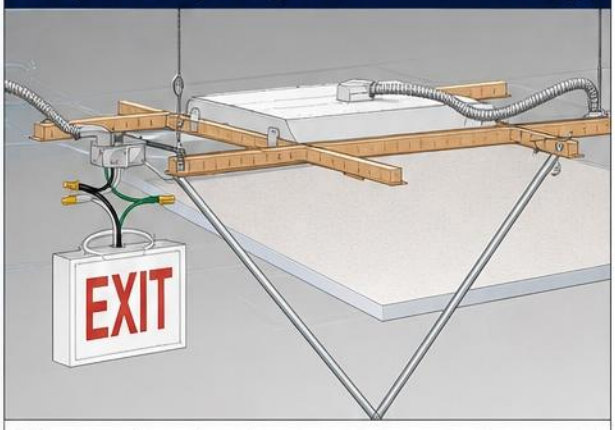
(D) Suspended-Ceiling. Enclosures not exceeding 100 cu. in. within suspended ceilings can be supported as follows:

(1) Ceiling Framing Members. Secured to suspended-ceiling framing member(s) with bolts, screws, rivets, clips, or other means that are identified for the suspended-ceiling framing members.

Figure 314–44 Supporting Enclosures Secured to Ceiling Framing Members 314.23(D)(1)

Enclosures not exceeding 100 cu. in. within suspended ceilings can be secured to the suspended-ceiling framing member(s) using identified fasteners.

Figure 314–44 Supporting Enclosures Secured to Suspended-Ceiling Framing Members 314.23(D)(1)

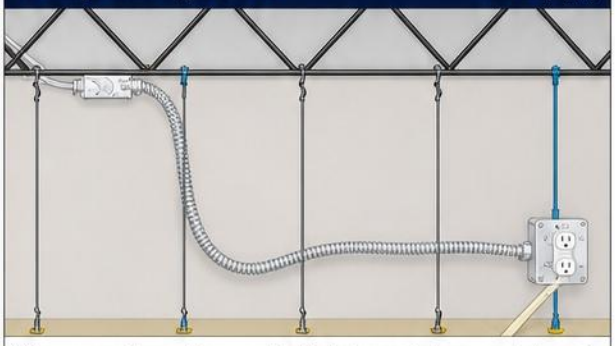


When an enclosure is used to support components of a suspended ceiling, it shall be securely fastened with bolts, screws, rivets, clips, or other suitable fasteners identified for the suspended-ceiling framing members.

(2) Independent Support Wires. Independent support wires with identified fittings to support wires that are distinguishable from the suspended-ceiling support wires by color, tagging, or other effective means in accordance with 300.13(B). Support wire(s) used for enclosure support must be fastened at each end so as to be taut within the ceiling cavity.

Figure 314–45

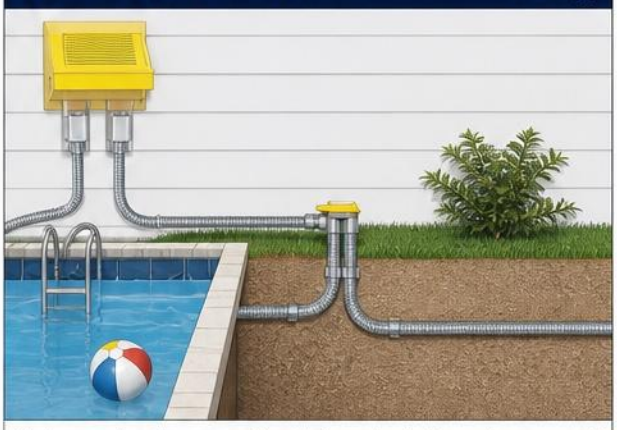
Figure 314–45 Supporting Enclosures Secured to Independent Support Wires 314.23(D)(2)



When an enclosure is secured with independent support wires, it shall be secured with identified fittings that distinguish the support wires from suspended-ceiling support wires by color, tagging, or other effective means.

(E) Enclosures without Devices or Luminaires to Threaded Conduits. Enclosures that do not contain a device or luminaire can be supported with two threaded intermediate metal conduits or rigid metal conduits, threaded wrenchtight—if each conduit is secured within 36 in. of the enclosure or within 18 in. of the enclosure if all conduit entries are on the same side of the enclosure. Figure 314–46

Figure 314–46 Supporting Enclosures without Devices or Luminaires to Two Threaded Conduits 314.23(E)



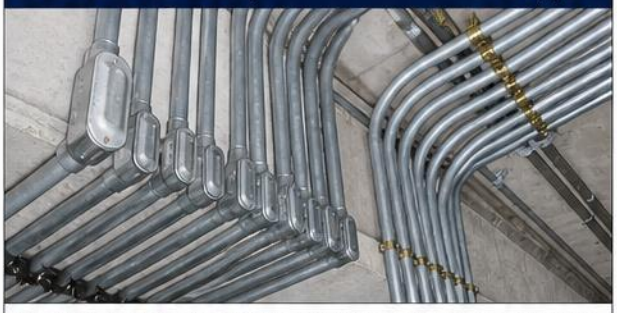
Enclosures that do not contain a device or luminaire can be supported with two threaded IMC or RMC, if each conduit is secured within 36 in. or within 18 in. of the enclosure if all conduit entries are on the same side of the enclosure.

Ex: A conduit body where the trade size of the conduit body is not larger than the raceway, an FS or FD single gang device box, or an explosionproof outlet box of any size, with one or more entries is permitted to be supported by a single raceway of the following wiring methods:

(1) Intermediate metal conduit
(2) Rigid metal conduit
(3) Rigid polyvinyl chloride conduit
(5) Electrical metallic tubing

Figure 314–47

Figure 314–47 Supporting Enclosures without Devices or Luminaires with Conduit Body 314.23(E) Ex

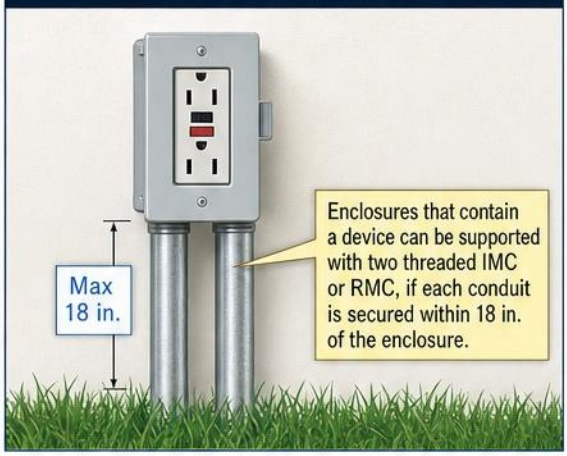


A conduit body where the trade size of the conduit body is not larger than the raceway is permitted to be supported by a single raceway of the following wiring methods:
(1) IMC (3) PVC
(2) RMC (5) EMT

(F) Enclosures with Devices or Luminaires to Threaded Conduits. Enclosures that contain a device or luminaire can be supported with two threaded intermediate metal or rigid metal conduits, threaded wrenchtight—if each conduit is secured within 18 in. of the enclosure.

Figure 314–48, Figure 314–49, and Figure 314–50

Figure 314–48 Supporting Enclosures with Devices—Two Threaded Conduits 314.23(F)

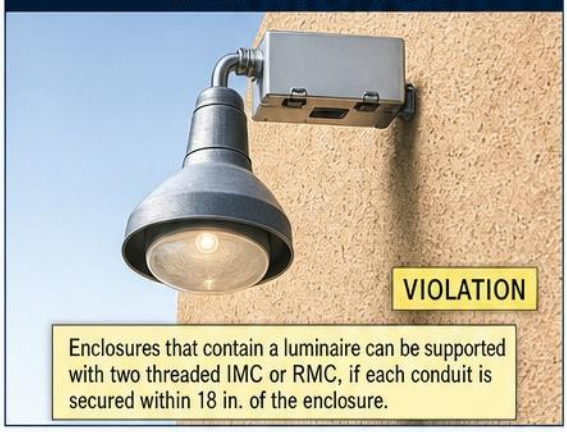


A device enclosure is mounted to two threaded metal conduits. Each conduit is fastened within 18 in. of the enclosure.

Figure 314–49 Supporting Enclosures with Devices—Two Threaded Conduits 314.23(F)

The supporting conduit(s) are not secured within 18 in. of the enclosure. This installation does not comply.

Figure 314–50 Supporting Enclosures with Luminaires—Two Threaded Conduits 314.23(F)



The supporting conduit(s) are not secured within 18 in. of the enclosure. This installation does not comply.

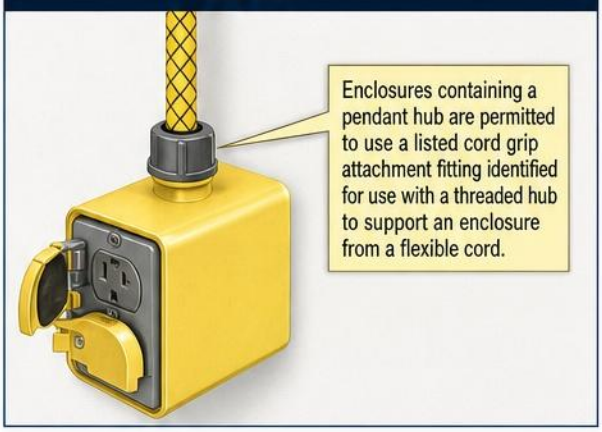
(G) Boxes in Concrete or Masonry. Enclosures that are identified as suitably protected from corrosion can be embedded in concrete or masonry.

(H) Pendant Enclosure.

(1) Flexible Cord.

(b) Enclosures containing a pendant hub are permitted to use a listed cord grip attachment fitting identified for use with a threaded hub to support an enclosure from a flexible cord [400.10(A)(1) and 400.14] Figure 314–51.

Figure 314–51 Securing Pendant Enclosures—Flexible Cord 314.23(H)(1)(b)

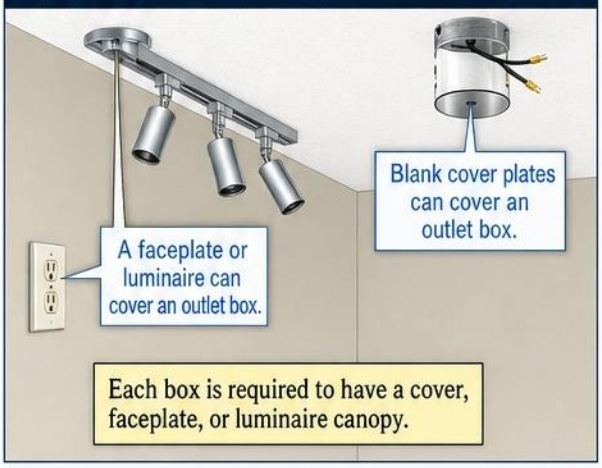


A pendant-type enclosure is securely supported by a listed cord grip fitting connected to a flexible cord.

314.25 Box Covers

Each box is required to have a cover, faceplate, or luminaire canopy. Figure 314–52.

Figure 314–52 Box Cover Required 314.25

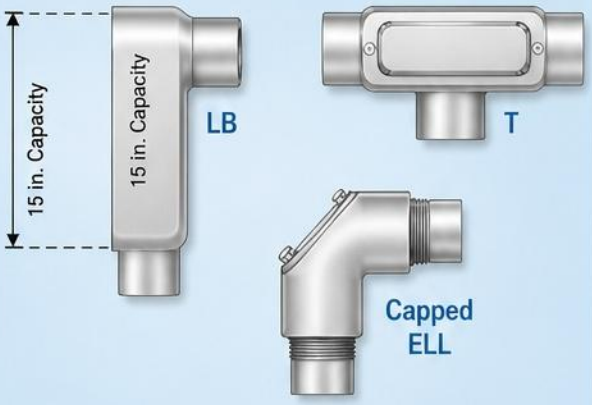


Outlet boxes must be provided with an approved cover, faceplate, or luminaire canopy.

Conduit body enclosures are required with a cover.

Figure 314–53 314.25

Conduit Body Cover Required

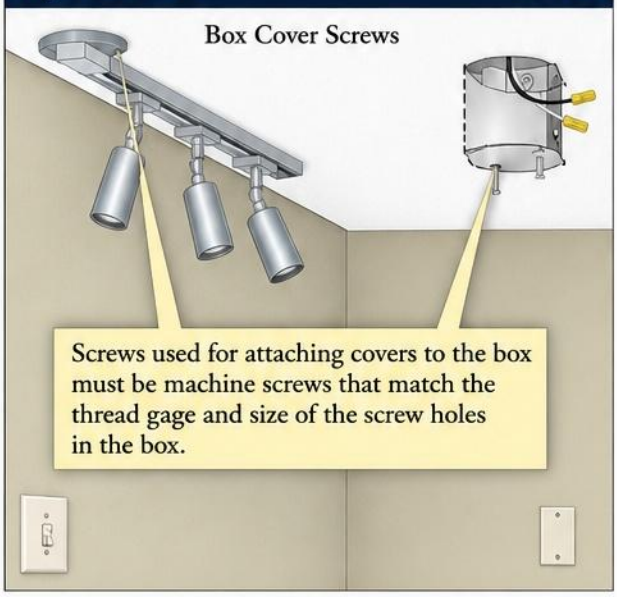


Conduit body enclosures are required with a cover.

Screws used for attaching covers to the box must be machine screws matching the thread gauge and size of the box screw holes.

Figure 314–54 314.25

Box Cover Screws



(A) Metal Covers. Metal box covers or plates must be connected to the circuit equipment grounding conductor.

Note: For connecting metal switch and receptacle faceplates to the circuit equipment grounding conductor, see 404.12 and 406.16(B).

Figure 314–55 314.25(A)

314.27 Box Requirements

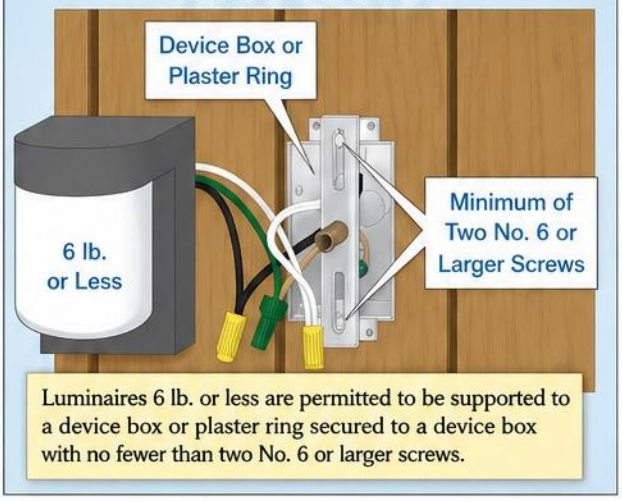
(A) Boxes for Luminaires.

(1) Boxes for Luminaires on Vertical Surfaces. Boxes used for the support of luminaires on a vertical surface must be in accordance with the following:

(a) Luminaires 6 lb. or Less. Luminaires 6 lb. or less are permitted to be supported to a device box or plaster ring (⅜-inch screws for mounting) secured to a device box—if the luminaire or supporting yoke is secured to the box with no fewer than two No. 6 or larger screws.

Figure 314–56 314.27(A)(1)(a)

Boxes for Luminaires on Vertical Surfaces
Luminaires 6 lb. or Less



(b) Luminaires Over 6 lb. Boxes used for luminaires weighing more than 6 lb must be identified and labeled on the inside of the box to state the maximum weight the luminaire the box can support if greater than 50 lb.

Figure 314–57 Boxes for Luminaires on Vertical Surfaces 314.27(A)(1)(b)

Lighting fixtures over 6 lb require boxes that are identified and labeled on the inside to indicate the maximum fixture weight the box can carry when that weight exceeds 50 lb.

(2) Boxes for Luminaires in a Ceiling.

(a) Luminaires 50 lb. or Less. Ceiling-mounted lighting fixtures that weigh 50 lb or less must be listed and labeled to support a luminaire with a maximum weight of 50 lb.

(b) Luminaires More than 50 lb. Lighting fixtures weighing more than 50 lb must be supported on their own by the outlet box, unless the box is listed and labeled by the manufacturer on the inside for the maximum fixture weight it is designed to support.

Figure 314–58 Boxes for Ceiling Luminaires 314.27(A)(2)(b)

Fixtures heavier than 50 lb must be supported independently by the outlet box, unless the box is listed and labeled on the inside by the manufacturer for the maximum fixture weight it will support.

(B) BOXES FOR CEILING PADDLE FANS

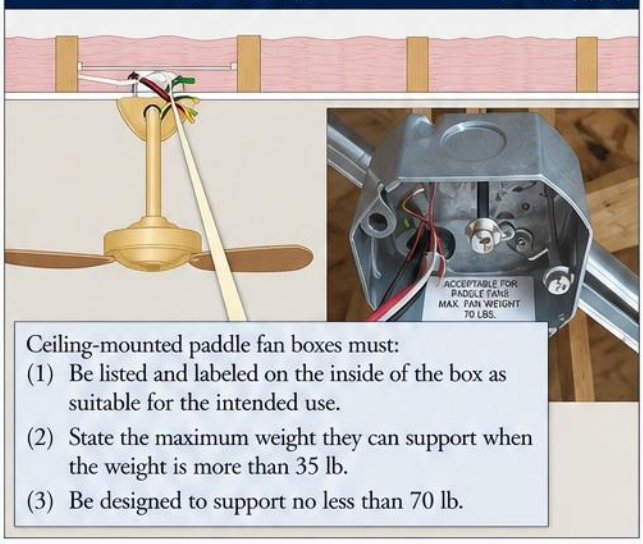
(1) General. Ceiling-mounted paddle fan boxes must:

(1) Be listed and labeled on the inside of the box as suitable for the intended use.

(2) State the maximum weight they can support when the weight is more than 35 lb.

(3) Be designed to support no less than 70 lb.

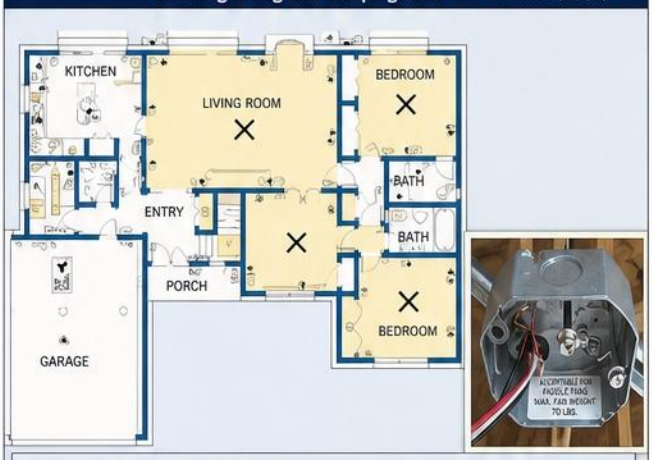
Figure 314–59 Boxes for Ceiling Paddle Fans—Listed and Labeled 314.27(B)(1)



Ceiling-mounted paddle fan boxes must:
(1) Be listed and labeled on the inside of the box as suitable for the intended use.
(2) State the maximum weight they can support when the weight is more than 35 lb.
(3) Be designed to support no less than 70 lb.

(2) Location. Outlet boxes mounted in the center of the ceiling in living and sleeping areas of a dwelling unit, and in other positions specified by the installer, designer, or builder for installing a ceiling-suspended paddle fan, must be listed for the exclusive support of ceiling-suspended paddle fans.

Figure 314–60 Boxes for Ceiling Paddle Fans—Dwelling Living and Sleeping Area 314.27(B)(2)



Outlet boxes mounted in the center of the ceilings of living and sleeping areas within dwelling units must be listed for the sole support of ceiling-suspended (paddle) fans.

(C) Floor Boxes for Receptacles. Floor boxes for receptacles must be specifically listed for the purpose. Figure 314–61

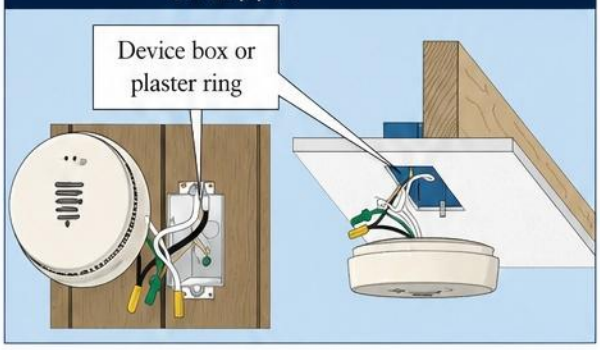
Figure 314–61 Boxes for Floor Receptacles 314.27(C)

Floor boxes for receptacles must be listed for the purpose.

(D) Boxes for Utilization Equipment.

Utilization equipment 6 lb or less can be supported by a box secured with two No. 6 or larger screws. Figure 314–62

Figure 314–62 Boxes for Smoke Alarms 314.27(D) Ex



Utilization equipment 6 lb or less can be supported by a box secured with two No. 6 or larger screws.

314.28 PULL AND JUNCTION BOXES

Boxes containing conductors 4 AWG and larger must be sized as follows:

Figure 314–63

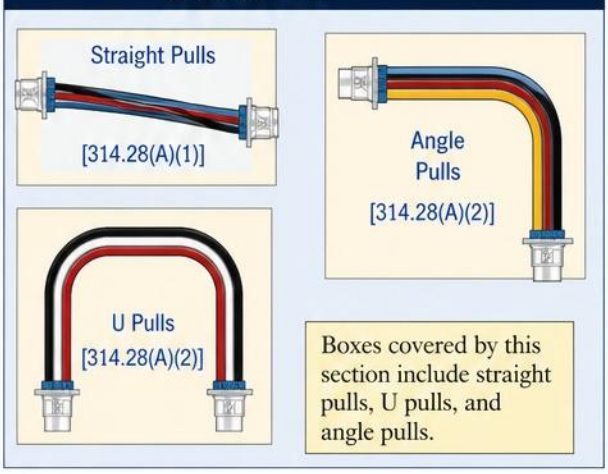
Figure 314–63 Pull and Junction Box Sizing Conductors 4 AWG and Larger 314.28

Boxes containing conductors 4 AWG and larger must be sized so the conductor insulation won't be damaged.

Author's Comment:

- The requirements for sizing boxes containing conductors 6 AWG and smaller are contained in 314.16.
- Boxes covered by this section include straight pulls, U pulls, and angle pulls. Figure 314–64

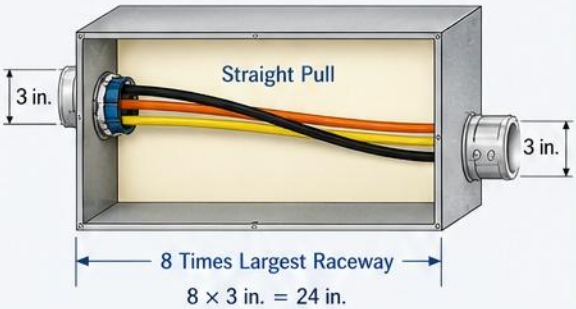
Figure 314–64 Pull and Junction Box Sizing Conductors 4 AWG and Larger 314.28 Comment



(A) Minimum Size. The minimum dimensions of boxes must comply with the following:

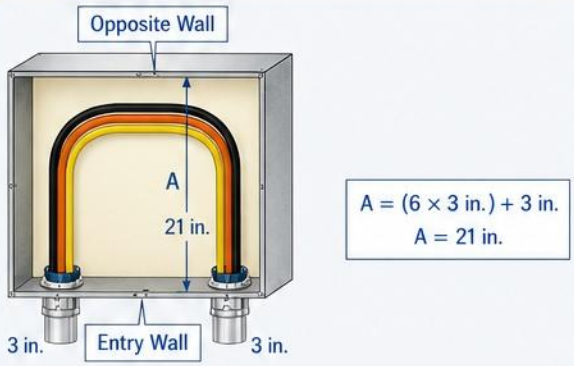
(1) Straight Pulls. The distance from where the raceway enters the box to the opposite wall of the box must be at least eight times the size of the largest raceway. Figure 314–65

Figure 314–65 Straight Pulls 314.28(A)(1)



The distance from where the raceway enters the box to the opposite wall of the box must be at least eight times the size of the largest raceway.

Figure 314–67 U Pulls 314.28(A)(2)

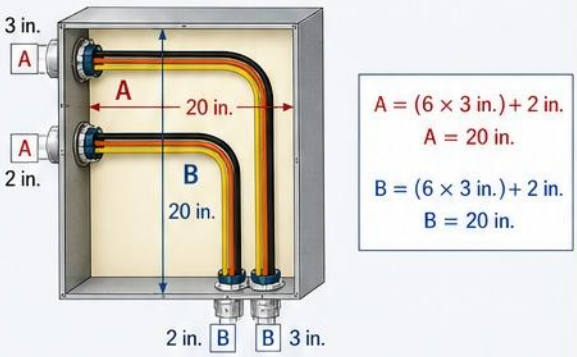


The distance from the raceway entry of the box to the opposite wall must be at least six times the size of the largest raceway, plus the sum of the sizes of the remaining raceways on the same wall.

(2) Angle Pulls, U Pulls, or Splices.

Angle Pulls. The distance from the raceway entry of the box to the opposite wall of the box must be at least six times the size of the largest raceway, plus the sum of the remaining raceway sizes on the same wall.
Figure 314–66

Figure 314–66 Angle Pulls 314.28(A)(2)

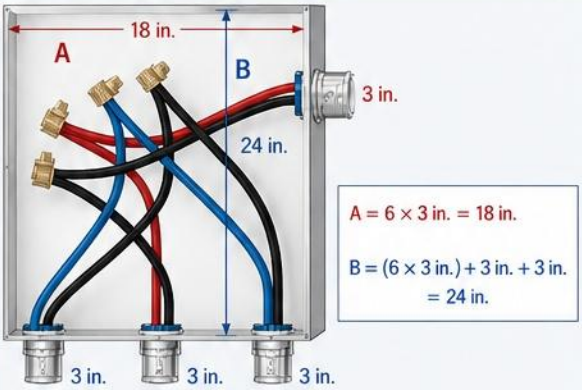


The distance from the raceway entry of the box to the opposite wall must be at least six times the size of the largest raceway, plus the sum of the sizes of the remaining raceways on the same wall.

U Pulls. When a conductor enters and leaves from the same wall of the box, the distance from the raceway entry of the box to the opposite wall of the box must be at least six times the size of the largest raceway, plus the sum of the remaining raceway sizes on the same wall.
Figure 314–67

Splices. When conductors are spliced, the distance from the raceway entry of the box to the opposite wall must be at least six times the size of the largest raceway, plus the sum of the remaining raceway sizes on the same wall.
Figure 314–68

Figure 314–68 Splices 314.28(A)(2)

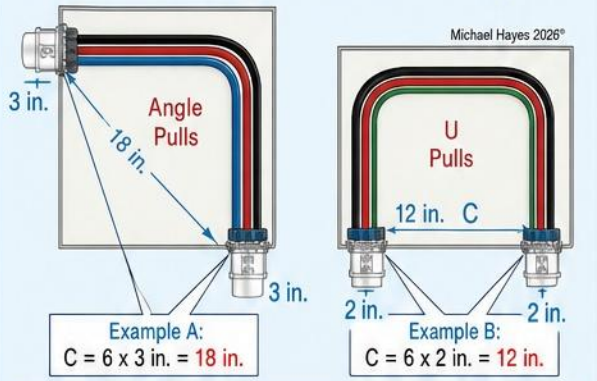


The distance from the raceway entry of the box to the opposite wall must be at least six times the size of the largest raceway, plus the sum of the sizes of the remaining raceways on the same wall.

Distance Between Raceways. The distance between raceway entries enclosing the same conductor must be at least six times the size of the largest raceway measured between the raceway entry openings.
Figure 314–69 and Figure 314–70

Figure 314–69 Pull and Junction Box Sizing **314.28(A)(2)**

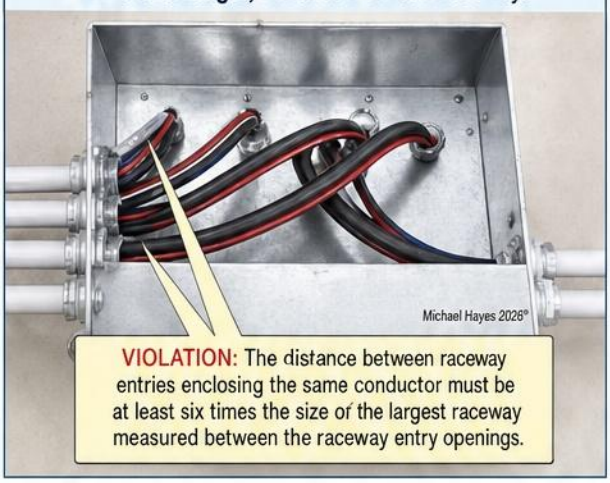
4 AWG and Larger, Distance Between Raceways



The distance between raceway entries enclosing the same conductor must be at least six times the size of the largest raceway measured between the raceway entry openings.

Figure 314–70 Pull and Junction Box Sizing **314.28(A)(2)**

4 AWG and Larger, Distance Between Raceways



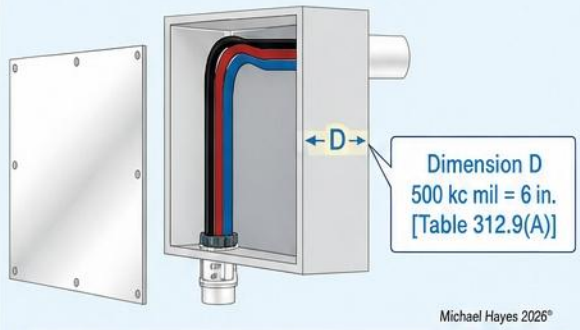
Ex: When conductors enter an enclosure opposite a cover, the distance from that wall to the removable cover is not permitted to be less than the bending distance as contained in Table 312.9(A) for one conductor per terminal. [Reference: Figure 314–71]

314.29 Wiring to be Accessible

Boxes, conduit bodies, and handhole enclosures must be installed so wiring and devices contained in the boxes, conduit bodies, or handhole enclosures can be *accessible* as follows:

Figure 314–71 Pull and Junction Box Sizing **314.28(A)(2) Ex**

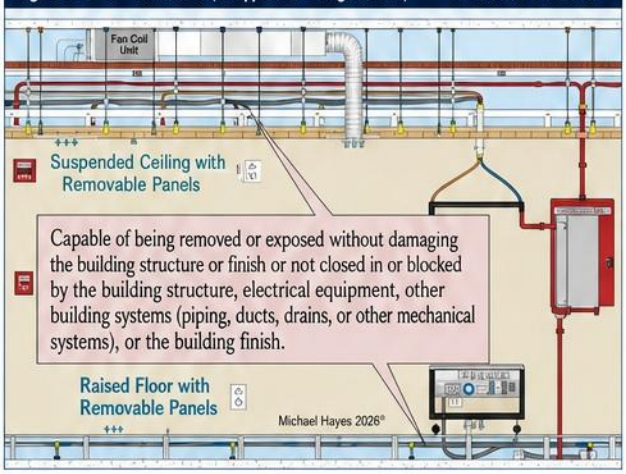
4 AWG and Larger, Removable Covers



The distance from that wall to the removable cover is not permitted to be less than the bending distance as contained in Table 312.9(A) for one conductor per terminal.

Accessible (as applied to wiring methods). Capable of being removed or exposed without damaging the building structure or finish or not closed in or blocked by the building structure, electrical equipment, other building systems (piping, ducts, drains, or other mechanical systems), or the building finish. *[Reference: Figure 314–72]*

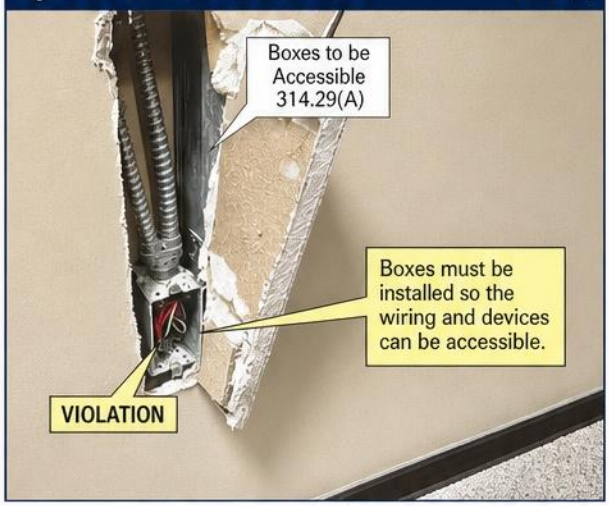
Figure 314–72 Accessible (As Applied to Wiring Methods) **Article 100 Definition**



(A) Boxes In Buildings. Boxes must be installed so the wiring and devices can be accessible. *[Reference: Figure 314–73]* and *[Reference: Figure 314–74]*

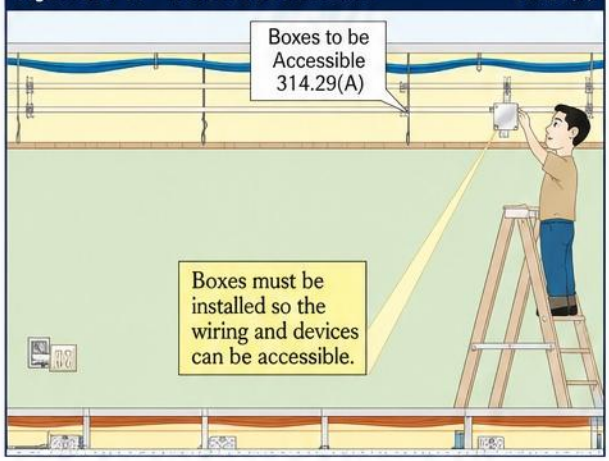
Boxes that are recessed into or behind finished surfaces of buildings must have access to their internal contents maintained by openings in their covers and in the building finish that comply with 314.29(A)(1), (A)(2), or (A)(3) as applicable. Removable finished covers and faceplates that maintain this access are permitted.

Figure 314–73 Boxes to be Accessible 314.29(A)



The box is not installed to allow access to the wiring and devices.

Figure 314–74 Boxes to be Accessible 314.29(A)



The box is installed to allow access to the wiring and devices.

(1) Box Sizes (100 in.^{3} or Less). If the box opening is reduced from the outer walls of the box, the opening must comply with the following:

(1) Be centered not more than 1 in. from the centerline of the box
(2) Not extend beyond the walls of the box
(3) If rectangular, the opening must be not less than 2⅞ in. × 1 3/16 in.
(4) If circular, the opening diameter must not be less than 3½ in.

Ex: Smaller openings for individual devices are permitted if the following conditions are met:

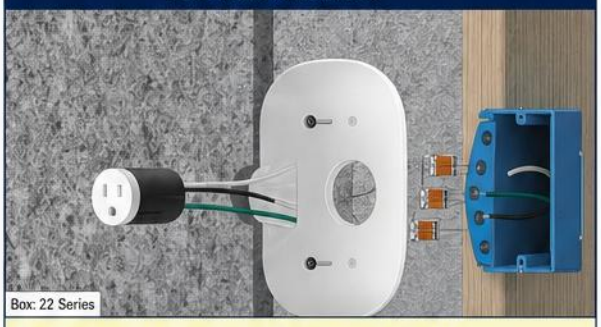
(1) The branch-circuit wiring that supplies each wiring device consists of a separate cable or raceway that originates outside the box and other than the connections to the device. These branch-circuit conductors are not spliced in the box or continued to another device, and no other wiring or raceways enter the box.

(2) Each device is capable of removal without being damaged. If a special tool is required for this purpose, the circuit directory must provide the location of the tool, together with a product or QR code for acquiring a replacement if necessary.

(3) All connections for each device are made with a listed clamping-type wire connector supplied with the device. The branch-circuit conductors are arranged to permit the connectors to be exposed after the device has been fully removed.

(4) The device assemblies are listed for this application. ▸ Figure 314–75

Figure 314–75 Boxes to be Accessible Behind Finished Surfaces 314.29(A) Ex



Smaller openings for individual devices are permitted if:
(1) The wiring that supplies each device consists of a separate cable or raceway and no other wiring enter the box.
(2) If a special tool is required for this purpose, the circuit directory must provide the location of the tool with a product code/QR code.
(3) All connections are made with listed clamping-type wire connectors supplied with the devices.
(4) The device assemblies are listed for this application.

This example illustrates permitted smaller openings behind a finished surface.

(2) Box Sizes (100 in.^{3} or Larger). Openings must not be smaller than the outer walls of the boxes.

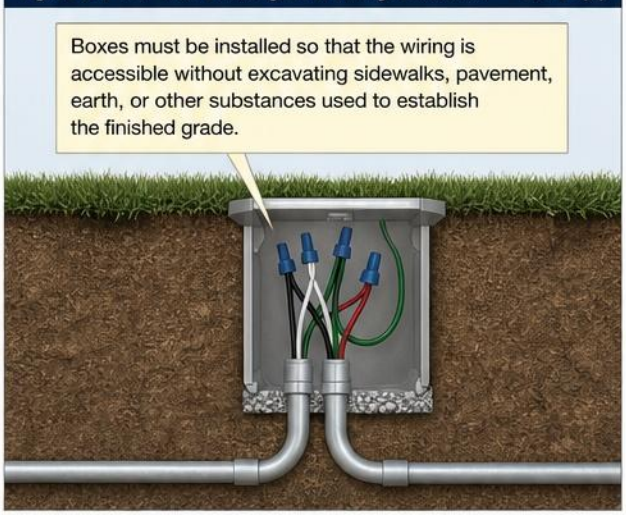
(B) Boxes Underground. Boxes must be installed so that the wiring is accessible without excavating sidewalks, pavement, earth, or other substances used to establish the finished grade. ▸ Figure 314–76

314.30 Handhole Enclosures

Handhole enclosures must be identified for underground use, designed, and installed to withstand all loads likely to be imposed on them. ▸ Figure 314–77

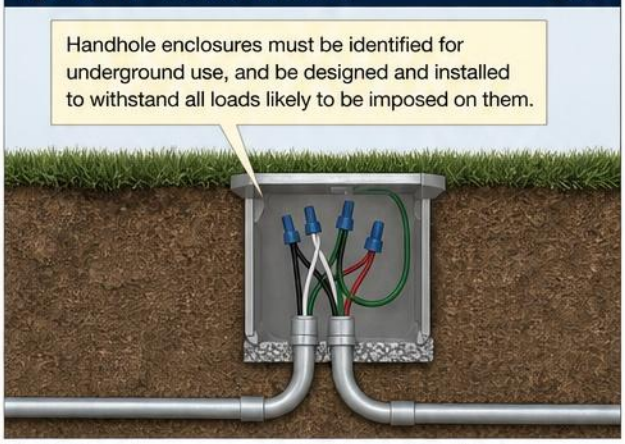
Handhole Enclosure. An underground enclosure with an open or closed bottom that is sized to allow personnel to reach into but not enter the enclosure. ▸ Figure 314–78

Figure 314–76 Boxes Underground Wiring Accessible 314.29(B)



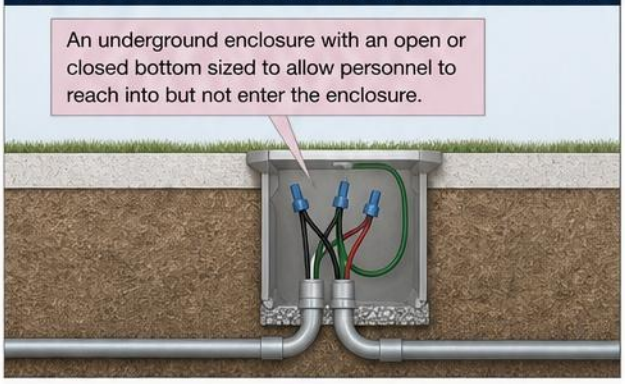
Boxes shall be positioned to allow access to wiring without the need to dig up sidewalks, pavement, soil, or any material that forms the finished grade.

Figure 314–77 Handhole Enclosures 314.30



Handhole enclosures are required to bear an identification for underground use and must be constructed and installed to resist anticipated loads.

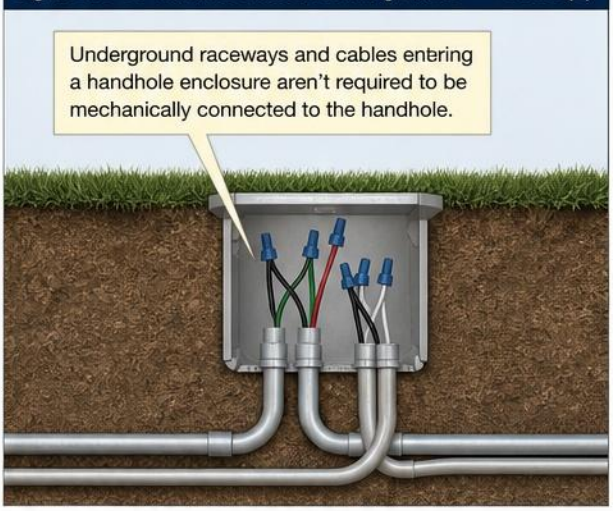
Figure 314–78 Handhole Enclosure Article 100 Definition Article 100



A handhole enclosure is an underground enclosure with either an open or closed bottom that is large enough for a person to reach into it but not to enter it.

(B) Mechanical Connection of Wiring Entries. Underground raceways and cables entering a handhole enclosure are not required to be mechanically connected to the handhole enclosure. Figure 314–79

Figure 314–79 Handhole Enclosures Wiring Entries 314.30(B)



Raceways and cables that enter a handhole enclosure beneath ground do not need to be mechanically secured to the enclosure.

(C) Wet Location Wiring. Splices and termination devices within a handhole enclosure must be listed for wet locations. Figure 314–80

Figure 314–80 Handhole Enclosures Splices and Terminations 314.30(C)

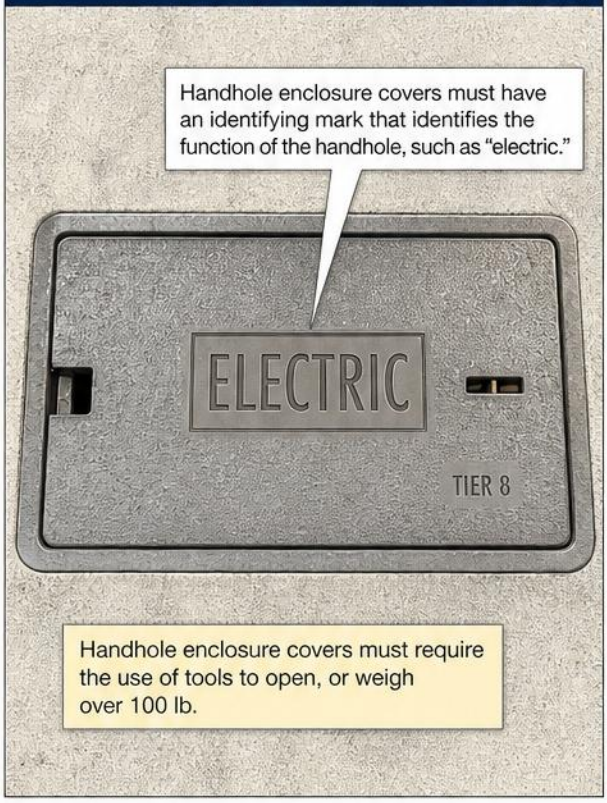
Any splices and termination equipment located inside a handhole enclosure must be listed for use in wet environments.

(D) Enclosure Covers.

(1) Marking. Handhole enclosure covers must have an identifying mark that identifies the function of the handhole (such as "electric").

(2) Access. Handhole enclosure covers must require the use of tools to open or weigh over 100 lb. Figure 314–81

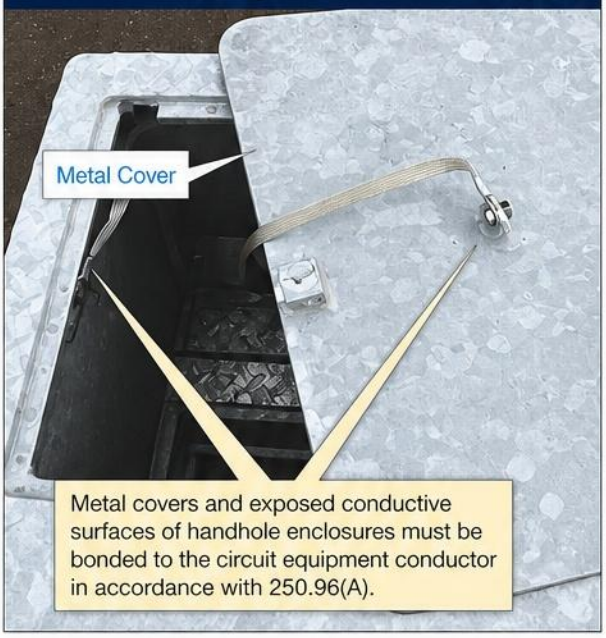
Figure 314–81 Handhole Enclosure Cover Marking and Access 310.30(D)(1) and (2)



Handhole enclosure covers must be marked to indicate the handhole's function. They must require tools for opening or have a weight greater than 100 pounds.

(3) Bonding. Metal covers and exposed conductive surfaces of handhole enclosures must be bonded to the circuit equipment conductor in accordance with 250.96(A).

Figure 314–82 Handhole Enclosure Cover Bonding 314.30(D)(3)

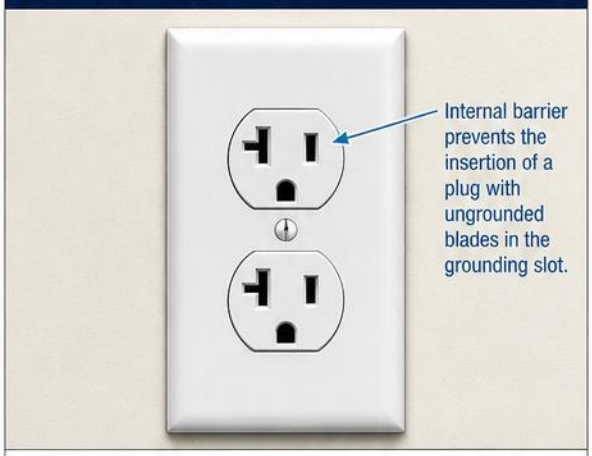


Metal covers and any exposed conductive surfaces on handhole enclosures must be bonded to the circuit equipment conductor per 250.96(A).

Article 100 Definitions

Receptacle, Barrier. A device configured to prevent simultaneous insertion of plugs with thicker grounding pins and non-grounding pins. This helps reduce the risk of shock that could occur if the equipment grounding conductor is absent or connected improperly.

Figure 1 Barrier-Type Receptacle 100

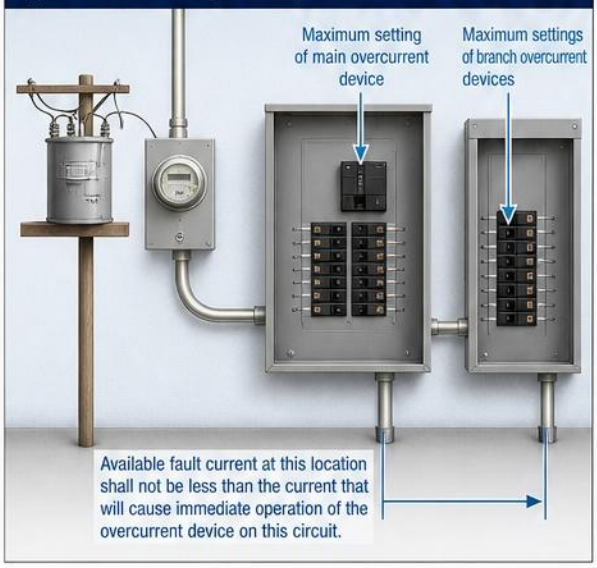


A barrier inside the receptacle blocks a non-grounding plug from inserting its blades into the grounding slot.

Article 110 Requirements for Electrical Installations

110.24 Available Fault Current. The available fault current at service terminals or equipment terminals supplied by a feeder or branch circuit, based on the maximum rating or setting of the combined system and overcurrent protective devices, shall not be less than the current that will cause the immediate operation of an overcurrent device on that feeder or branch circuit.

Figure 2 Maximum Rating or Setting of Overcurrent Protective 110.24



Article 210 Branch Circuits

210.52 (A) Dwelling Unit Receptacle Outlets. Receptacle outlets serving dwelling unit kitchen countertop surfaces shall be provided so that no point measured horizontally along the wall line is more than 24 in. (600 mm) from a receptacle outlet in that space.

Figure 3 Kitchen Countertop Receptacle Spacing 210.52 (A)

Along the wall line, no point on the countertop can be more than 24 in. (600 mm) from a receptacle outlet.

210.63 Outdoor Outlets. Receptacle outlets installed outdoors and not under an eave, roof extension, or similar covering shall be weather-resistant as specified in 406.9(B)(1) and shall comply with one of the following:

(1) Have an enclosure that is weatherproof whether the attachment plug cap is inserted in the receptacle or not.

(2) Be of the weather-resistant type.

Figure 4 Weather-Resistant Outdoor Receptacles 210.63

Outdoors and not under cover: either the receptacle has an enclosure that remains weatherproof with or without the plug inserted, or the receptacle is of the weather-resistant type.

ARTICLE

320 Armored Cable (AC Cable)

Introduction to Article 320—Armored Cable (AC Cable)

Article 320 covers the use, installation, and construction specifications of ***armored cable (AC cable)***. AC cable is an assembly of up to four phase conductors and one neutral insulated conductor individually wrapped in a moisture-resistant, fire-retardant paper, and contained within a flexible spiral metal armor. This cable type is often used in commercial and residential applications where flexibility, mechanical protection, and speed of installation are important.

Don't confuse AC cable with MC cable—AC cable has a bonding strip and must be terminated with connectors listed for AC to ensure an effective ground-fault current path.

Cable, Armored Cable (AC). A fabricated assembly of conductors in a flexible interlocked metallic armor with an internal bonding strip in intimate contact with the armor for its entire length. **Figure 320–1**

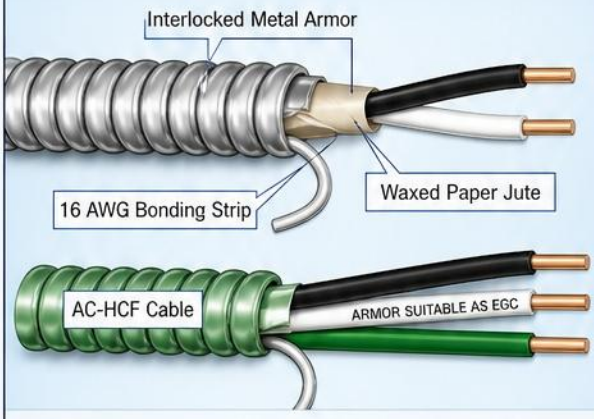
Part I. General

320.1 Scope

This article contains the requirements for the use, installation, and construction specifications of armored cable (AC cable). **Figure 320–2**

Figure 320–1 Article 100 Definition Article 100 Definition

Armored Cable (AC Cable)

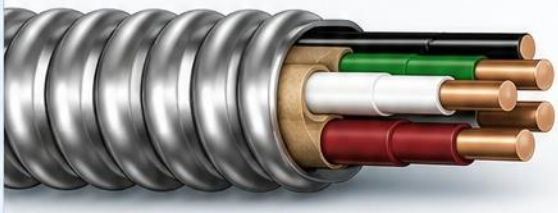


A fabricated assembly of conductors in a flexible interlocked metallic armor with an internal bonding strip in intimate contact with the armor for its entire length.

Figure 320–2 320.1 Scope 320.1 Scope

Armored Cable (AC Cable)
320.1 Scope

Type AC-HCF Steel Armor Health Care Facility



This article contains the requirements for the use, installation, and construction specifications of armored cable (AC cable).

320.2 LISTING REQUIREMENTS

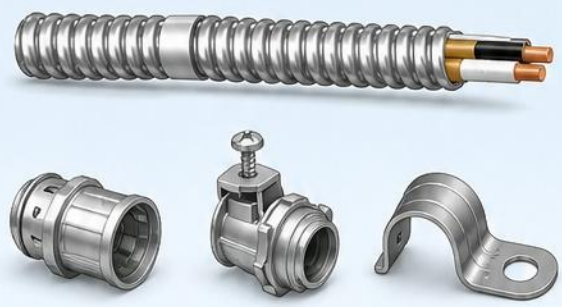
The following must be listed and identified:

(1) AC cable

(2) Cable ties, staples, straps, and hangers

(3) Fittings used to connect AC cable to boxes, cabinets, or equipment Figure 320–3

Figure 320–3 AC Cable, Listing Requirements 320.2



The following must be listed and identified:
(1) AC cable
(2) Cable ties, staples, straps, and hangers
(3) Fittings used to connect AC cable to boxes, cabinets, or equipment

(3) In air voids of block or tile walls where such walls are exposed or subject to excessive moisture or dampness

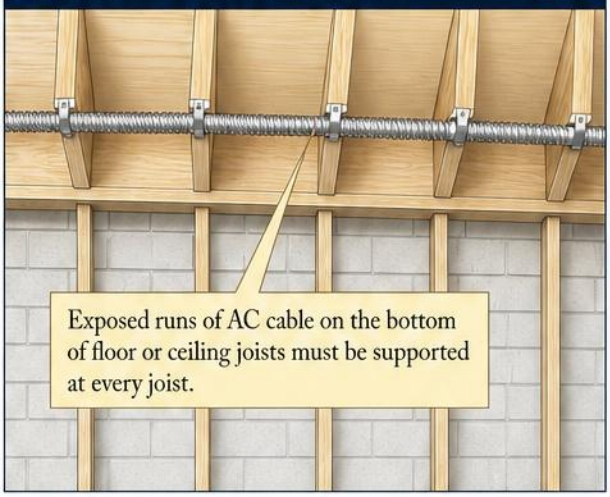
(4) Where exposed to corrosive conditions

(5) Embedded in plaster finish or concrete in wet or damp locations

320.15 EXPOSED WORK

Exposed runs of AC cable on the bottom of floor or ceiling joists must be supported at every joist. Figure 320–4

Figure 320–4 AC Cable, Exposed Work 320.15



Part II. Installation

320.10 USES PERMITTED

AC cables are permitted to be used as follows:

(1) Feeders and branch circuits

(2) In cable trays

(3) In dry locations

(4) Embedded in plaster in dry locations

(5) In air voids of block walls where not exposed to excessive moisture or dampness

320.12 USES NOT PERMITTED

AC cable is not permitted to be used as follows:

(1) Where subject to physical damage as determined by the AHJ

(2) In damp or wet locations

320.17 THROUGH OR PARALLEL TO FRAMING MEMBERS

AC cable installed through or parallel to framing members or furring strips must be protected against physical damage from penetration by screws or nails. This is done by maintaining a 1¼ in. separation between the cable and nearest edge of a wood framing member or furring strip or suitable metal plate in accordance with 300.6(A), (C), and (D). Figure 320–5 and Figure 320–6

Figure 320-5 Protection from Physical Damage Through Wood Framing Members 320.17

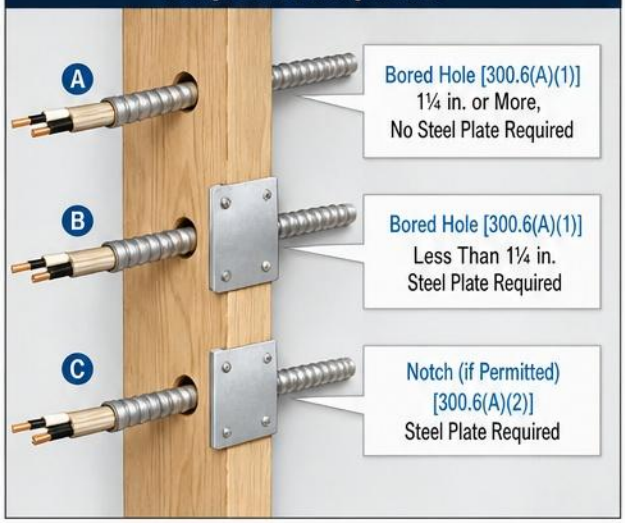


Figure 320-7 AC Cable in Attic Spaces Not Accessible by Permanent Means 320.23(A)(2)

Figure 320-6 AC Cable, Protection from Physical Damage Parallel to Framing Members 320.17

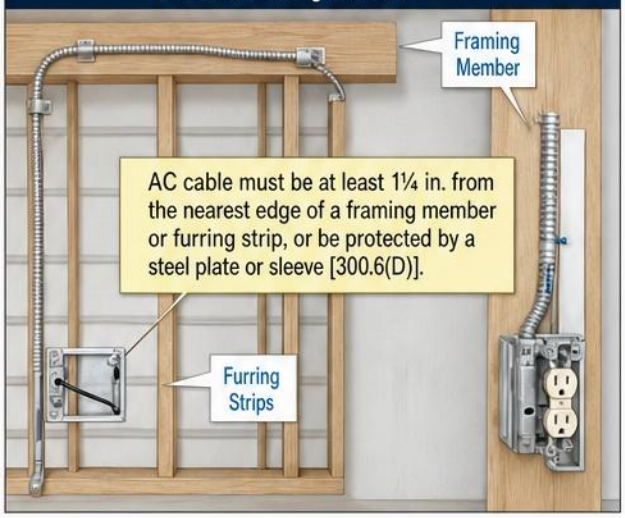
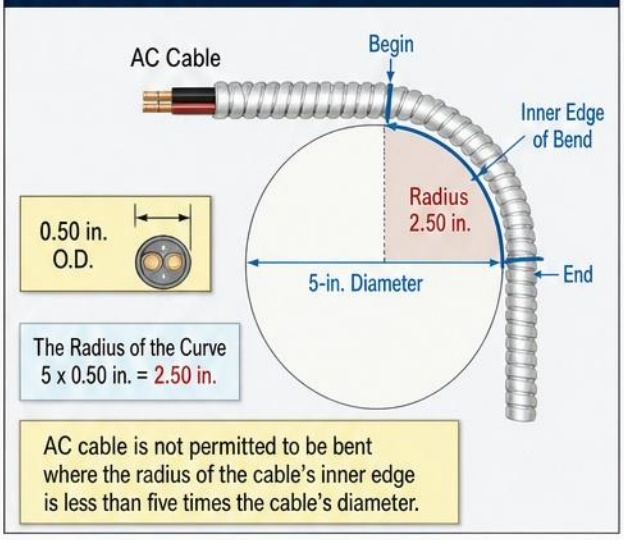


Figure 320-8 AC Cable Bending Radius 320.24



320.23 In Accessible Attic Spaces

(A) Cables Run Across the Top of Framing Members.

(1) Accessible by Permanent Means. AC cable in attic spaces accessible by permanently installed stairs or ladders run across the top of framing members, or across the face of rafters or studding within 7 ft of the floor or horizontal surface, must be protected by guard strips that are at least as high as the cable.

(2) Not Accessible by Permanent Means. AC cable in attic spaces not accessible by permanently installed stairs or ladders run across the top of framing members within 6 ft of the nearest edge of the attic space entrance must be protected by guard strips that are at least as high as the cable. Figure 320-7

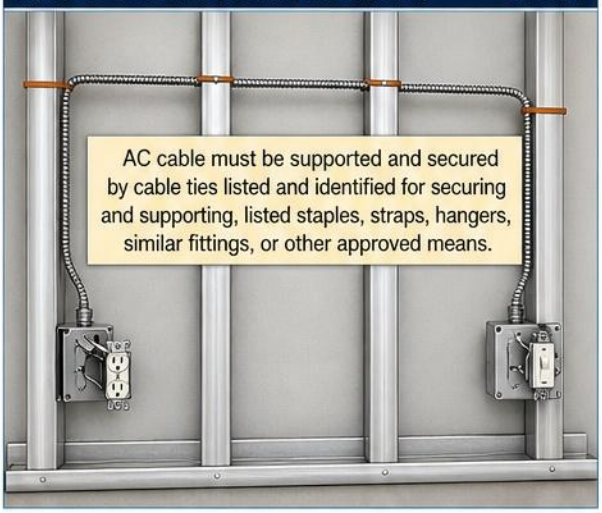
320.24 Bending Radius

AC cable is not permitted to be bent where the radius of the cable's inner edge is less than five times the cable's diameter. Figure 320-8

320.30 Securing and Supporting

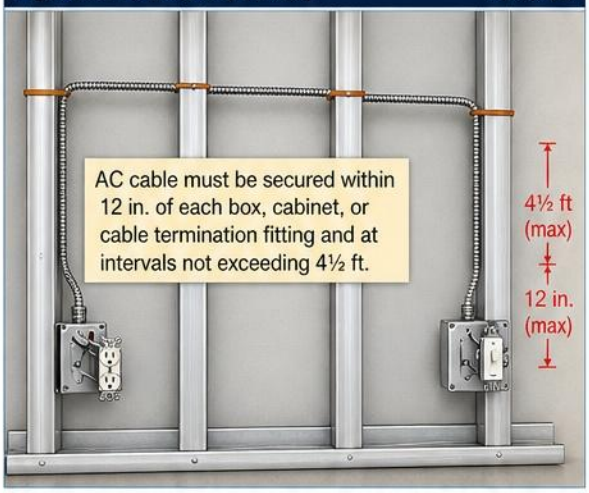
(A) General. AC cable must be supported and secured by cable ties listed and identified for securing and supporting listed staples, straps, hangers, similar fittings, or other approved means. Figure 320-9

Figure 320–9 AC Cable, Securing and Supporting 320.30(A)



AC cable shall be held in place and fastened using cable ties that are listed and identified for the purpose, listed staples, straps, hangers, comparable fittings, or other approved methods.

Figure 320–10 AC Cable, Securing 320.30(B)



AC cable shall be fastened within 12 in. of each box, cabinet, or cable termination fitting, and at distances not greater than 4½ ft between fastenings.

(B) Securing. AC cable must be secured within 12 in. of each box, cabinet or cable termination fitting. AC cable must be secured at intervals not exceeding 4½ ft. ▶Figure 320–10

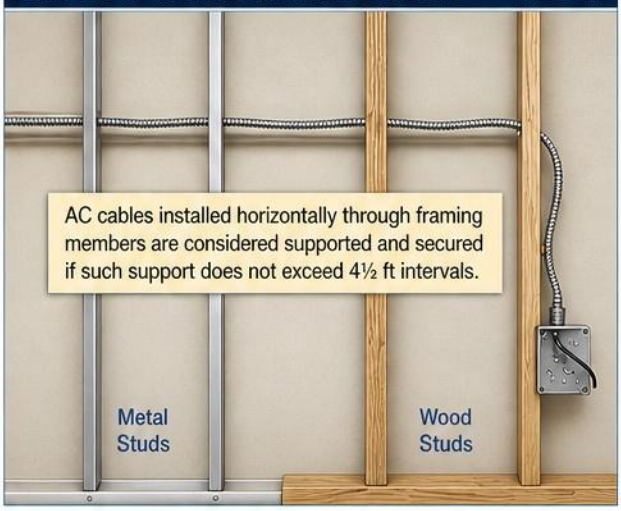
(C) Supporting. AC cables installed horizontally through framing members are considered supported and secured—if such support does not exceed 4½ ft intervals. ▶Figure 320–11

(D) Unsupported and Unsecured Cables. AC cable can be unsupported and unsecured as follows:

(1) Where fished through concealed spaces and supporting is impracticable

(2) Where not more than 2 ft long at terminals

Figure 320–11 AC Cable, Supporting Horizontal Runs 320.30(C)



Where the distance from the last point of cable support to the connection point of a luminaire or other equipment is more than 6 ft, that distance must be within an accessible ceiling.

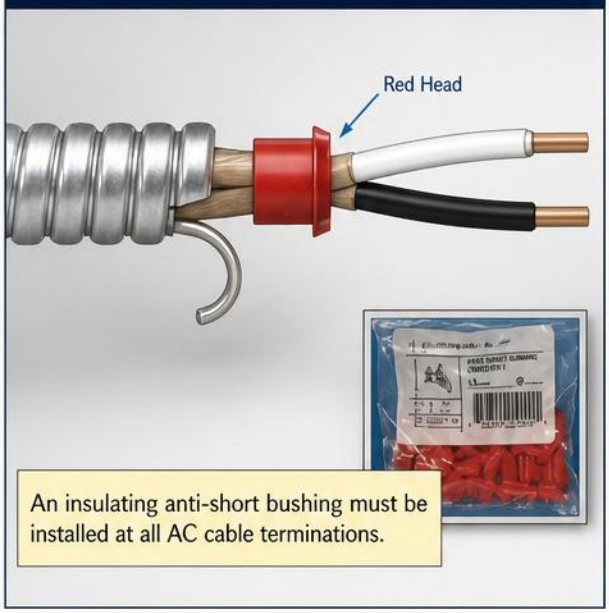
Figure 320–12 AC Cable, Unsupported and Unsecured Accessible Ceiling 320.30(D)(3)

(3) Where not more than 6 ft long from the last point of cable support to the point of connection to a luminaire or other equipment within an accessible ceiling ▶Figure 320–12

320.40 Boxes and Fittings

An insulating anti-short bushing (sometimes called a "redhead") must be installed at all AC cable terminations. ▶Figure 320–13

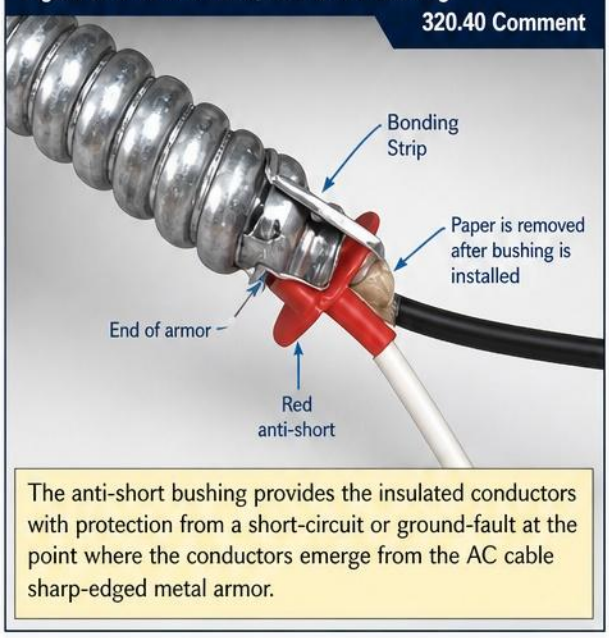
Figure 320–13 AC Cable, Boxes and Fittings, Anti-Short Bushing 320.40



Author's Comment:

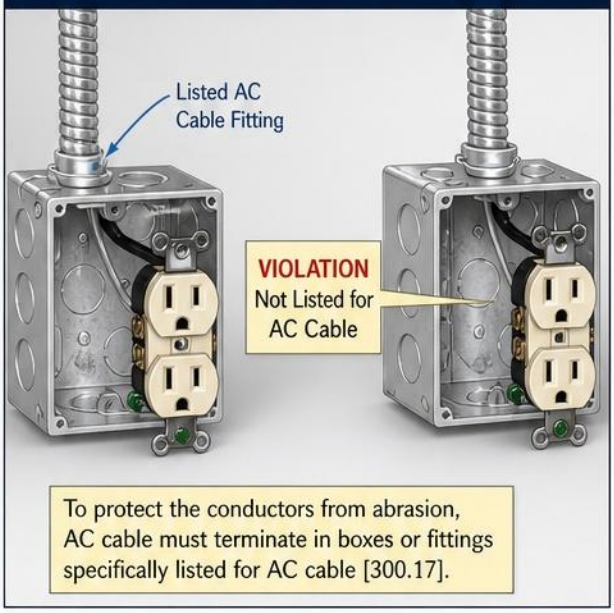
- The anti-short bushing provides the insulated conductors with protection from a short-circuit or ground-fault at the point where the conductors emerge from the AC cable's sharp-edged metal armor. [Figure 320–14]

Figure 320–14 AC Cable, Anti-Short Bushing 320.40 Comment



- To protect the conductors from abrasion, AC cable must terminate in boxes or fittings specifically listed for AC cable [300.17]. [Figure 320–15]

Figure 320–15 AC Cable, Boxes and Fittings, Protection from Abrasion 320.40 Comment



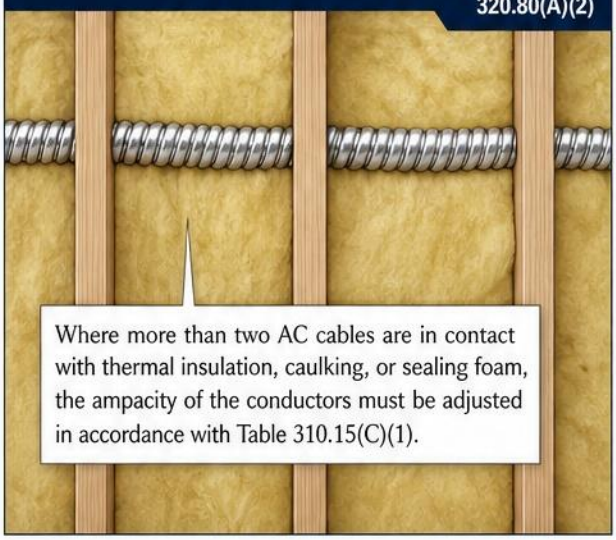
320.80 Conductor Ampacity

The ampacity of AC cable must be determined in accordance with 310.14.

(A) Thermal Insulation.

(2) Ampacity Adjustments. Where more than two AC cables are in contact with thermal insulation, caulking, or sealing foam, the ampacity of the conductors must be adjusted in accordance with Table 310.15(C)(1). [Figure 320–16]

Figure 320–16 AC Cable, Conductor Ampacity Adjustment Thermal Insulation, Caulking, or Sealing Foam Foam 320.80(A)(2)

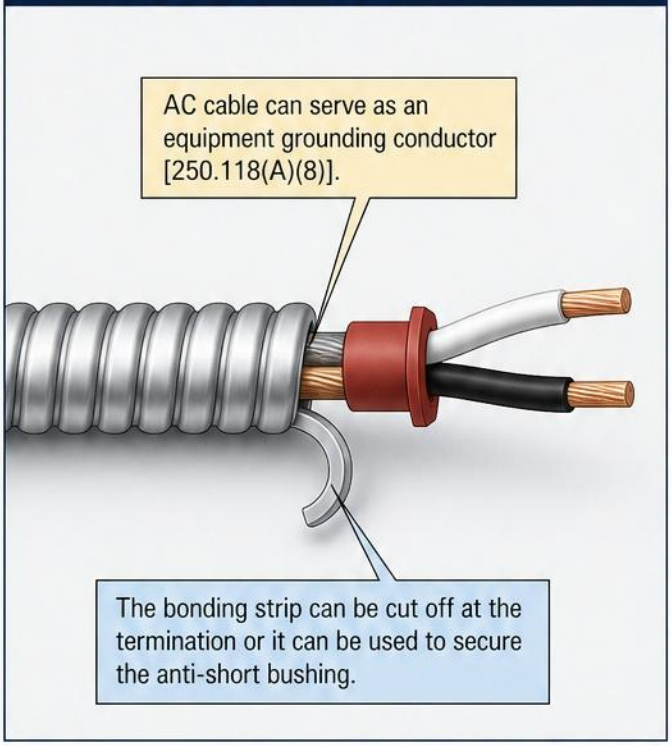


Part III. Construction Specifications

320.108 Equipment Grounding Conductor

AC cable can serve as an equipment grounding conductor [250.118(A)(8)].

Figure 320–17 **320.108**
AC Cable, Equipment Grounding Conductor



The internal bonding strip of AC cable may be trimmed off at the end of the run or retained and used to fasten the anti-short bushing.

Author's Comment:

- The internal aluminum bonding strip is not an equipment grounding conductor, but it allows the interlocked armor to serve as one because it reduces the impedance of the armored spirals to ensure a ground fault will be cleared. It is the combination of the aluminum bonding strip and the cable armor that creates the equipment grounding conductor.
- Once the bonding strip exits the cable, it can be cut off because it no longer serves any purpose. The effective ground-fault current path must be maintained by using fittings specifically listed for AC cable, see 300.15.

ARTICLE

330 Metal-Clad Cable (MC Cable)

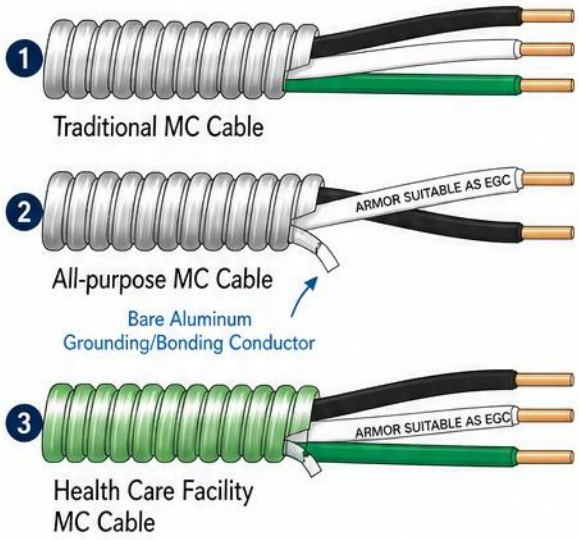
Introduction to Article 330—Metal-Clad Cable (MC Cable)

Article 330 sets forth the rules for the use, installation, and construction of *metal-clad cable (MC Cable)*. MC cable is a assembly of one or more insulated conductors 18 AWG through 2000 kcmil with an overall polypropylene wrap enclosed in a metal sheath of either corrugated or smooth copper or aluminum tubing, or spiral interlocked steel or aluminum. Unlike AC cable, MC cable includes an insulated equipment grounding conductor, making it suitable for a wider range of applications.

Metal-clad cable (MC Cable). MC cable is a factory assembly of conductors enclosed in an interlocking metal tape armor.

See **Figure 330–1** and **Figure 330–2**.

Figure 330–1: MC Cable Composition 330.1



A factory assembly of conductors enclosed in an interlocking metal tape armor.

Figure 330–2: MC Cable Construction 330.2

A factory assembly of conductors enclosed in an armor of interlocking metal tape.

Part I. General

330.1 Scope

This article sets forth the rules for the use, installation, and construction of metal-clad cable (MC Cable).

See **Figure 330–3**.

Figure 330–3 Metal-Clad Cable (MC Cable) 330.1 Scope

This article sets out the rules for using, installing, and constructing metal-clad cable (MC cable).

Author's Comment:

The three most common tools used for cutting MC cable sheathing are the rotary cutter, ring cut saw, and hacksaw.

330.2 Listing Requirements

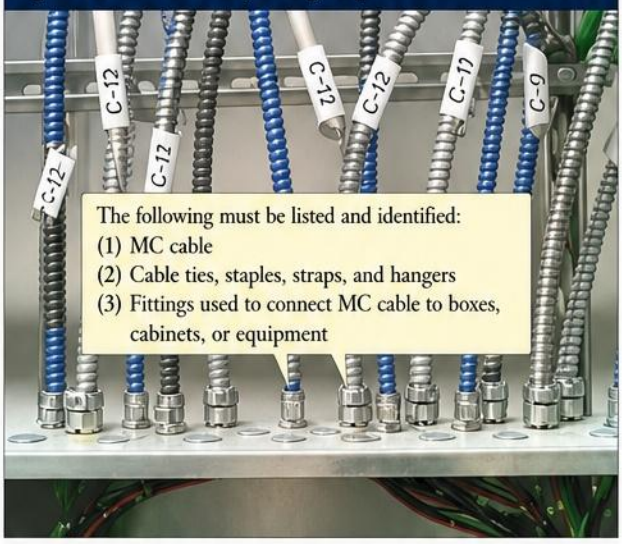
The following must be listed and identified:

(1) MC cable

(2) Cable ties, staples, straps, and hangers

(3) Fittings used to connect MC cable to boxes, cabinets, or equipment ▶ Figure 330–4

Figure 330–4 MC Cable, Listing Requirements 330.2



MC cable and related fittings must be listed and identified for the connections specified.

Author's Comment:

- MC cable is made with several types of metal sheaths. Steel and aluminum are the most common, but they are also available with a corrugated copper sheath or a PVC outer jacket for use in environments requiring such protection.
- MC^AP® cable has a full-size equipment grounding conductor in intimate contact with the metal outer sheath armor throughout the cable's entire length.
- Section 320.40 requires anti-short bushing (redheads) at all terminations of AC cable. However, the *Code* does not require anti-short bushings at the termination of MC cable.

Part II. Installation

330.10 Uses Permitted

(A) General Uses. MC cable is permitted to be used as follows:

(1) Branch circuits, feeders, and services

(2) Power, lighting, and power-limited circuits

(3) Indoor or outdoor locations

(4) Exposed or concealed

(5) Directly buried (if identified for the purpose)

(6) In a cable tray (if identified for the purpose)

(7) In a raceway

(8) As aerial cable on a messenger

(9) Hazardous locations as permitted in 501.10(B)(5), 502.10(B)(4), and 503.10(A)(1)

(10) Embedded in plaster in dry locations

(11) Damp or wet locations where a moisture-impervious jacket is provided over the metallic covering

(B) Specific Uses.

(1) **Cable Tray.** Installed in a cable tray in accordance with Article 392.

(2) **Direct Buried.** Direct-buried MC cables must be protected in accordance with 300.7.

(3) **Installed as Service-Entrance Cable.** Used as service-entrance cable when installed in accordance with 230.43.

(4) Installed Outside Buildings. Installed outside buildings must comply with 225.10, 396.10, and 396.12.

330.12 Uses Not Permitted

MC cable is not permitted to be used where:

(1) Subject to physical damage as determined by the AHJ

(2) Exposed to the destructive corrosive conditions, unless the metallic sheath or armor is resistant to the conditions, or is protected by material resistant to the conditions as follows:

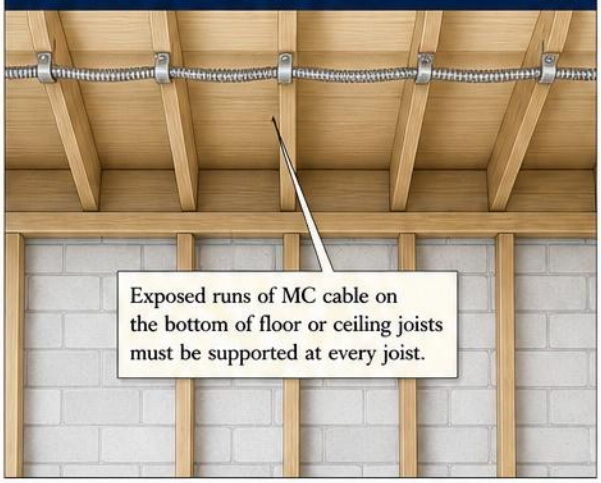
a. Direct burial or embedded in concrete, unless identified for the application

b. Exposed to cinder fills, strong chlorides, caustic alkalis, or vapors of chlorine or hydrochloric acids

330.15 Exposed Work

Exposed runs of MC cable on the bottom of floor or ceiling joists must be supported at every joist.

Figure 330–5: MC Cable, Exposed Work 330.15

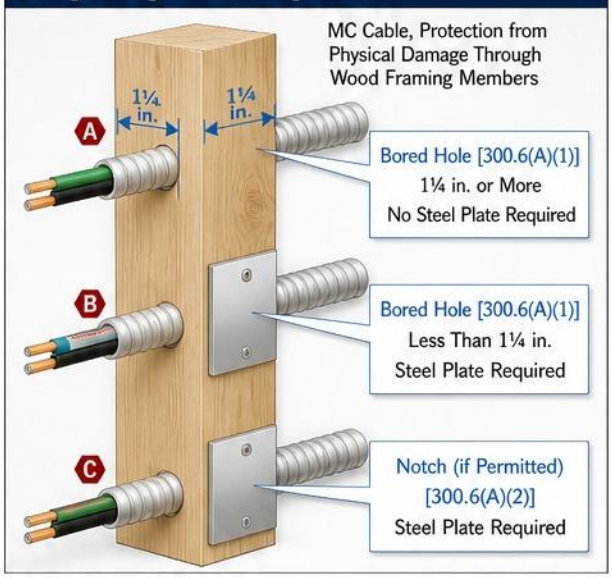


330.17 Through or Parallel to Framing Members

MC cable installed through or parallel to framing members or furring strips must be protected against physical damage from the penetration of screws or nails by maintaining a 1¼ in. separation from the nearest edge of a framing member or furring strip, or by installing a suitable metal plate in accordance with 300.6(A), (C), and (D).

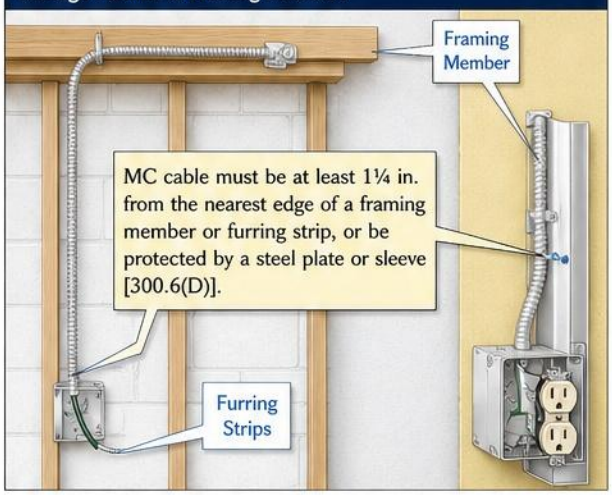
Figure 330–6 and Figure 330–7

Figure 330–6: MC Cable, Protection from Physical Damage Through Wood Framing Members 330.17



Maintain at least 1¼ in. from the nearest edge of framing members, or use steel plates as shown, in accordance with 300.6(A).

Figure 330–7: MC Cable, Protection from Physical Damage Parallel to Framing Members 330.17



When installed parallel to framing members or furring strips, maintain a 1¼ in. separation or provide steel-plate protection per 300.6(D).

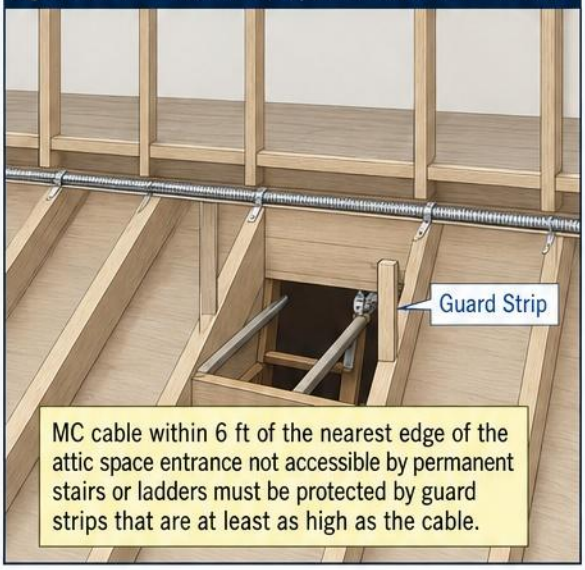
330.23 In Accessible Attic Spaces

Cables Run Across the Top of Framing Members.

Accessible by Permanent Means. MC cable in accessible attic spaces accessible by permanently installed stairs or ladders run across the top of framing members, or across the face of rafters or studding within 7 ft of the floor or horizontal surface, the cable must be protected by guard strips that are at least as high as the cable.

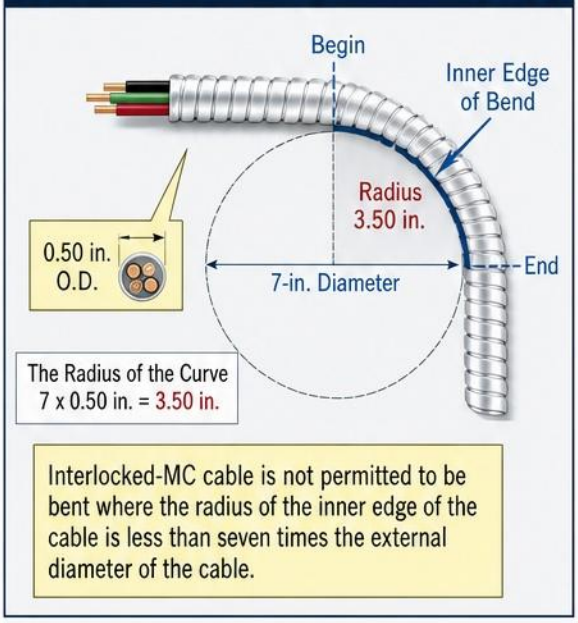
Not Accessible by Permanent Means. MC cable in spaces not accessible by permanently installed stairs or ladders run across the top of framing members within 6 ft of the nearest edge of the attic space entrance must be protected by guard strips that are at least as high as the cable. Figure 330–8

Figure 330–8 Not Accessible by Permanent Means 330.23



(B) Interlocked Armor. Interlocked-MC cable is not permitted to be bent where the radius of the inner edge of the cable is less than seven times the external diameter of the cable. Figure 330–9

Figure 330–9 Interlocked Armor 330.24(B)



330.30 SECURING AND SUPPORTING

(A) General. MC cable must be supported and secured by:

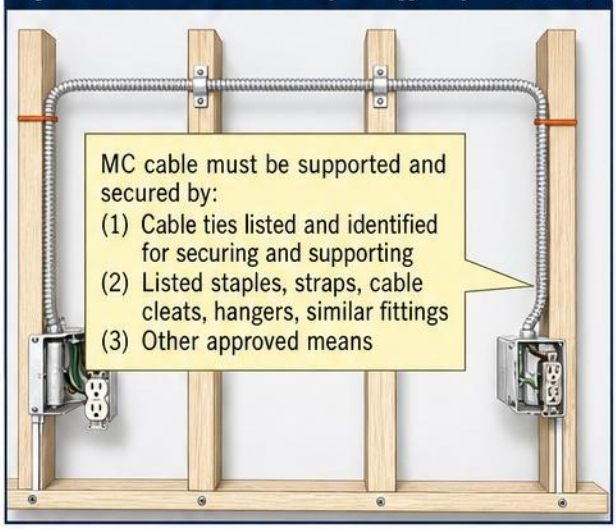
(1) Cable ties listed and identified for securing and supporting

(2) Listed staples, straps, cable cleats, hangers, and similar fittings

(3) Other approved means

Figure 330–10

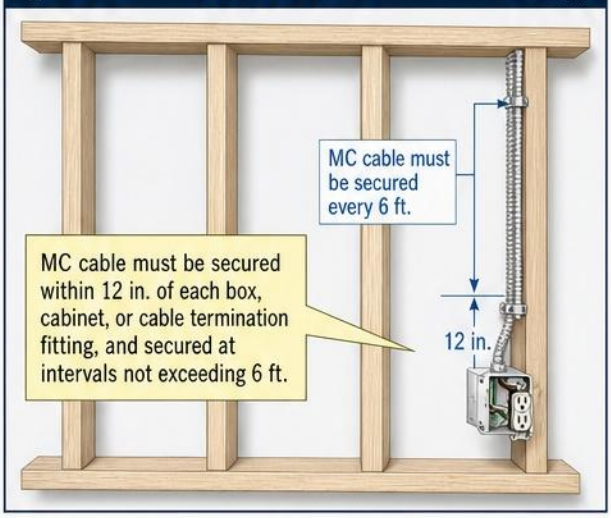
Figure 330–10 MC Cable Securing and Supporting 330.30(A)



(B) Securing.

10 AWG and Smaller. MC cable containing four or less conductors 10 AWG and smaller must be secured within 12 in. of each box, cabinet, or cable termination fitting, and secured at intervals not exceeding 6 ft. Figure 330–11

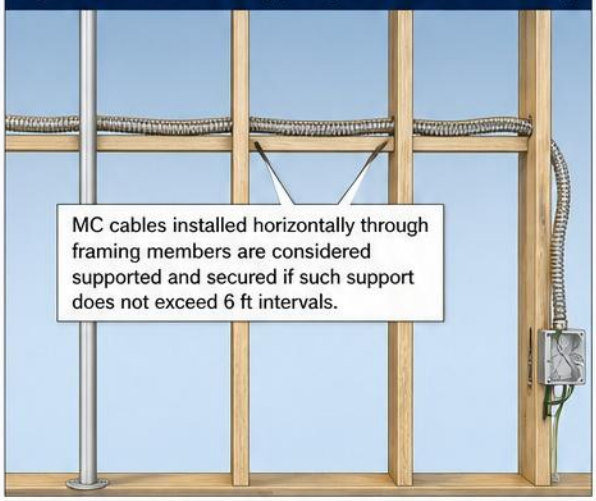
Figure 330–11 10 AWG and Smaller 330.30(B)



8 AWG and Larger. MC cable is not required to be secured within 12 in. of each box, cabinet, or cable termination fitting, but must be secured at intervals not exceeding 6 ft.

(C) Supporting. MC cables installed horizontally through framing members are considered secured and supported—if such support does not exceed 6 ft intervals. ▸ Figure 330–12

Figure 330–12 MC Cable, Supporting Horizontal Runs 330.30(C)



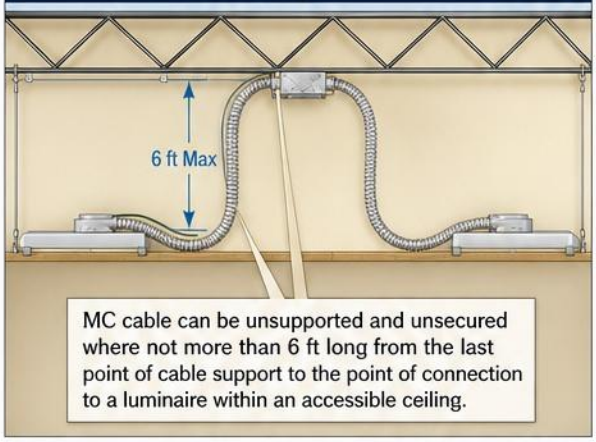
MC cable is run horizontally through studs and supported at intervals of 6 ft or less.

(D) Unsupported and Unsecured Cables. MC cable can be unsupported and unsecured as follows:

(1) Where fished through concealed spaces in a finished building and support is impractical

(2) Where not more than 6 ft long from the last point of cable support to the point of connection to a luminaire or other equipment within an accessible ceiling ▸ Figure 330–13

Figure 330–13 MC Cable, Unsupported and Unsecured Accessible Ceiling 330.30(D)(2)



The unsupported length of MC cable from the last point of support to the luminaire connection is 6 ft or less.

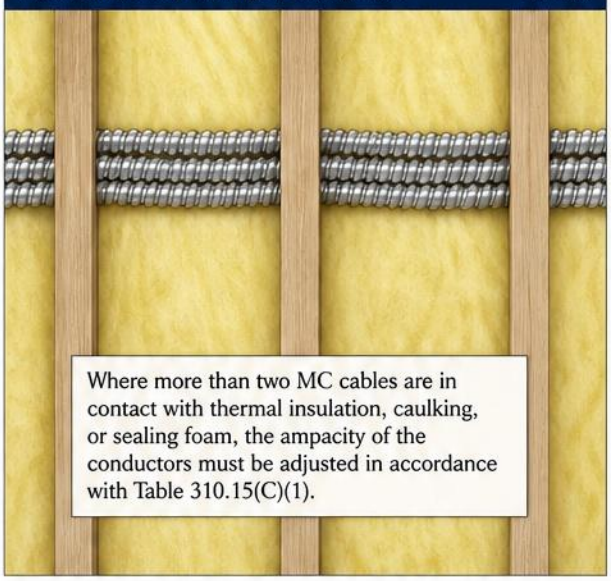
(3) Where not more than 3 ft from the last point where it is securely fastened to provide flexibility for equipment that requires movement after installation, or to connect equipment where flexibility is necessary to minimize the transmission of vibration from the equipment

330.80 Conductor Ampacities

The ampacity of MC cable must be determined in accordance with 310.14.

(C) Thermal Insulation. Where more than two MC cables are in contact with thermal insulation, caulking, or sealing foam, the ampacity of the conductors must be adjusted in accordance with Table 310.15(C)(1). ▸ Figure 330–14

Figure 330–14 MC Cable, Conductor Ampacity—Thermal Insulation, Caulking, or Sealing Foam 330.80(C)



Three or more MC cables in contact with thermal insulation require ampacity adjustment per Table 310.15(C)(1).

▶ Conductor Ampacity [330.80(A)(2)] Example

Question: Is MC cable containing four 12 AWG current-carrying conductors suitable to be protected by a 20A circuit breaker?

(*a*) *Yes* (*b*) *No*

Solution:

Step 1: Determine the ampacity of the circuit conductors in accordance with 310.16 and Table 310.15(C)(1).

12 AWG is rated 30A at 90°C [Table 310.16].

Conductor Adjustment = 80% [Table 310.15(C)(1)]

Conductor Adjusted Ampacity = 30A × 80%

= 24A

Step 2: Verify that the adjusted conductor ampacity can be protected by the 20A circuit breaker. In this case, 12 AWG is rated 24A after adjustment at 90°C and 20A at 60°C [240.4(D)].

Answer: (*a*) *Yes*

Part III. Construction Specifications

330.108 Equipment Grounding Conductor

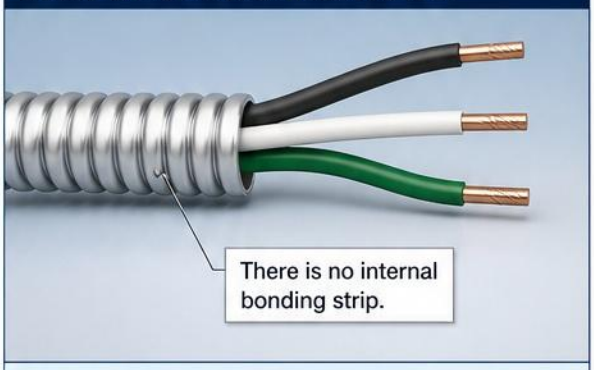
If MC cable is to serve as an equipment grounding conductor, it must comply with 250.118(A)(10) and 250.122.

Author's Comment:

▶ The outer metal sheath of traditional interlocked MC cable is not permitted to serve as an equipment grounding conductor, so this cable must contain an equipment grounding conductor of the wire-type in accordance with 250.118(A)(10)a.

Figure 330–15

Figure 330–15 250.118(A)(10)a.
Traditional MC Cable Not Listed as an EGC



The outer metal sheath of traditional interlocked MC cable is not permitted to serve as an equipment grounding conductor, so this cable must contain an equipment grounding conductor of the wire-type in accordance with 250.118(A)(10)a.

The outer metal sheath of all-purpose MC cable with an uninsulated aluminum grounding and bonding conductor can serve as an equipment grounding conductor in accordance with 250.118(A)(10)b.

Figure 330–16 250.118(A)(10)b.
MC Cable, Listed as an EGC

The outer metal sheath of all-purpose MC cable with an uninsulated aluminum grounding/bonding conductor can serve as an equipment grounding conductor in accordance with 250.118(A)(10)b.

ARTICLE 334

Nonmetallic-Sheathed Cable (NM Cable)

Introduction to Article 334—Nonmetallic-Sheathed Cable (NM Cable)

Article 334 addresses the use, installation, and construction requirements for nonmetallic-sheathed cable (NM Cable). NM cable consists of insulated conductors and an insulated or bare equipment grounding conductor 16 AWG through 2 AWG, all contained within an overall nonmetallic flame-retardant sheath. This cable type offers limited physical protection for the conductors within the sheath, so its use is generally restricted by the type of building construction. Its low cost and ease of installation make it a common wiring method for residential and light commercial applications.

Cable, Nonmetallic-Sheathed Cable (NM Cable). A cable that has insulated circuit conductors and an equipment grounding conductor enclosed within an outer nonmetallic jacket.
Figure 334–1 and Figure 334–2

Figure 334–1 **NEC 334.2**

A cable that has insulated circuit conductors and an equipment grounding conductor enclosed within an outer nonmetallic jacket.

Author's Comment:

It is the generally accepted practice in the electrical industry to call NM cable "Romex®," a registered trademark of the Southwire Company.

Figure 334–2 **NEC 334.2**

Nonmetallic-Sheathed Cable (NM Cable)
Article 100 Definition

A cable that has insulated circuit conductors and an equipment grounding conductor enclosed within an outer nonmetallic jacket.

Part I. General

334.1 Scope

This article sets forth the requirements for the use, installation, and construction specifications of nonmetallic-sheathed cable (NM Cable).
Figure 334–3

Figure 334-3 Nonmetallic-Sheathed Cable (NM Cable) 334.1 Scope

Article 334 specifies the requirements for the use, installation, and construction specifications of nonmetallic-sheathed cable (NM Cable).

334.2 Listing Requirements

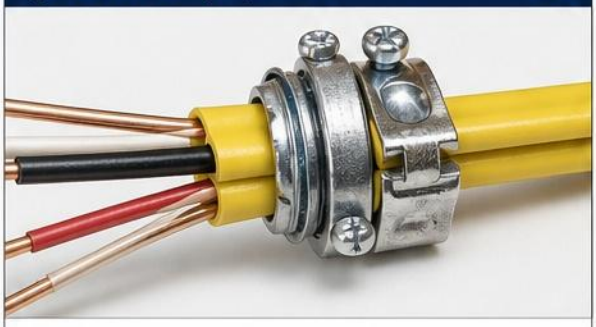
The following must be listed and identified:

(1) NM cable

(2) Cable ties, staples, straps, and hangers

(3) Fittings used to connect NM cable to boxes, cabinets, or equipment

Figure 334-4 Listing Requirements 334.2



The following must be listed and identified:

(1) NM cable

(2) Cable ties, staples, straps, and hangers

(3) Fittings used to connect NM cable to boxes, cabinets, or equipment

Part II. Installation

334.10 Uses Permitted

NM cable is permitted to be used in:

(1) One- and two-family dwellings, their garages, and storage buildings

Figure 334-5 Uses Permitted — One- and Two-Family Dwellings 334.10(1)

NM cable may be used in one- and two-family dwellings, their garages, and storage buildings.

(2) Multifamily dwellings and their detached garages in buildings of Types III, IV, and V construction

Figure 334-6 Uses Permitted — Multifamily Dwellings 334.10(2)

NM cable may be used in multifamily dwellings and their detached garages in buildings of Types III, IV, and V construction.

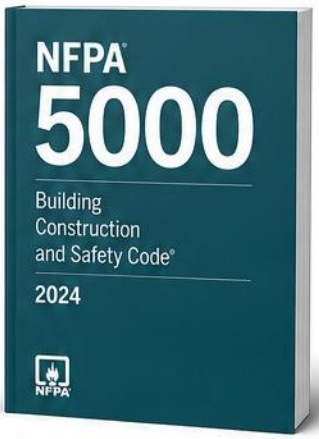
(3) Other buildings of Types III, IV, and V construction where the cable must be installed within walls, floors, or ceilings that provide a thermal barrier of material with at least a 15-minute finish rating as identified in listings of fire-rated assemblies

Figure 334–7 NM Cable, Uses Permitted
Buildings of Types III, IV, and V Construction 334.10(3)

NM cable is permitted in other buildings of Types III, IV, and V construction where the cable is installed within walls, floors, or ceilings that provide a thermal barrier of material with at least a 15-minute finish rating.

Note 2: To determine building types and the maximum number of stories allowed for each type, see *NFPA 5000, Building Construction and Safety Code*.

Figure 334–8 NM Cable, Uses Permitted
NFPA 5000, Building Construction and Safety Code 334.10(3) Note 2



To determine building types and the limits on the number of stories permitted for each type, see NFPA 5000, Building Construction and Safety Code.

Ex to (3): *Non-habitable grade level storage garages and storage buildings (less than 1500 ft² with Type V construction) are permitted to have NM cable without a 15-minute thermal barrier.*

(A) Type NM. Type NM cable is permitted as follows:

(1) For both exposed and concealed work in normally dry locations except as prohibited in 334.10(3)

(2) Installed or fished in air voids in masonry block or tile walls

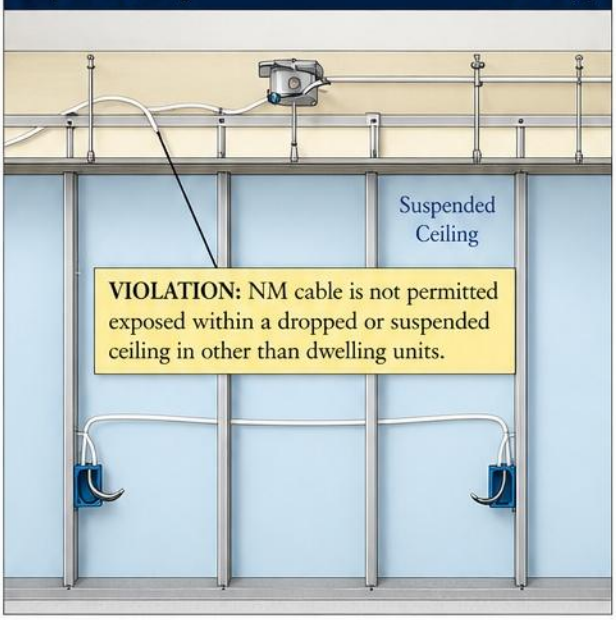
334.12 Uses Not Permitted

Type NM cable is not permitted to be used as follows:

(1) Any dwelling not specifically permitted in 334.10(1), 334.10(2), 334.10(3), and 334.10(5)

(2) Exposed within a dropped or suspended ceiling in other than dwelling units ▶ Figure 334–9

Figure 334–9 NM Cable, Uses Not Permitted
Suspended Ceiling 334.12(2)



(3) As service-entrance cable

(4) Commercial garages having hazardous locations, as defined in 511.5

(5) Theaters and similar locations, except where permitted in 518.6(C)

(6) Motion picture studios

(7) Storage battery rooms

(8) Hoistways or on elevators or escalators

(9) Embedded in poured cement, concrete, or aggregate

(10) Any hazardous location, except where permitted by other sections in this *Code*

(11) Direct-buried in the earth

(12) Where subject to physical damage as determined by the AHJ

(A) NM Cable. NM cable is not permitted to be used in:

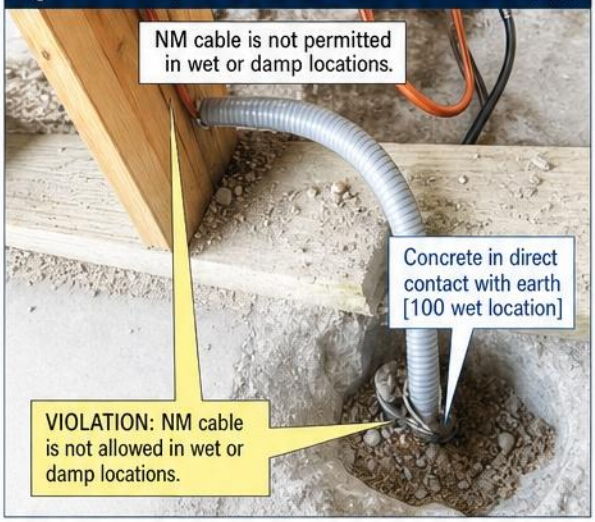
(1) Exposed to corrosive fumes or vapors

(2) Embedded in masonry, concrete, adobe, fill, or plaster

(3) Installed in shallow grooves in masonry, concrete, or adobe and covered with plaster, adobe, or similar finish.

(4) Installed in wet or damp locations. **See Figure 334–10.**

Figure 334–10 | NM Cable—Uses Not Permitted 334.12(A)(4)



NM cable installed where concrete is in direct contact with earth is not permitted in wet or damp locations.

Location, Wet Location. A location that is one of the following:

(1) Unprotected and exposed to weather

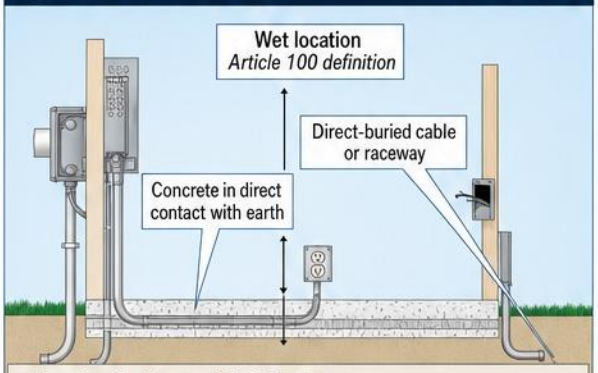
(2) Subject to saturation by water or other liquids

(3) Underground

(4) In concrete slabs or masonry in direct contact with the earth

See Figure 334–11.

Figure 334–11 | Wet Location *Article 100 Definition*

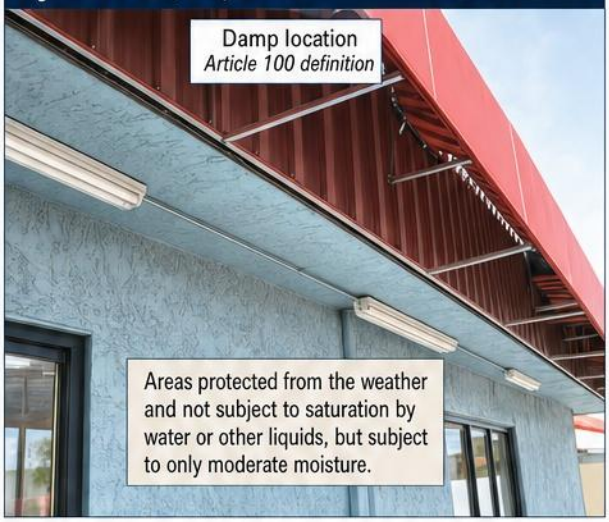


A location that is one of the following:
(1) Unprotected and exposed to weather
(2) Subject to saturation by water or other liquids
(3) Underground
(4) In concrete slabs or masonry in direct contact with the earth

Wet locations include areas exposed to the elements, subject to water saturation, underground installations, and concrete or masonry in direct contact with earth.

Location, Damp Location. Areas protected from the weather and not subject to saturation by water or other liquids, but subject to only moderate moisture. **See Figure 334–12.**

Figure 334–12 | Damp Location *Article 100 Definition*



Damp locations are protected from the weather and not subject to saturation by liquids, but are exposed only to moderate moisture.

334.15 Exposed Work

Except as provided in 300.11(B), NM cable may be installed as follows:

(B) Protected from Physical Damage.

(1) NM Cable.

(a) Protection from Physical Damage. Nonmetallic-sheathed cable must be protected from physical damage as required by the AHJ in accordance with Schedule 80 PVC, electrical metallic tubing, rigid metal conduit, intermediate metal conduit, guard strips, or other approved means authorized by the AHJ. **See Figure 334–13.**

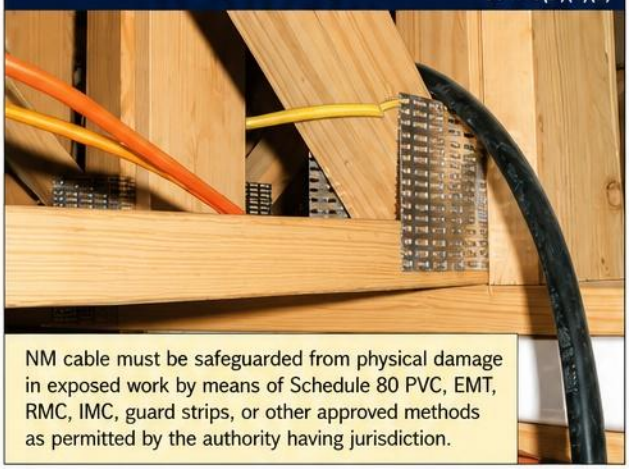
(c) Protection from Abrasion. A bushing or adapter that provides protection against abrasion is required where NM cable enters or exits the raceway. **See Figure 334–14.**

(C) In Unfinished Basements and Crawl Spaces.

Not Smaller than 6/2 or 8/3 NM Cable. In unfinished basements and crawl spaces, NM cables not smaller than 6/2 AWG or 8/3 AWG may be installed by securing them directly to the bottom edges of the joists.

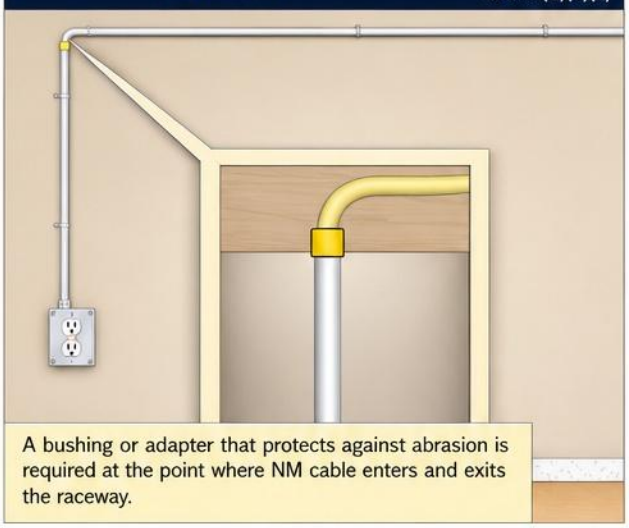
Smaller than 6/2 or 8/3 NM Cable. In unfinished basements and crawl spaces, NM cables smaller than 6/2 AWG or 8/3 AWG must be installed through bored holes in joists or on running boards. **See Figure 334–15.**

Figure 334–13 NM Cable, Exposed Work Protection from Physical Damage 334.15(B)(1)(a)



NM cable must be safeguarded from physical damage in exposed work by means of Schedule 80 PVC, EMT, RMC, IMC, guard strips, or other approved methods as permitted by the authority having jurisdiction.

Figure 334–14 NM Cable, Exposed Work Protection from Abrasion 334.15(B)(1)(c)



A bushing or adapter that protects against abrasion is required at the point where NM cable enters and exits the raceway.

Figure 334–15 NM Cable, Exposed Work Protection in Unfinished Spaces 334.15(C)

In unfinished basements and crawl spaces, NM cables must be smaller than 6/2 AWG, or 8/3 AWG, and installed through bored holes in joists or on running boards.

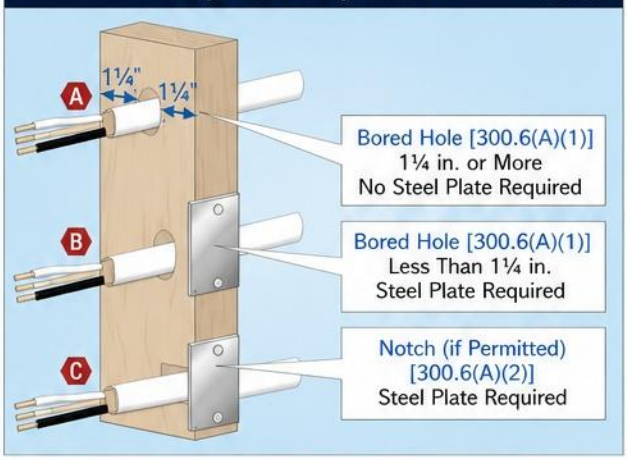
NM cable that can be damaged physically must be installed within a raceway or provided with a nonmetallic bushing that shields it from abrasion where it passes through a hole in the raceway. The cable must be secured within 12 in. of the point where it enters the raceway.

334.17 Through or Parallel to Framing Members

NM cables installed through or run parallel to framing members or furring strips must be protected by maintaining a 1¼ in. of separation between the cable and the nearest edge of a framing member, or by a suitable metal plate in accordance with 300.6(A), (C), and (D).

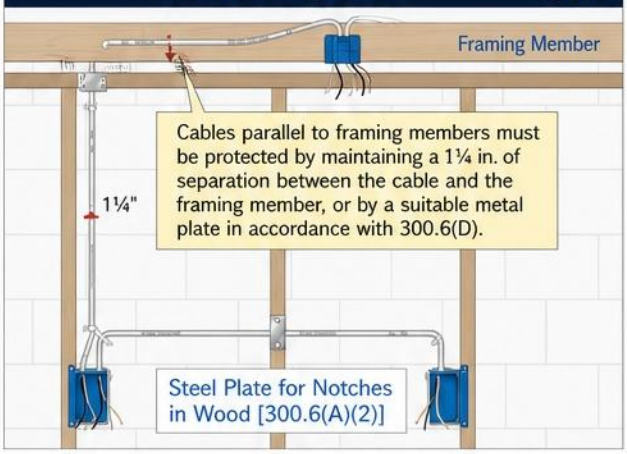
See Figures 334–16 and 334–17.

Figure 334–16 NM Cable, Protection from Physical Damage Through Wood Framing Members 334.17



When NM cable passes through wood framing members, holes or notches must meet 300.6(A) requirements, and steel plates are required where specified.

Figure 334–17 NM Cable, Protection from Physical Damage Parallel to Framing Members 334.17



When NM cable runs parallel to framing members, it must be kept 1¼ in. from the framing member or protected with a metal plate in accordance with 300.6(D).

NM cables passing through openings in metal framing members must be protected by listed bushings or grommets in accordance with 300.6(B)(1). ▸ Figure 334–18

Figure 334–18 Protection of NM Cable in Metal Members 300.6(B)(1)

NM cables passing through openings in metal framing members must be protected by listed bushings or grommets in accordance with 300.6(B)(1).

AUTHOR'S COMMENT:

- The diameter of the holes bored must not exceed one-third the depth of the joist members and must not be any closer than 2 in. to the top, bottom, or any hole in the member. The referenced sections are in the *International Building Code* (IBC) *Section* 2308.4, and the *International* Residential Code (IRC) *Section* 502.8.
- If NM cable passes through factory or field openings in metal framing members, the cable must be protected by listed bushings or grommets that cover all metal edges [300.6(B)(1)]. The protection fitting must be securely fastened in the opening before installing the cable.

334.19 CABLES ENTERING ENCLOSURES

The sheath on nonmetallic-sheathed cable must extend no less than ¼ in. beyond any cable clamp or cable entry inside enclosures or boxes.
▸ Figure 334–19

AUTHOR'S COMMENT:

- No more than one NM cable is permitted to be installed into a box cable entry, unless the box is listed for more than one NM cable [110.3(B)]. See *UL Guide Information for Nonmetallic Outlet Boxes* (QCMZ).

Figure 334–19 NM Cable Entering Enclosures 334.19

The sheath on nonmetallic-sheathed cable must extend no less than ¼ in. beyond any cable clamp or cable entry inside enclosures or boxes.

334.23 ACCESSIBLE ATTIC SPACES

Cables Run Across the Top of Framing Members.

Accessible by Permanent Means. NM cable in accessible attic spaces accessible by permanently installed stairs or ladders run across the top of framing members, or across the face of rafters or studding within 7 ft of the floor or horizontal surface, the cable must be protected by guard strips that are at least as high as the cable.

Not Accessible by Permanent Means. NM cable in accessible attic spaces not accessible by permanently installed stairs or ladders run across the top of framing members within 6 ft of the nearest edge of the attic space entrance must be protected by guard strips that are at least as high as the cable.
▸ Figure 334–20

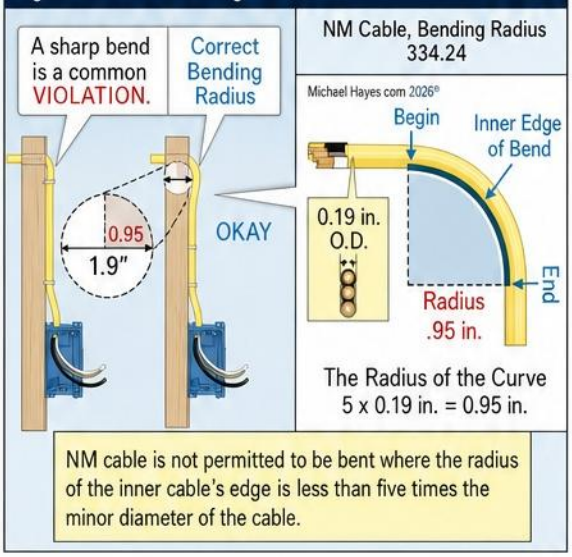
Figure 334–20 NM Cable in Attic Spaces Not Accessible by Permanent Means 334.23

NM cable within 6 ft of the nearest edge of the attic space entrance not accessible by permanent stairs or ladders must be protected by guard strips that are at least as high as the cable.

334.24 BENDING RADIUS

NM cable is not permitted to be bent where the radius of the inner cable's edge is less than five times the minor diameter of the cable.

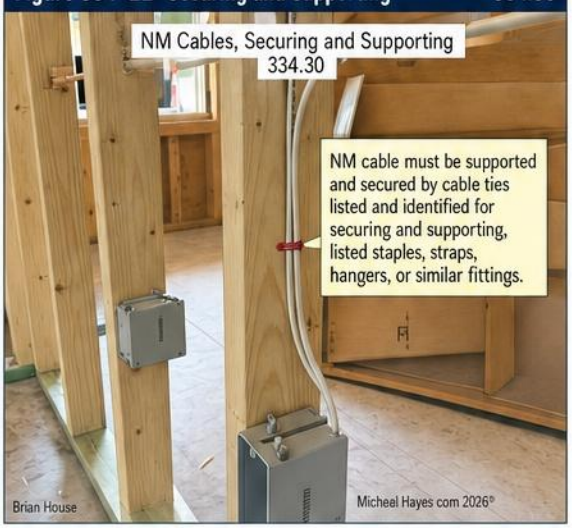
Figure 334–21 Bending Radius 334.24



334.30 SECURING AND SUPPORTING

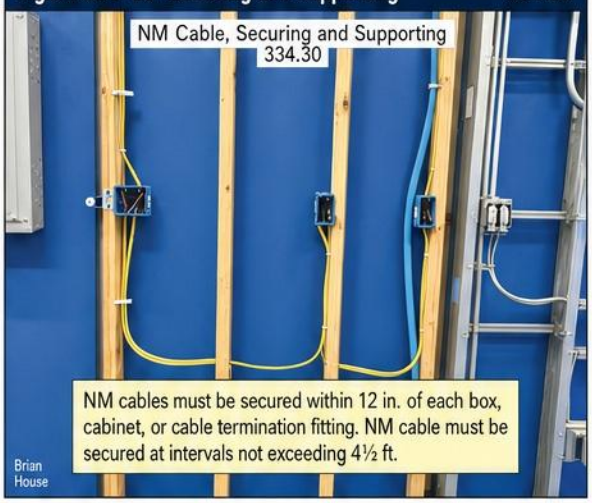
NM cable must be supported and secured by cable ties listed and identified for securing and supporting listed staples, straps, hangers, or similar fittings.

Figure 334–22 Securing and Supporting 334.30



NM cables must be secured within 12 in. of each box, cabinet, or cable termination fitting. NM cable must be secured at intervals not exceeding 4½ ft.

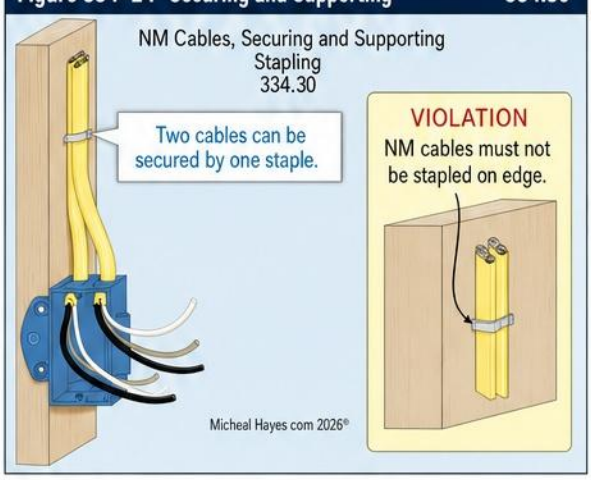
Figure 334–23 Securing and Supporting 334.30



NM cables must be secured within 12 in. of each box, cabinet, or cable termination fitting. NM cable must be secured at intervals not exceeding 4½ ft.

Flat NM cable is not permitted to be stapled on edge.

Figure 334–24 Securing and Supporting 334.30



Flat NM cable is not permitted to be stapled on edge.

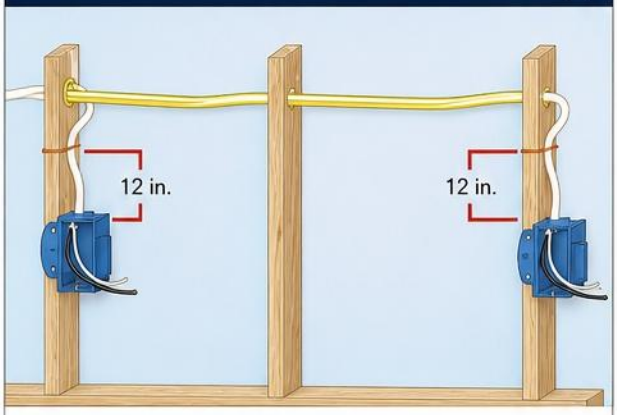
(A) Horizontal Runs. NM cable installed horizontally through bored or punched holes in wood or metal framing members or notches in wooden members, is considered secured and supported—if the distance between supports does not exceed 4½ ft, and the NM cable is secured within 1 ft of termination.

(B) Unsupported and Unsecured Cables. NM cable can be unsupported and unsecured in the following situations:

(1) Cable is fished between access points through concealed spaces in finished buildings where securing and supporting is impractical

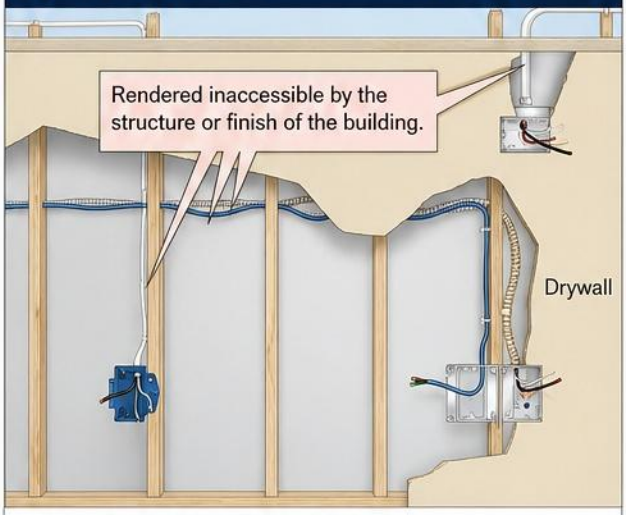
(2) Not more than 4½ ft of unsupported cable is permitted from the last point of support within an accessible ceiling for the connection of luminaires or equipment in a dwelling unit

Figure 334–25 NM Cable, Securing and Supporting Horizontal Runs 334.30(A)



A horizontally run NM cable installed between framing members is regarded as adequately secured and supported if the spacing between supports does not exceed 4½ ft, and the cable is fastened within 1 ft of each termination.

Figure 334–27 Concealed Article 100 Definition



Concealed. Considered to be hidden from view because it is inaccessible due to the building's construction or interior finish.

ARTICLE 334.40 BOXES AND FITTINGS

(B) NM Cable Interconnector Devices. A recognized nonmetallic-sheathed cable interconnector device is permitted to be used in locations that are either exposed or concealed.

Figure 334–26 NM Cable, Interconnector Devices 334.40(B)

A listed nonmetallic-sheathed cable interconnector device may be used in exposed or concealed installations.

Concealed. Considered to be hidden from view because it is inaccessible due to the building's construction or interior finish. (See *Figure 334–27.*)

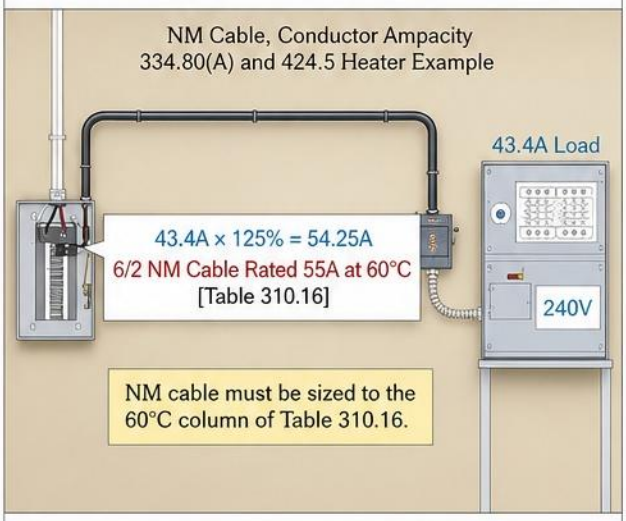
ARTICLE 334.80 CONDUCTOR AMPACITY

(A) General. The ampacity of NM cable must be based on the 60°C column in Table 310.16.

Figure 334–28 Space Heater NM Cable Sizing [210.19(A)(1) and 424.5] Example

Question: *What size NM cable is required for a 9,600W, 240V fixed electric space heater with a 3.4A, 240V blower motor?*

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



Solution:

Step 1: *Determine the total load.*

I = Watts/Volts

I = 9,600W/240V

I = 40A

Total Amperes = 40A (heat) + 3.4A (blower)

Total Amperes = 43.4A

Step 2: *Size the conductors at 125 percent of the total current load [110.14(C)(1)(a)(2), 210.19(A)(1), 424.5(B), and Table 310.16].*

Conductor = 43.4A × 125%

Conductor = 54.25A

Conductor = 6 AWG rated 55A at 60°C

Note: *Size the overcurrent protective device at 125 percent of the total current load [210.20(A), 240.4(B), and 240.6(A)].*

Overcurrent Protection = 43.4A × 125%

Overcurrent Protection = 54.25A, use the next size up: 60A [240.6(A)].

Answer: *(c) 6 AWG*

▶ EVSE NM Cable Sizing [210.19(A)(1) and 625.41] Example

Question: What size NM cable is required for an EV charger (EVSE) rated 40A that is plugged into a 50A receptacle, where the cable is rated for 60°C conductor sizing? The conductor to an EVSE is considered a continuous load, therefore it must be sized no smaller than 125 percent of the EVSE load

▶ Figure 334–29

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

Figure 334–29 EVSE NM Cable Sizing Example 210.19(A)(1) 625.41

Solution:

Note: *When NM cable is used, 334.80 requires the conductors to be sized based on the 60°C column of Table 310.16.*

Step 1: *Determine the minimum circuit rating.*

Conductor Rating = (40A × 125%) [210.19(A)(1) and 625.41]
Conductor Rating = 50A

Step 2: *Size the conductors in accordance with the 60°C column of Table 310.16 [310.16(C)(1)(a)(3)].*

6 AWG is rated 55A at 60°C.

Answer: *(c) 6 AWG*

(B) Cables through Same Opening

Where more than two NM cables pass through the same wood framing opening that is sealed with thermal insulation, caulking, or sealing foam, the ampacity of each conductor must be adjusted in accordance with Table 310.15(C)(1) based on the 90°C rating.

If the final calculated ampacity does not exceed that of a 60°C rated conductor [310.15(A) and 334.80(A)].

▶ Figure 334–30

Figure 334–30 NM Cables Through Same Opening 310.15(A) 334.80(A)(B)

Where more than two NM cables pass through the same wood framing opening that is sealed, the ampacity of each conductor must be adjusted per Table 310.15(C)(1) based on the 90°C rating of the conductor, provided the final calculated ampacity does not exceed that of a 60°C rated conductor [310.15(A) and 334.80(A)].

▶ NM Cable Through Same Opening [334.80(B)] Example 1

Question: *What is the ampacity of each of four two-wire 14 AWG NM cables passing through the same wood framing opening that is sealed with thermal insulation, caulking, or sealing foam?*

(a) 13A *(b) 14A* *(c) 15A* *(d) 16A*

Solution:

Determine the adjusted ampacity of the circuit conductors in accordance with Table 310.15(C)(1) and Table 310.16.

14 AWG is rated 25A at 90°C [Table 310.16].

Conductor Adjustment = 70% [Table 310.15(C)(1)]

Conductor Adjusted Ampacity = 25A × 70%
Conductor Adjusted Ampacity = 17.50A

Note: *The final calculated ampacity is not permitted to exceed the ampacity of 14 AWG at the 60°C column of Table 310.16 [334.80(A)].*

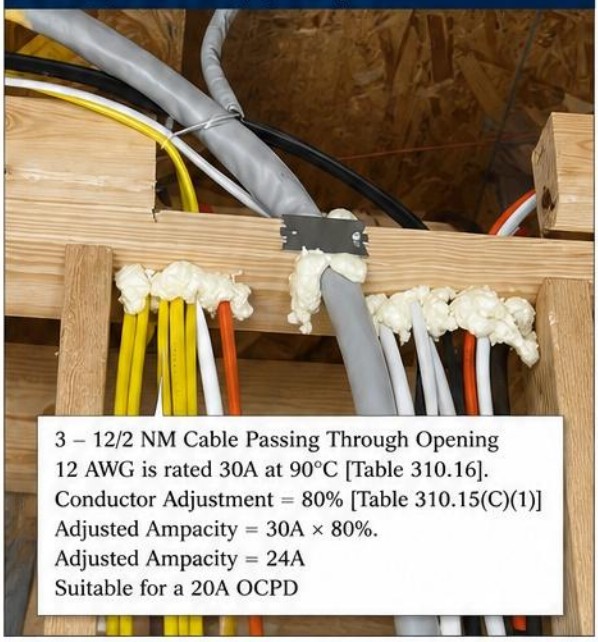
Answer: *(c) 15A*

NM Cable Through Same Opening [334.80(B)] Example 2

Question: What is the ampacity of each of five two-wire 12 AWG NM cables passing through the same wood framing opening that is sealed with thermal insulation, caulking, or sealing foam? **Figure 334–31**

(a) 13A (b) 14A (c) 15A (d) 16A

Figure 334–31 334.80(B)
NM Cable, Conductor Ampacity
Cables Through Same Opening
334.80(B) and 310.15(C)(1) Example 2



Solution:

Determine the adjusted ampacity of the circuit conductors in accordance with Table 310.15(C)(1) and Table 310.16.

12 AWG is rated 30A at 90°C [Table 310.16].

Conductor Adjustment = 50% [Table 310.15(C)(1)]

Conductor Adjusted Ampacity = 30A × 50%

Conductor Adjusted Ampacity = 15A

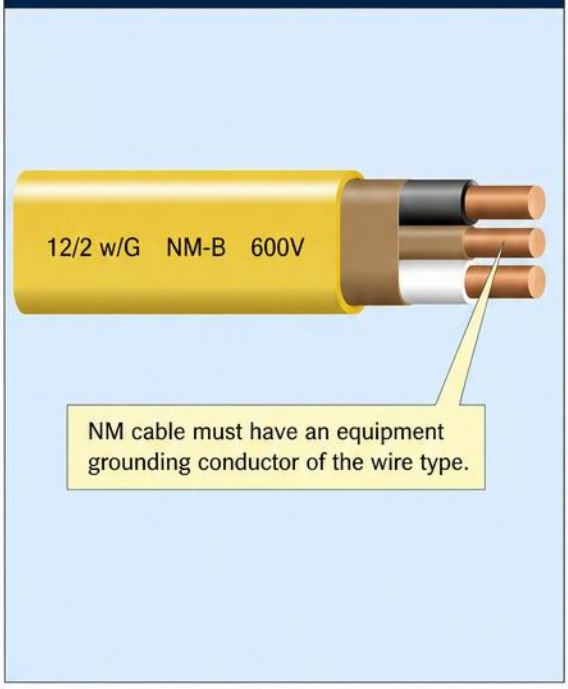
Answer: *(c) 15A*

Part III. Construction Specifications

334.108 Equipment Grounding Conductor

NM cable must have a wire-type equipment grounding conductor. **Figure 334–32.**

Figure 334–32 334.108
NM Cable Equipment
Grounding Conductor
334.108



NM cable must have a wire-type equipment grounding conductor. **Figure 334–32.**

ARTICLE
336 Power and Control Tray Cable (TC cable)

Introduction to Article 336—Power and Control Tray Cable (TC Cable)

Article 336 sets out the requirements for using and installing power and control tray cable (TC cable). TC cable is flexible, economical, and straightforward to install. This makes it an appealing wiring solution for industrial environments and generator installations.

Cable, Power and Control Tray Cable (TC). A factory assembly of conductors with or without bare or covered equipment grounding conductors under a nonmetallic jacket. ▶ Figure 336–1

Figure 336–1 Power and Control Tray Cable (TC Cable) Article 100 Definition

A factory assembly of conductors with or without bare or covered equipment grounding conductors, under a nonmetallic jacket.

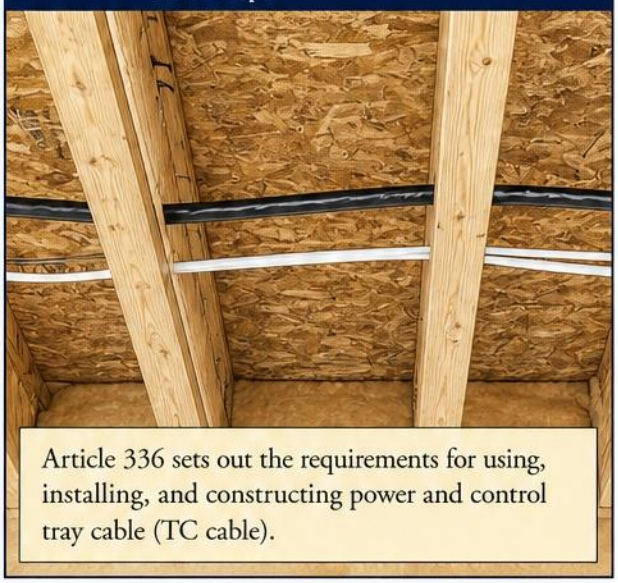
Part I. General

336.1 Scope

This article sets out the requirements for the use, installation, and construction specifications of power and control tray cable (TC cable).

▶ Figure 336–2

Figure 336–2 Power and Control Tray Cable (TC Cable) 336.1 Scope



336.2 Listing Requirements

The following must be listed and identified:

(1) TC cable

(2) Cable ties, cable cleats, staples, straps, and hangers

(3) Fittings used to connect TC cable to boxes, cabinets, or equipment

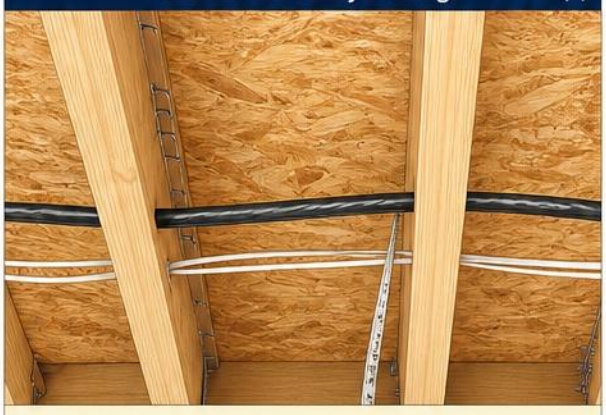
▶ Figure 336–3

Figure 336–3 TC Cable, Listing Requirements 336.2

The following must be listed and identified:

(1) TC cable
(2) Cable ties, cable cleats, staples, straps, and hanger
(3) Fittings used to connect TC cable to boxes, cabinents, or equipment

Figure 336–4 TC Cable, Uses Permitted One-and Two-Family Dwellings 336.10(9)



TC-ER-JP cable containing power conductors and control circuits must be installed in accordance with Part II of Article 334 for interior wiring and Part II of Article 340 for exterior wiring.

Part II. Installation

336.10 Uses Permitted

TC cable is permitted to be used as follows:

(1) Power, lighting, and power-limited circuits

(2) In cable trays (including those with mechanically discontinuous segments up to 1 ft)

(3) In raceways

(4) Outdoor locations supported by a messenger wire

(5) Class 1 power-limited circuits installed in accordance with Article 724

(7) Between a cable tray, raceway, or enclosure and equipment—if it complies with 336.10(7)(a) through (e)

(8) Wet locations where the cable is resistant to moisture and corrosive agents

(9) For one-and two-family dwelling units, TC-ER-JP cable containing power conductors and control circuits must be installed in accordance with Article 334 Part II for interior branch circuit and feeder wiring, and Article 340 Part II for exterior wiring

Ex: Where TC cable is used to connect a generator and its associated equipment, the cable ampacity limitations of 334.80 and 340.80 do not apply.

(10) Direct buried where identified for direct burial

(11) Hazardous locations as permitted in this *Code*

(12) Service-entrance conductors where identified for such use and marked "TC-ER"

336.12 Uses Not Permitted

TC cable is not permitted to be used where:

(1) Exposed to physical damage as determined by the AHJ

(2) Outside a raceway or cable tray system, except as permitted in 336.10(4), (7), (9), and (10)

(3) Exposed to the direct rays of the sun—unless identified as sunlight resistant

336.24 Bending Radius

TC cable without metal shielding is not permitted to be bent where the radius of the inner edge of the cable is less than the following:

(1) Four times the overall diameter for cables 1 in. or less in diameter

(2) Five times the overall diameter for cables larger than 1 in.—but not more than 2 in. in diameter

336.30 Securing and Supporting

TC cable must be supported and secured by:

(1) Cable ties listed and identified for securement and support

(2) Listed staples, cable cleats, straps, hangers, or similar fittings

(3) Other approved means

ARTICLE
338 Service-Entrance Cable (SE and USE cable)

Introduction to Article 338—Service-Entrance Cable (SE and USE Cable)

Article 338 addresses the use, installation, and construction requirements for service-entrance cables (SE and USE cables). These cables may be a single conductor or a multiconductor assembly in sizes 14 AWG and larger for copper, and 12 AWG and larger for aluminum or copper-clad aluminum within an overall nonmetallic jacket or covering. SE cables feature a flame-retardant and moisture-resistant jacket suitable for aboveground installations. USE cables are identified as a wiring method allowed for underground use because their jacket is moisture-resistant but not flame-retardant.

Cable, Service-Entrance Cable (SE and USE Cable). A single or multiconductor cable primarily used for services.

Figure 338–1 Cable, Service-Entrance Cable (SE and USE Cable) *NEC 338*

Figure 338–1: SE cable is approved only for aboveground use and may be used for branch circuits or feeders when installed in accordance with 338.10(B). USE cable is identified for underground installations; its jacket resists moisture but does not provide flame retardance and is not intended for indoor use.

Cable, Service Entrance Cable (SE). SE cables have a flame-retardant, moisture-resistant jacket suitable for aboveground installations.

Cable, Service Entrance Cable (USE). USE cables have a moisture-resistant jacket that does not provide flame retardance and are identified as a wiring method allowed for underground use.

Part I. General

338.1 Scope

This article specifies the requirements for the use, installation, and construction of service-entrance cable (SE and USE cable).

Figure 338–2 Service-Entrance Cable (SE and USE Cable): Scope *NEC 338.1*

Figure 338–2: Article 338 specifies the requirements for the use, installation, and construction of service-entrance cable (SE and USE cable).

338.2 LISTING REQUIREMENTS

The following must be listed and identified:

(1) SE and USE cables

(2) Cable ties, staples, straps, and hangers

(3) Fittings used to connect SE and USE cable to boxes, cabinets, or equipment

Figure 338–3: SE and USE Cable, Listing Requirements 338.2

The following must be listed and identified:

(1) SE and USE cable

(2) Cable ties, staples, straps, and hangers

(3) Fittings used to connect SE and USE cable to boxes, cabinets, or equipment

PART II. INSTALLATION

338.10 USES PERMITTED

(A) Service-Entrance Conductors. SE and USE cables may be used as service-entrance conductors in accordance with Article 230.

(B) Branch Circuits or Feeders.

(2) Uninsulated Conductors. SE cable is permitted to be used for branch circuits and feeders where the neutral conductor is insulated.

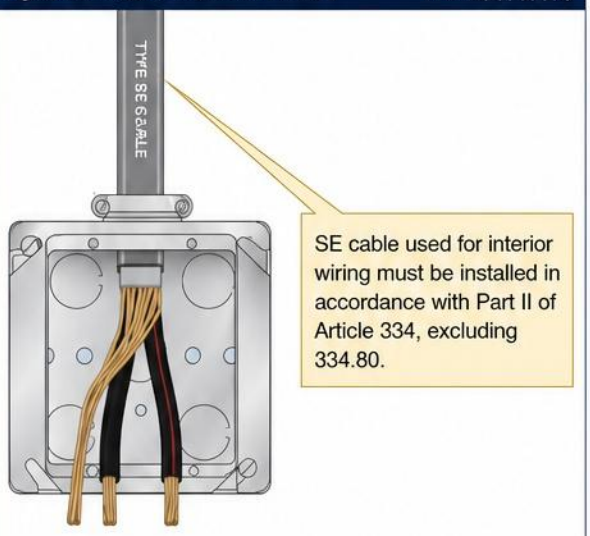
(4) Installation Methods for Branch Circuits and Feeders.

(a) Interior Installations.

(1) SE cable used for interior wiring must be installed in accordance with Part II of Article 334, excluding 334.80 → Figure 338–4

(2) Where more than two SE cables used for interior wiring are in contact with thermal insulation, caulking, or sealing foam, the ampacity of each conductor must be adjusted in accordance with Table 310.15(C)(1).

Figure 338–4: SE Cable, Uses Permitted 338.10(B)(4)(a)(1)



SE cable may be used for interior installations in accordance with 338.10(B)(4)(a)(1).

(3) SE cable conductors (10 AWG and smaller) used for interior wiring installed in contact with thermal insulation must be sized in accordance with 60°C column of Table 310.16.

AUTHOR'S COMMENT:

▶ When SE cable conductors (10 AWG and smaller) are not in contact with thermal insulation, the conductors can be sized in accordance with 75°C column of Table 310.16, see 110.14(C)(1).

(b) Exterior Installations.

(1) USE cable used for exterior wiring must be installed in accordance with Part I of Article 225 and supported in accordance with 334.30.

(2) Where USE cable used for exterior wiring is run underground, the cable must comply with Part II of Article 340.

338.12 USES NOT PERMITTED

(A) Service-Entrance Cable. Service-entrance cable is not permitted:

(1) Where subject to physical damage as determined by the AHJ

(2) Underground with or without a raceway

(B) Underground Service-Entrance Cable. USE cable is not permitted:

(1) Underground service-entrance cable is not permitted for interior wiring

(2) Underground service-entrance cable is not permitted above ground, except where protected against physical damage in accordance with 300.7(D)

338.24 Bending Radius

SE and USE cables are not permitted to be bent where the radius of the inner edge of the cable is less than five times the minor diameter of the cable.

▶ Figure 338–5

Figure 338–5 Bending Radius for SE and USE Cable **338.24**

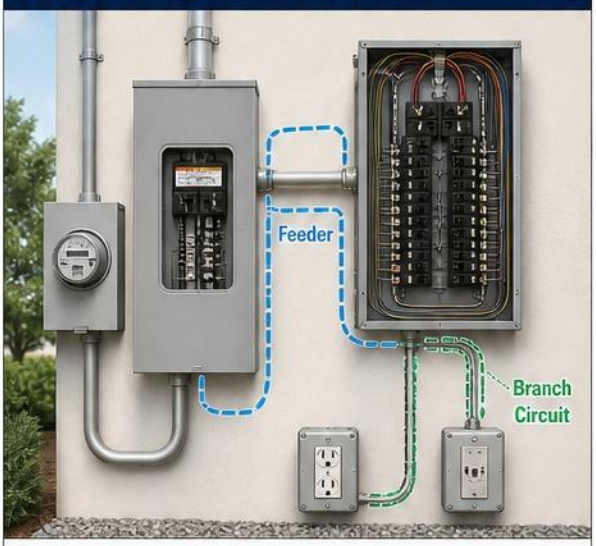
ARTICLE 100
Definitions

Article 100 contains terms that are used throughout the NEC. The following are some of the terms that are used in this section.

Branch Circuit. The circuit conductors between the overcurrent device protecting the circuit and the outlet(s). (See Figure 100-1.)

Feeder. The circuit conductors between the service equipment and the branch-circuit overcurrent device(s) or the busbars of the distribution panel or other equipment. (See Figure 100-1.)

Figure 100-1 Branch Circuit and Feeder 100



The feeder supplies power from the service equipment to the distribution panel. The branch circuit supplies power from the distribution panel to the outlet(s).

Feeder Tap. The conductors and the overcurrent device between the tap conductors of a feeder and the branch-circuit overcurrent device or the terminal(s) of the equipment supplied. (See Figure 100-2.)

Outlet. A point on the wiring system at which current is taken to supply utilization equipment.

Overcurrent Device. A device that opens a circuit when the current exceeds a predetermiend value.

Reach-In Closet. A closet not over 6 ft (1.8 m) wide and not over 2½ ft (762 mm) deep.

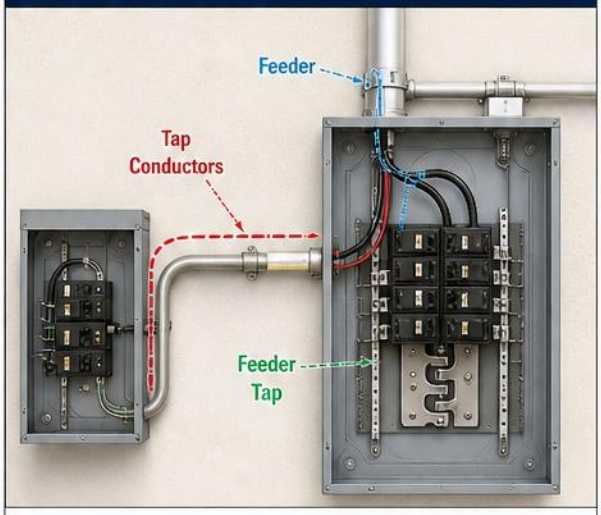
Service. The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

Service Equipment. The equipment and the conductors at the service, including the service disconnecting means, service overcurrent devices, and the equipment necessary for metering and the associated current transformers.

Supply-Side Bonding Jumper. A bonding jumper between the grounded conductor and the equipment grounding conductor on the supply side of the service equipment disconnecting means.

Tap Conductors. The conductors between the feeder and the feeder tap.

Figure 100-2 Feeder Tap 100



The tap conductors supply power from the feeder to the feeder tap overcurrent device. The feeder tap overcurrent device supplies power to the equipment.

Utilization Equipment. Equipment that utilizes electrical energy to perform a function.

Working Space. The space required and maintained about electrical equipment to permit ready and safe operation and maintenance of such equipment.

Note: These definitions are not all inclusive. For complete definitions, see Article 100.

ARTICLE 340 Underground Feeder and Branch-Circuit Cable (UF cable)

Introduction to Article 340—Underground Feeder and Branch-Circuit Cable (UF Cable)

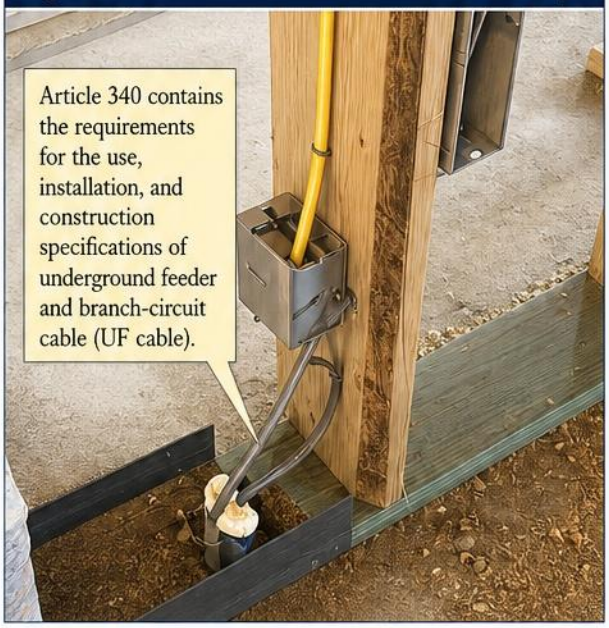
This article contains the requirements for the use, installation, and construction specifications of *underground feeder and branch-circuit cable (UF cable)*. UF cable is an assembly of conductors in sizes 14 AWG through 4/0 AWG covered in a moisture-, fungus-, and corrosion-resistant sheath suitable for direct burial. The sheath of multiconductor UF cable is a molded plastic that encases the insulated conductors. It can be difficult to strip off the sheath without damaging the conductor insulation or cutting yourself, so be careful.

Cable, Underground Feeder and Branch-Circuit Cable (UF). A factory assembly of conductors with an integral or overall covering of nonmetallic material suitable for direct burial.

Figure 340–1 — **Article 100 Definition**

A factory assembly of conductors with an integral or overall covering of nonmetallic material suitable for direct burial.

Figure 340–2 — **340.1 Scope**



Part I. General

340.1 Scope — 340.1

This article contains the requirements for the use, installation, and construction specifications of underground feeder and branch-circuit cable (UF cable).

340.2 Listing Requirements — 340.2

The following must be listed and identified:

(1) UF cables

(2) Cable ties, staples, straps, and hangers

(3) Fittings used to connect UF cable to boxes, cabinets, or equipment

Part II. Installation

340.10 Uses Permitted

UF cable is allowed for use in the following situations:

(1) Buried underground in compliance with 300.7

(2) As the only conductor in a trench or raceway together with circuit conductors

(3) In damp, dry, or corrosive environments

(4) When installed as a multiconductor, nonmetallic-sheathed cable, the requirements of 334 Part II and Part III apply, with the exception of 334.12(A)

340.12 Uses Not Permitted

UF cable is not allowed for use in the following situations:

(1) As the service-entrance cable [230.43]

(2) In commercial garages [Article 511]

(3) In theaters [520.5]

(4) In motion picture studios [530.11]

(5) In storage battery rooms [Article 480]

(6) In hoistways [Article 620]

(7) In hazardous (classified) locations, except as specifically permitted by other articles in this *Code*

(8) Embedded in concrete

(9) Exposed to direct sunlight (unless identified)

(10) In locations where it would be subject to physical damage as determined by the AHJ (authority having jurisdiction) (see Figure)

(11) As overhead cable, except when installed as messenger-supported wiring in accordance with Part II of Article 396

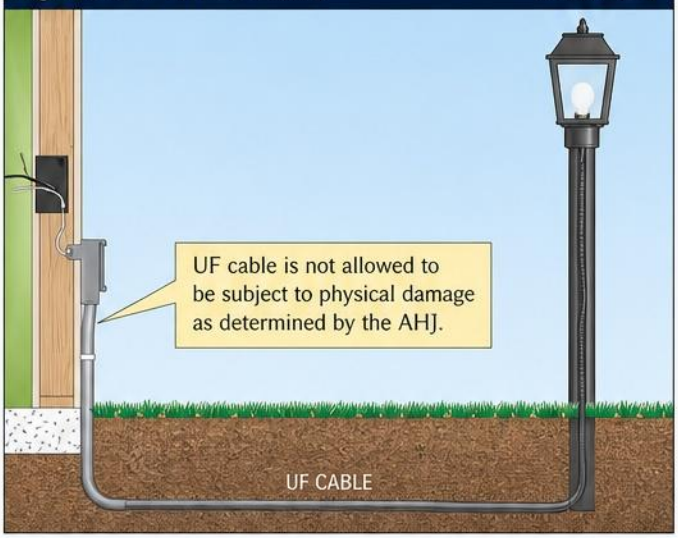
340.24 Bends

UF cable is not permitted to be bent where the radius of the inner edge of the cable is less than five times the minor diameter of the cable.

340.80 Ampacity

The ampacity of conductors is determined using the 60°C insulation rating listed in Table 310.16.

Figure 340–3 Not Permitted **340.12(10)**



UF cable that is exposed and subject to physical damage—such as lawn equipment, vehicles, or other impacts—is not permitted.

Author's Comment:

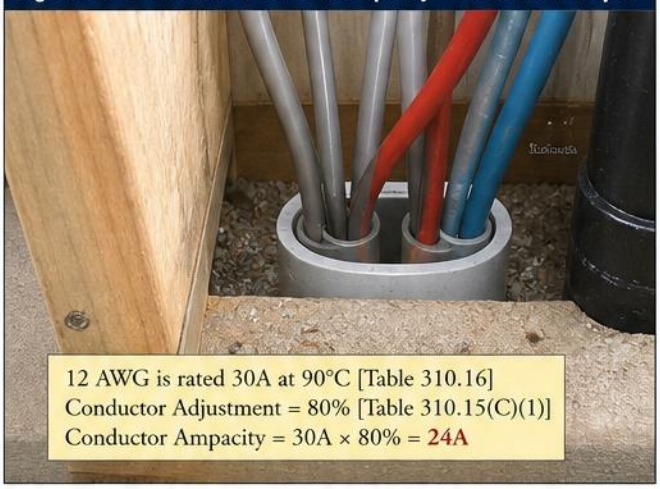
Both Table 310.4 for UF cable and 340.10(4) require UF cable using more than one conductor to comply with Article 340, Part II. When used as an alternative wiring method for NM cable, 340.112 states the conductor insulation must be rated 90°C. For ampacity adjustments, 310.15(A) requires 90°C.

UF Cable Ampacity [340.80] Example

Question: *What is the ampacity of each 12 AWG conductor when* three 12/2 UF cables are installed in a PVC raceway underground to supply island receptacle outlets for the dishwasher and disposal? See Figure 340–4.

(a) 12A (b) 18A (c) 24A (d) 30A

Figure 340–4 UF Cable Conductor Ampacity **340.80 Example**



After applying the adjustment in 310.15(C)(1), the ampacity of each 12 AWG conductor is 24A.

Solution:

Step 1: Calculate the ampacity of the 12 AWG conductors contained in UF Cable. Table 310.4 for UF cable and 340.10(4) state that UF cable using more than one conductor must comply with Article 340, Part II. Where a substantial wiring method for NM cable is installed as a substitute for NM cable, 340.112 requires that the conductor insulation be rated 90°C. For ampacity adjustments, 310.15(A) indicates that the 90°C column is used.

12 AWG is rated 30A at 90°C [Table 310.16].

Step 2: Determine the ampacity adjustment factor [Table 310.15(C)(1)].

Conductor Adjustment = 80%

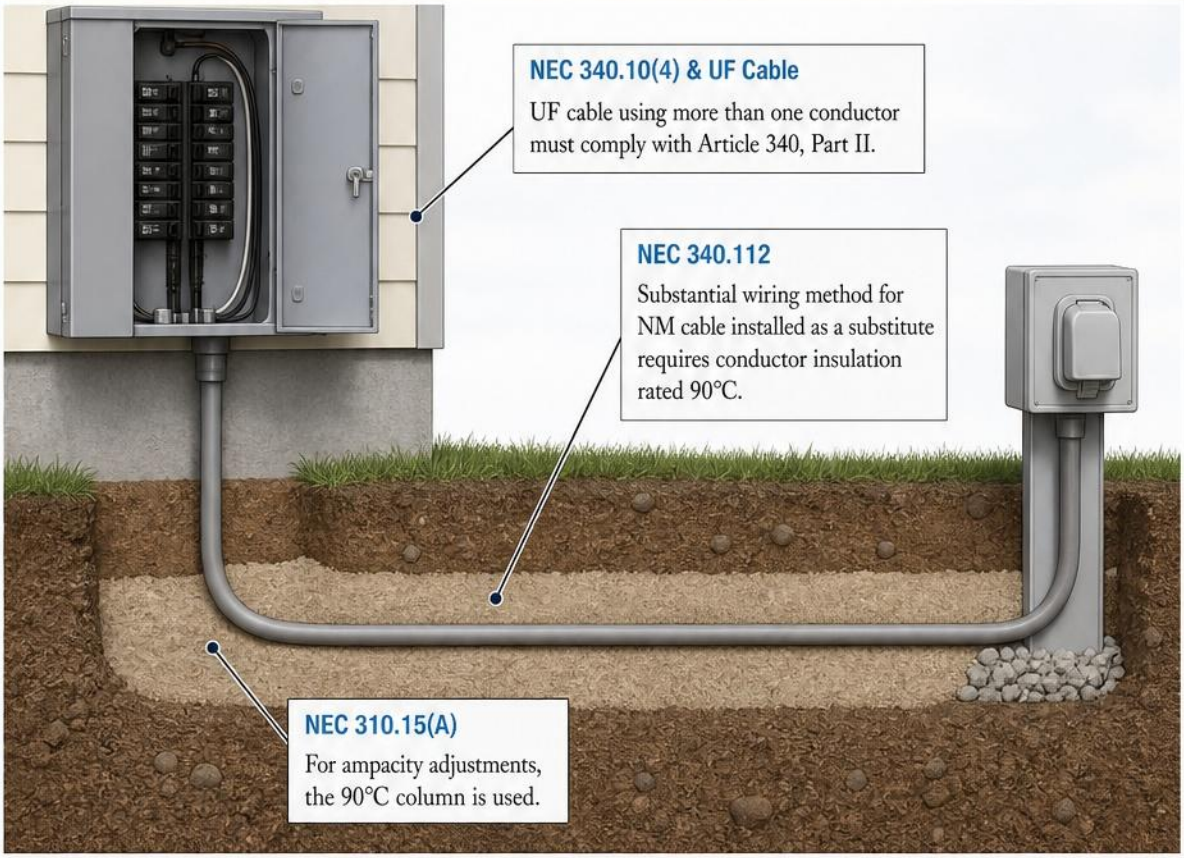
Step 3: Determine the adjusted conductor ampacity.

Adjusted Conductor Ampacity = 30A × 80%

Adjusted Conductor Ampacity = 24A

Answer: (c) 24A

Figure 1 UF Cable in Underground Feeder and Branch-Circuit Application NEC 340.80



UF cable installed underground for feeder and branch-circuit applications must comply with Article 340. When replacing NM cable, conductor insulation must be rated 90°C, and ampacity adjustments are based on the 90°C column.

Article 100
Definitions

Article 100 contains general definitions used throughout the NEC.

100 Term Definitions

Many important terms are defined in Article 100. These definitions are essential for properly interpreting and applying the NEC.

100.1 General

Words used in the present tense include the future; words in the plural number include the singular, and words in the singular number include the plural.

The word "shall" is always mandatory, and the word "should" is advisory only.

The word "installation" means the equipment and all wiring, raceways, and other associated equipment on the premises.

100.4 Access

"Access" means the opportunity and means for immediate visual inspection of the interior of an equipment, or the readily accessible exterior surface of an enclosure for the purpose of examination, adjustment, servicing, or maintenance.

100.5 Accessible

"Accessible" means capable of being reached quickly for operation, renewal, servicing, or inspection without requiring those to whom ready access is not intended to remove any obstacle or to resort to portable ladders, and includes the height and space allowances required for such access.

100.6 Readily Accessible

"Readily accessible" means that the equipment can be reached quickly for operation, renewal, servicing, or inspection without requiring removal of barriers, without requiring tools, and without requiring portable ladders.

100.7 Readily Accessible, Outdoor

"Readily accessible, outdoor" means not more than 25 ft (7.6 m) from the equipment in a horizontal direction or not more than 8 ft (2.4 m) above grade level.

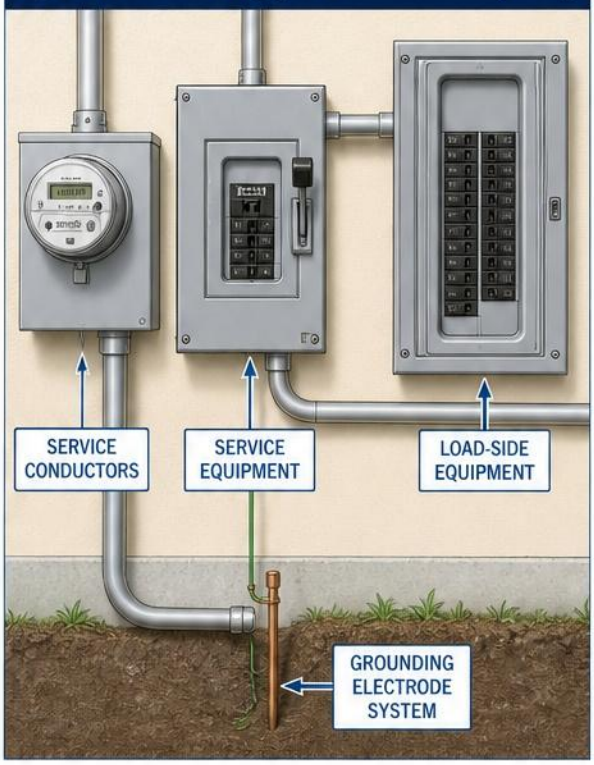
100.8 Service

"Service" means the conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

100.10 Service Equipment

"Service equipment" means the equipment at the point where the service conductors terminate and that is intended to be the equipment from which service conductors are to be supplied.

Figure 100–1 Service Equipment (100.10)



The service equipment is the equipment at the point where the service conductors terminate and that is intended to be the source of supply for service conductors.

100.14 Wiring System

"Wiring system" means all of the conductors, raceways, and cables, together with associated fittings, devices, lighting fixtures, lampholders, and other equipment, and their accessories and appurtenances that are installed or used for the distribution of electric energy.

ARTICLE 342

Intermediate Metal Conduit (IMC)

Introduction to Article 342—Intermediate Metal Conduit (IMC)

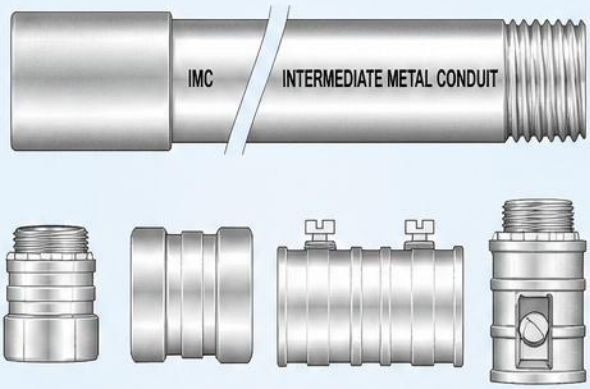
Article 342 addresses the use, installation, and construction specifications for *intermediate metal conduit (IMC)* and related fittings. IMC is a circular metal raceway that can be threaded and is available in trade sizes ½ to 6. It shares the same outside diameter as *rigid metal conduit (RMC)* [Article 344], but is manufactured from stronger metal, enabling a thinner wall. This results in a lighter product while providing a larger interior cross-sectional area for conductor capacity.

Conduit, Intermediate Metal Conduit (IMC). A steel raceway of circular cross section that can be threaded with couplings and fittings listed for the installation of electrical conductors.

Figure 342–1 Intermediate Metal Conduit (IMC) Article 100 Definition

A steel raceway of circular cross section that can be threaded with couplings and fittings.

Figure 342–2 Intermediate Metal Conduit (IMC) 342.1 Scope



Article 342 sets forth the requirements for the use, installation, and construction specifications of intermediate metal conduit (IMC) and associated fittings.

Part I. General

342.1 Scope

This article establishes the requirements for the use, installation, and construction of intermediate metal conduit (IMC) and associated fittings.

342.2 Listing Requirements

Intermediate metal conduit and its associated fittings must be listed.

Author's Comment:

- Raceway support hardware is not considered an associated IMC fitting and is not required to be listed. However, support hardware must be constructed of materials suitable for the environment for which they are to be installed, see 300.8.

Part II. Installation

342.10 Uses Permitted

(A) Atmospheric Conditions and Occupancies. IMC is permitted in all atmospheric conditions and occupancies.

Figure 342–1 IMC in All Conditions 342.10(A)

Wet locations | Dry locations | Outdoor locations

(B) Corrosive Environments. IMC is permitted for concrete, direct burial, or areas subject to severe corrosive influences, where provided with corrosion protection approved for the condition.

Figure 342–2 Corrosion Protection Examples 342.10(B)

Galvanized steel IMC | PVC-coated steel IMC (direct burial)

Note: Galvanized steel and PVC-coated steel IMC are examples of corrosion protection.

AUTHOR'S COMMENT

- In accordance with *UL Guide Information DYBY*, supplementary corrosion protection is required when IMC and associated fittings are buried in soil having a resistivity less than 2000 ohms.
- In addition, supplementary corrosion protection is required at the point where IMC transitions from concrete encasement to the soil.

(E) Severe Physical Damage. Where subject to severe physical damage.

Figure 342–3 Severe Physical Damage 342.10(E)

IMC is permitted where severe physical damage may occur.

342.14 Dissimilar Metals

Where practical, contact of IMC with dissimilar metals should be avoided to prevent the deterioration of the metal because of galvanic action. Aluminum and stainless steel fittings and enclosures are permitted to be used with galvanized steel IMC—where not subject to severe corrosive influences.

342.20 Trade Size

(A) Minimum. IMC smaller than trade size ½ is not permitted.

(B) Maximum. IMC larger than trade size 6 is not permitted.

342.22 Number of Conductors

The number of conductors is not permitted to exceed the percentage fill specified in Chapter 9, Table 1.

AUTHOR'S COMMENT

- When all conductors within a raceway are the same size, same insulation type, number of conductors permitted, or raceway size, see Annex C, Note (1) of Chapter 9.
- For examples of how to size raceways when conductors are not all the same size, see 300.19.

Cables are permitted in the raceway if the total area of the cables does not exceed the allowable percentage fill specified in Chapter 9, Table 1.

IMC Annex C Table Example

Question: How many 12 AWG, THWN-2 conductors can be installed in ¾ IMC?

(a) 11 *(b) 13* *(c) 15* *(d) 17*

Answer: *(d) 17 [Annex C, Table C.4]*

342.24 Bends

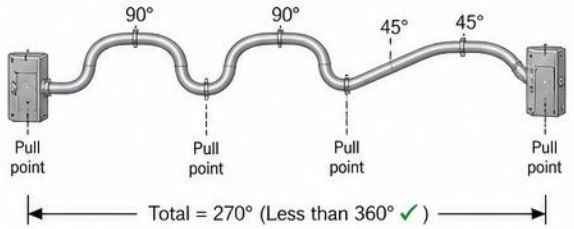
(A) How Made. When bending IMC, the bends must not damage or significantly change the internal diameter (no kinks) of the raceway.

AUTHOR'S COMMENT

- This is not a problem if you use a bender in accordance with the manufacturer's instructions.

(B) Degrees of Bends in One Run. The total degree of bends including offsets between pull points is not permitted to exceed 360 degrees.

Figure 342–4 Bends in One Run 342.24(B)



AUTHOR'S COMMENT

- There is no maximum distance between pull boxes because this is a design issue rather than a safety issue.

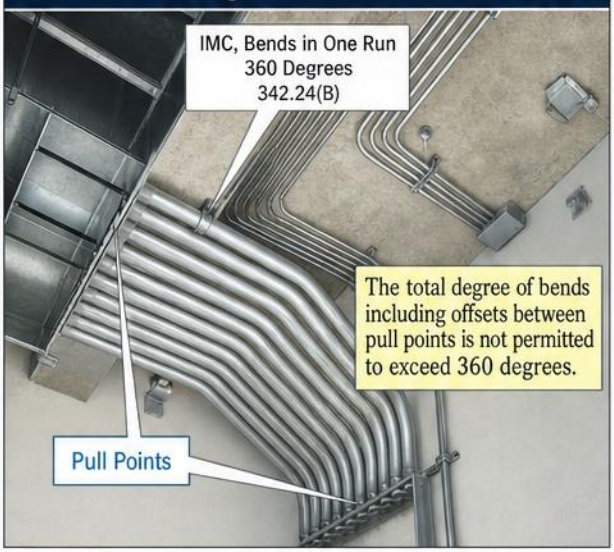
342.28 Reaming

When the raceway is cut in the field, reaming is required to remove the rough edges.

Figure 342–5 Reaming After Cutting 342.28

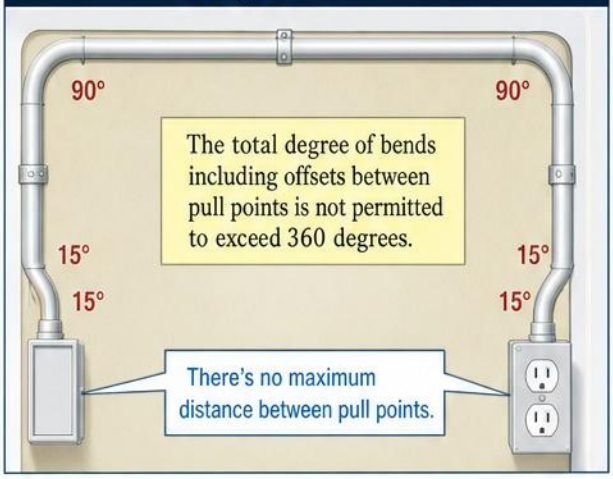
Ream the ends to remove burrs and sharp edges.

Figure 342–3 IMC, Bends in One Run 360 Degrees 342.24(B)



Conduit runs that include bends and offsets between pull points must not total more than 360 degrees.

Figure 342–4 IMC, Bends in One Run 360 Degrees 342.24(B) *Comment*



Even if pull points are very far apart, the overall angle created by bends and offsets between them must not be more than 360 degrees.

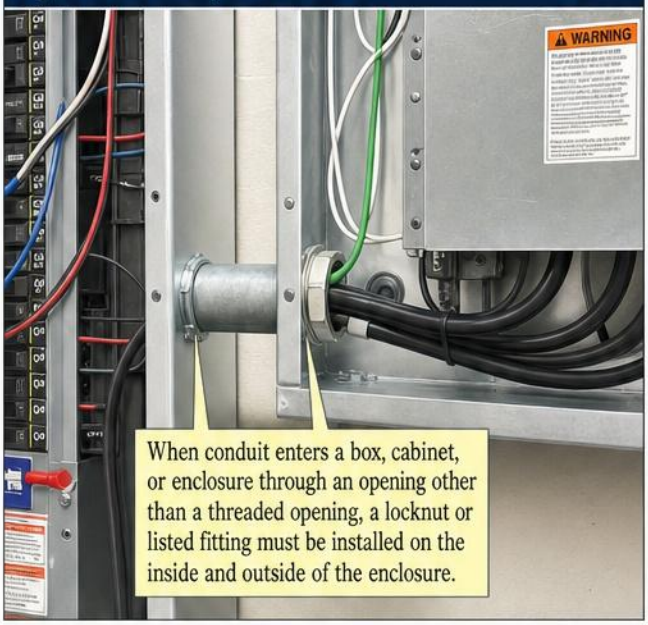
Author's Comment:

This is a common method used to ream narrow races with a screwdriver or the back end of pliers. However, when the raceway has a cut with a three-wheel pipe cutter, a reaming tool is needed to remove the sharp edge or burr from the inside of the race. When conduits are threaded in the field, the threads must be coated with an electrically conductive, corrosion-resistant compound that is approved by the authority having jurisdiction (AHJ) in accordance with 300.6(A).

342.29 Paired Locknuts

When conduit enters a box, cabinet, or enclosure through an opening other than a threaded opening, a locknut or listed fitting must be installed on both the interior and exterior surfaces of the enclosure. ▸ Figure 342–5

Figure 342–5 IMC, Paired Locknuts 342.29



Locknuts or listed fittings must be placed on both sides of the enclosure when conduit enters through a nonthreaded opening.

342.30 Securing and Supporting

IMC must be securely fastened and supported in accordance with 342.30(A) and (B).

(A) Securely Fastened. IMC must be secured in accordance with any of the following:

(1) Within 3 ft of each box, cabinet, conduit body, or IMC termination. ▸ Figure 342–6

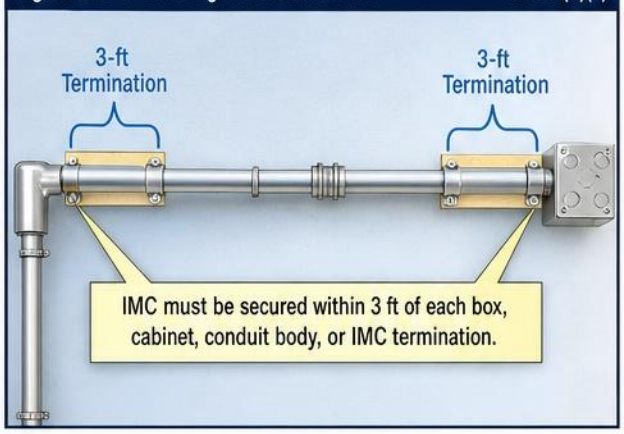
Author's Comment:

Securing is required within 3 ft of terminations—not within 3 ft of each coupling.

(2) Within 5 ft of the termination when structural members do not permit the IMC to be secured within 3 ft of each box or cabinet. ▸ Figure 342–7

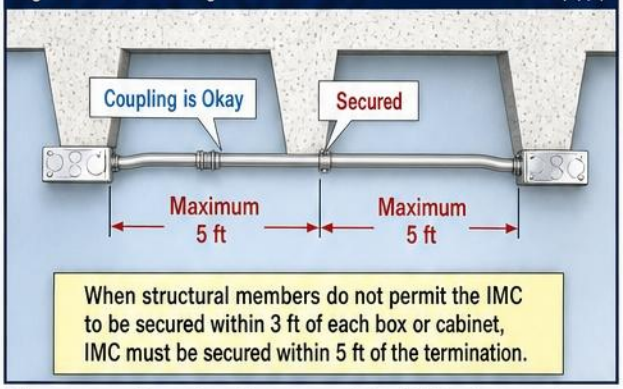
(3) Within 3 ft of the service head for an above-the-roof termination of a mast ▸ Figure 342–8

Figure 342–6 Securing IMC Within 3 Feet 342.30(A)(1)



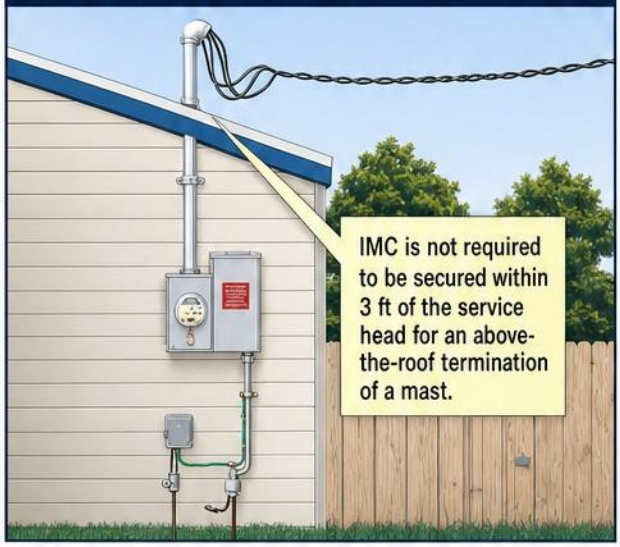
IMC must be secured within 3 ft of each box, cabinet, conduit body, or IMC termination.

Figure 342–7 Securing IMC Within 5 Feet 342.30(A)(2)



When structural members do not permit the IMC to be secured within 3 ft of each box or cabinet, IMC must be secured within 5 ft of the termination.

Figure 342–8 Above-the-Roof Termination 342.30(A)(3)



IMC is not required to be secured within 3 ft of the service head for an above-the-roof termination of a mast.

(B) Supports. IMC must be supported as follows:

(1) General. IMC must be supported at intervals not exceeding 10 ft.

(2) Straight Runs. Straight horizontal runs of IMC with threaded couplings can be supported in accordance with the distances contained in Table 344.30(B). Figure 342–9.

Figure 342–9 IMC Supporting Straight Runs 342.30(B)(2)

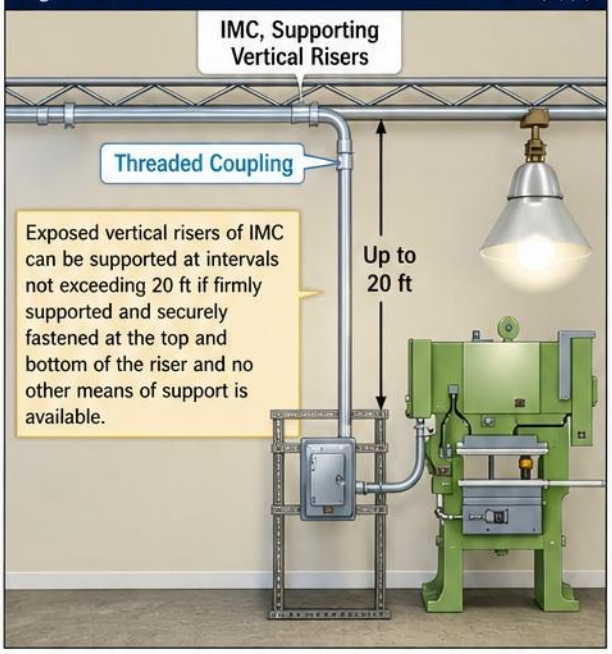
Table 344.30(B) Supports for Rigid Metal Conduit

Trade Size	Support Spacing
½–¾	10 ft
1	12 ft
1¼–1½	14 ft
2–2½	16 ft
3 and larger	20 ft

(3) Vertical Risers. Exposed vertical risers for fixed equipment can be supported at intervals not exceeding 20 ft if the conduit is made up with threaded couplings, firmly supported, securely fastened at the top and bottom of the riser, and if no other means of support is available. Figure 342–10.

(4) Horizontal Runs. IMC installed horizontally through framing members is considered supported and secured if such support does not exceed 10-ft intervals, and the conduit is secured within 3 ft of termination.

Figure 342–10 342.30(B)(3)



IMC vertical risers may be supported at intervals up to 20 ft if secured at both ends and no alternative support is available.

342.42 COUPLINGS AND CONNECTORS

(A) General. Coupling and connectors must be made tight.

> **AUTHOR'S COMMENT**
>
> Loose locknuts have been found to nearly disintegrate before a fault was cleared because loose termination fittings increase the impedance of the ground-fault current path.

(1) Concrete Buried. If installed in concrete, IMC fittings must be listed for concrete-tight type.

Figure 342–11 342.42(A)(1)

For installations in concrete, IMC fittings must be listed for the concrete-tight type.

> **AUTHOR'S COMMENT**
>
> Fittings suitable for use in poured concrete are indicated on the device or carton with the term "Concrete-Tight" or "Concrete-Tight When Taped," see *UL Guide Information DWTT*.

(2) Wet Locations. When used in wet locations, IMC fittings must be listed for use in wet locations. See Figure 342–12.

Figure 342–12 342.42(A)(2)

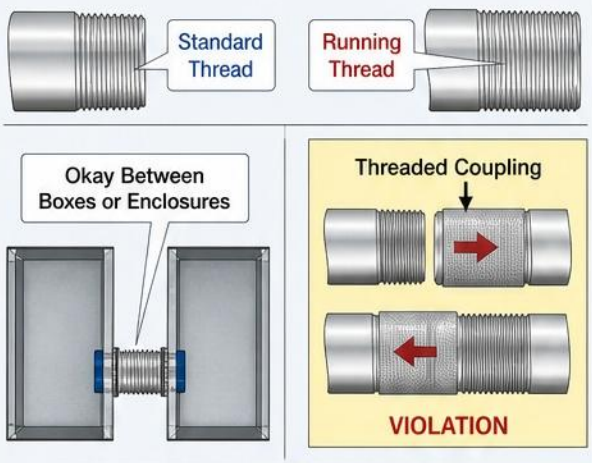
When installed in wet locations, IMC fittings must be listed for wet-location use.

> **AUTHOR'S COMMENT**
>
> Fittings suitable for use in a wet location are indicated on the device or carton with the term "Rain-Tight" or "Wet-Location," see *UL Guide Information DWTT*.

(B) Running Threads. Running threads are not permitted for the connection of couplings, but they are permitted between enclosures.

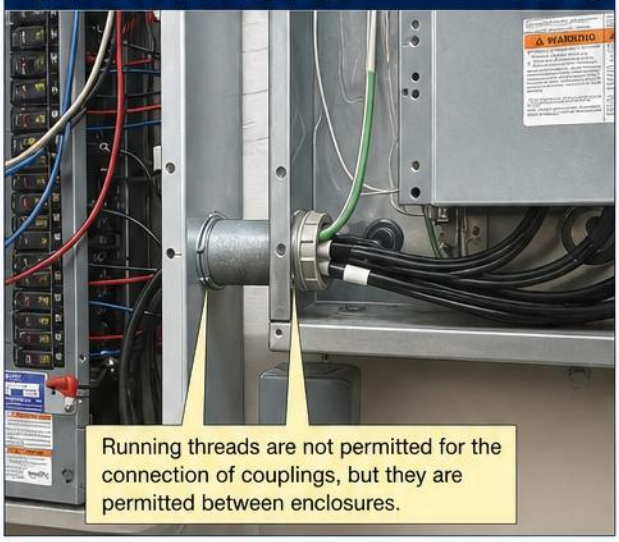
See Figure 342–13 and Figure 342–14.

Figure 342-13 IMC, Running Threads 342.42(B)



Running threads are not permitted for the connection of couplings, but they are permitted between enclosures.

Figure 342-14 IMC, Running Threads 342.42(B)



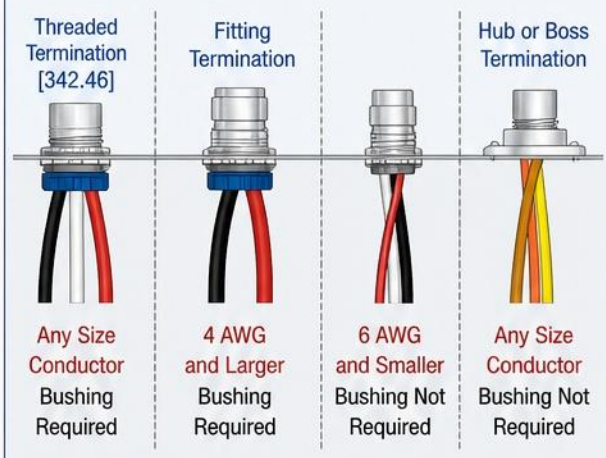
Running threads are not permitted for the connection of couplings, but they are permitted between enclosures.

342.46 Bushings

A bushing must be installed on IMC threaded conduit to protect conductors from abrasion while exiting the IMC, unless the conduit enters a threaded entry in a box, fitting, or enclosure.

Note: Conductors 4 AWG and larger exiting a conduit connector must be protected from abrasion by a fitting that provides a smooth rounded surface in accordance with 300.6(G). **Figure 342-15**

Figure 342-15 IMC, Bushings Conductor Protection 342.46 Note



Conductors 4 AWG and larger exiting a conduit connector must be protected from abrasion by a fitting that provides a smooth rounded surface in accordance with 300.6(G).

342.60 Equipment Grounding Conductor

IMC can serve as an equipment grounding conductor in accordance with 250.118(A)(3). **Figure 342-16**

Figure 342-16 IMC, Equipment Grounding Conductor 342.60

IMC can serve as an equipment grounding conductor in accordance with 250.118(A)(3).

Author's Comment:

- The Steel Tube Institute and Georgia Tech provided studies that show ground-fault current paths travel effectively on metal raceways rather than on equipment grounding conductors. Visit https://steeltubeinstitute.org for more information.

ARTICLE

344 Rigid Metal Conduit (RMC)

Introduction to Article 344—Rigid Metal Conduit (RMC)

This article sets out the rules for the use, installation, and construction requirements of rigid metal conduit (RMC) and the fittings used with it. RMC—commonly referred to as "rigid"—has been the standard raceway for safeguarding conductors from physical harm and harsh environments for many years. Available in trade sizes up to 6, it can be threaded and has the same outside diameter as intermediate metal conduit, but its wall is thicker. RMC is manufactured from a range of metals, including steel, aluminum, red brass, and stainless steel.

Conduit, Rigid Metal Conduit (RMC). A metal raceway of circular cross section that can be threaded with couplings and fittings listed for the installation of electrical conductors. **Figure 344–1**

Figure 344–1 Article 100 Definition NEC Article 100

A metal raceway of circular cross section that can be threaded with couplings and fittings.

Part I. General

344.1 Scope

This article sets out the rules for the use, installation, and construction requirements of rigid metal conduit (RMC) and the fittings used with it. **Figure 344–2**

Figure 344–2 Scope NEC 344.1

Article 344 contains the requirements for the use, installation, and construction specifications of rigid metal conduit (RMC) and associated fittings.

344.2 Listing Requirements

RMC and associated fittings must be listed. **Figure 344–3**

Author's Comment:

- Raceway support hardware is not considered an associated RMC fitting and is not required to be listed. However, support hardware must be constructed of materials suitable for the environment for which they are to be installed, see 300.8.

Figure 344–3 RMC, Listing Requirements 344.2

Rigid metal conduit and its associated fittings must be listed.

Part II. Installation

344.10 Uses Permitted

(A) Atmospheric Conditions and Occupancies. RMC may be used in all atmospheric conditions and occupancies.

(B) Corrosive Environments. RMC may be used in concrete, direct burial, or in areas where severe corrosive influences exist, provided the condition is approved for which corrosion protection has been provided.

Author's Comment:

- In accordance with *UL* Guide Information DYX, when RMC and associated fittings are installed underground in soil having a resistivity of less than 2000 ohms, additional corrosion protection is required. In addition, supplementary corrosion protection is required at the point where RMC transitions from concrete encasement to soil.

(D) Wet Locations. Support fittings (such as screws, straps, and so forth) used in wet locations must be made of corrosion-resistant material or be protected with corrosion-resistant coatings.

Note: For protection against corrosion, see 300.8.

(E) Severe Physical Damage. Where subject to severe physical damage.

344.14 Dissimilar Metals

When it is practical, avoid letting RMC come into contact with dissimilar metals to prevent deterioration of the metal caused by galvanic action.

344.20 Trade Size

(A) Minimum. RMC smaller than trade size ½ is not permitted.

(B) Maximum. RMC larger than trade size 6 is not permitted.

344.22 Number of Conductors

The number of conductors is not permitted to exceed the percentage fill specified in Chapter 9, Table 1.

Author's Comment:

- Whenever all conductors in a raceway have the same size, insulation type, quantity, or raceway size, refer to Annex C, Note (1) of Chapter 9.
- For examples of sizing raceways when conductors are not all the same size, see 300.19.

Cables may be placed in the raceway only if the total cross-sectional area of the cables does not exceed the allowable percentage fill specified in Chapter 9, Table 1.

▶ RMC Annex C Table Example

Question: *How many 12 AWG, THWN-2 conductors can be installed in ¾ RMC?*

(a) 10 *(b) 12* *(c) 14* *(d) 16*

Answer: *(d) 16 [Annex C, Table C.9]*

344.24 Bends

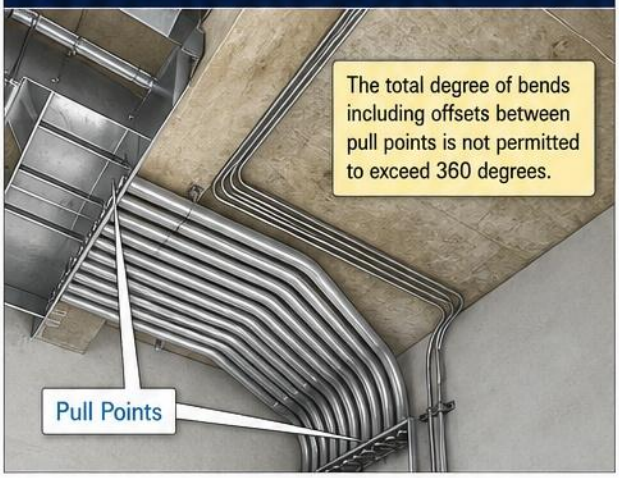
(A) How Made. When bending RMC, the bends must not crush or significantly alter the internal diameter (no kinks) of the raceway.

Author's Comment:

- This is not an issue when you use a bender in accordance with the manufacturer's instructions.

(B) Degrees of Bends in One Run. The total degree of bends including offsets between pull points is not permitted to exceed 360 degrees. ▶ Figure 344–4

Figure 344–4 Degrees of Bends in One Run 344.24(B)

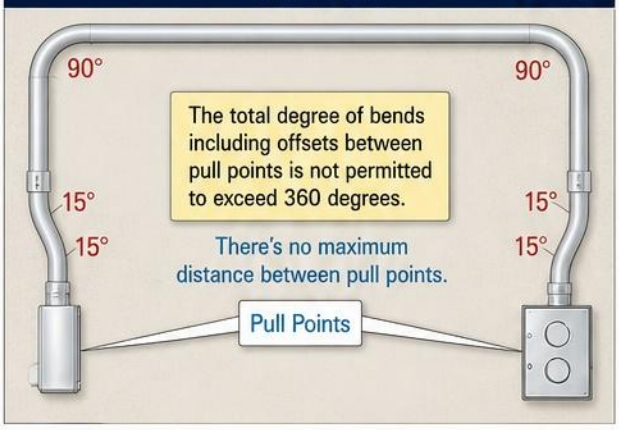


The conduit run includes multiple bends with pull points at each end.

AUTHOR'S COMMENT:

There is no maximum distance between pull boxes because this is a design issue—not a safety issue. ▶ Figure 344–5

Figure 344–5 Degrees of Bends in One Run 360 Degrees 344.24(B) Comment



This example totals 360 degrees of bends while maintaining pull points at both ends.

344.28 Reaming

When the raceway is cut in the field, reaming is required to remove the rough edges.

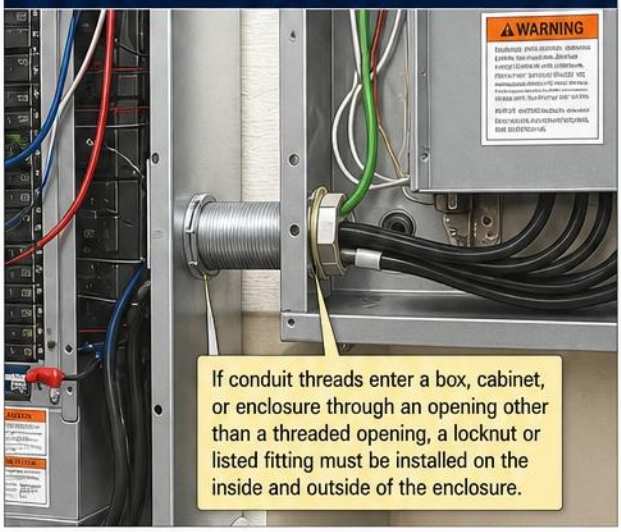
AUTHOR'S COMMENT:

It is a commonly accepted practice to ream small raceways with a screwdriver or the backside of pliers. However, when the raceway is cut with a three-wheel pipe cutter, a reaming tool is required to remove the sharp edge of the indented raceway. When the conduit is threaded in the field, the threads must be coated with an electrically conductive, corrosion-resistant compound approved by the authority having jurisdiction (AHJ) in accordance with 300.8(A).

344.29 Paired Locknuts

If conduit threads enter a box, cabinet, or enclosure through an opening other than a threaded opening, a locknut or listed fitting must be installed on the inside and outside of the enclsoure. ▶ Figure 344–6

Figure 344–6 Paired Locknuts 344.29



Conduit is threaded through a nonthreaded opening with locknuts on both sides.

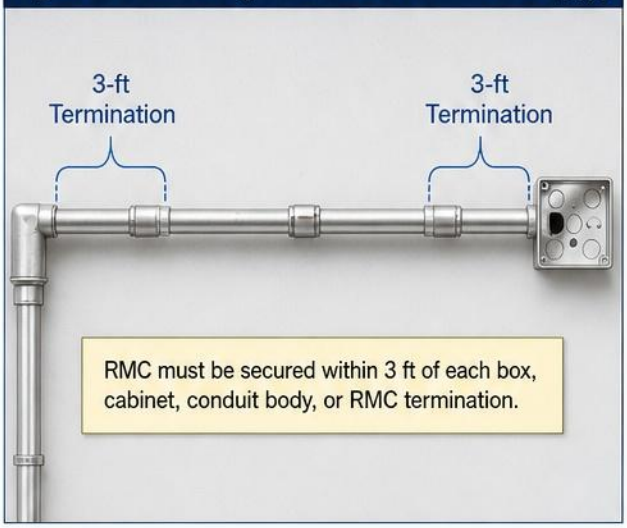
344.30 Securing and Supporting

RMC must be securely fastened and supported in accordance with 344.30(A) and (B).

(A) Securely Fastened. RMC must be secured in accordance with any of the following:

(1) Secured within 3 ft of each box, cabinet, conduit body, or RMC termination. ▶ Figure 344–7

Figure 344–7 Securing RMC Within 3 Feet 344.30(A)(1)

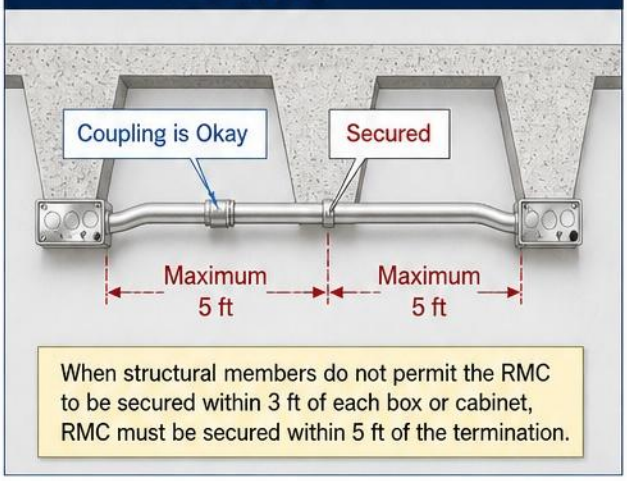


Author's Comment:

- Securing is required within 3 ft of terminations—not within 3 ft of each coupling.

(2) When structural members do not permit the RMC to be secured within 3 ft of each box or cabinet, RMC ▶Figure 344–8

Figure 344–8 Securing RMC Maximum 5 Feet 344.30(A)(2)



(3) Secured within 5 ft of the termination, when secured within 3 ft of the service head for an above-the-roof termination of a mast ▶Figure 344–9

(B) Supports. RMC must be supported as follows:

(1) General. RMC must be supported at intervals not exceeding 10 ft.

Figure 344–9 Securing RMC Above the Roof 344.30(A)(3)

(2) Straight Runs. Straight horizontal runs of RMC with threaded couplings can be supported in accordance with the distances contained in Table 344.30(B). ▶Figure 344–10 and ▶Figure 344–11

Figure 344–10 Supporting RMC Straight Runs 344.30(B)(2)

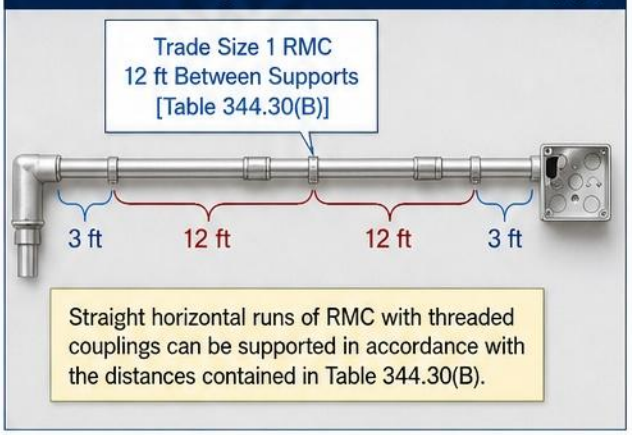


Table 344.30(B) Supports for Rigid Metal Conduit

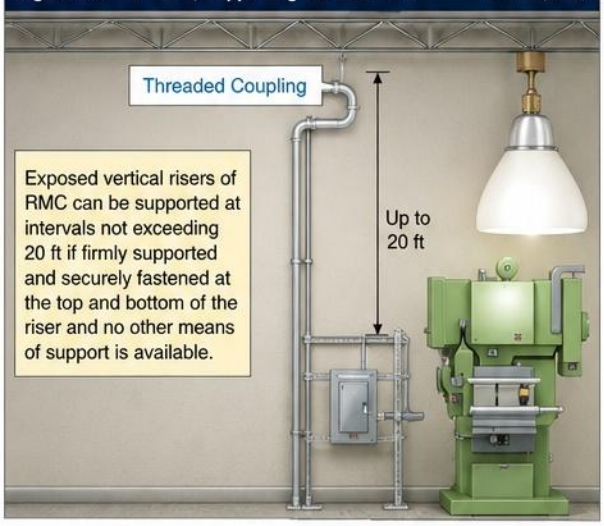
Trade Size	Support Spacing
½–¾	10 ft
1	12 ft
1¼–1½	14 ft
2–2½	16 ft
3 and larger	20 ft

Figure 344–11 RMC, Supporting Straight Runs 344.30(B)(2)

Straight horizontal runs of RMC with threaded couplings may be supported at intervals in accordance with Table 344.30(B).

(3) Vertical Risers. Exposed vertical risers for fixed equipment can be supported at intervals not exceeding 20 ft if the conduit is made up with threaded couplings, firmly supported, securely fastened at the top and bottom of the riser, and no other means of support is available.

Figure 344–12 RMC, Supporting Vertical Risers 344.30(B)(3)



Exposed vertical risers of RMC may be supported at intervals not exceeding 20 ft if they are firmly supported, securely fastened at the top and bottom, and no other means of support is available.

(4) Horizontal Runs. RMC installed horizontally through framing members are considered supported and secured if such support does not exceed 10-ft intervals, and the conduit is secured within 3 ft of termination.

Author's Comment:

- RMC must be provided with expansion fittings where necessary to compensate for thermal expansion and contraction [300.9(B)]. The expansion characteristics for metal raceways are determined by multiplying the values from Table 352.44 by 20 percent. The expansion characteristics for aluminum raceways are determined by multiplying the values from Table 352.44 by 40 percent [300.8(B) Note].

344.42 Couplings and Connectors

(A) General. Couplings and connectors must be made tight.

Author's Comment:

- Loose locknuts have been found to burn away before a fault was cleared because loose connections increase the impedance of the ground-fault current path.

(1) Concrete Buried. If buried in concrete, RMC fittings must be listed for concrete-tight type.

Figure 344–13 RMC, Couplings and Connectors, Concrete Buried 344.42(A)(1)

If RMC fittings are buried in concrete, they must be listed for concrete-tight use.

Author's Comment:

- Fittings suitable for use in poured concrete are indicated on the device or carton with the term "Concrete-Tight" or "Concrete-Tight When Taped," *UL Guide Information DWTT.*

(2) Wet Locations. Where RMC is installed in wet locations, RMC fittings shall be listed for use in wet locations. Figure 344–14

Figure 344–14 RMC, Couplings and Connectors 344.42(A)(2)

RMC fittings used in wet locations must be listed for use in wet locations.

Author's Comment:

- Fittings suitable for use in a wet location are indicated on the device or carton with the term "Rain-Tight" or "Wet-Location," see *UL Guide info DWTT.*

(B) Running Threads. Running threads are not permitted for the connection of couplings, but they are permitted between enclosures. Figure 344–15 and Figure 344–16

Figure 344–15 RMC, Running Threads 344.42(B)

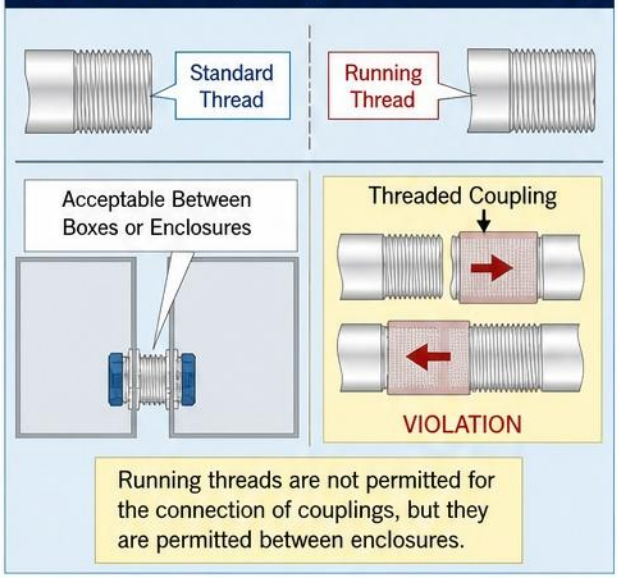
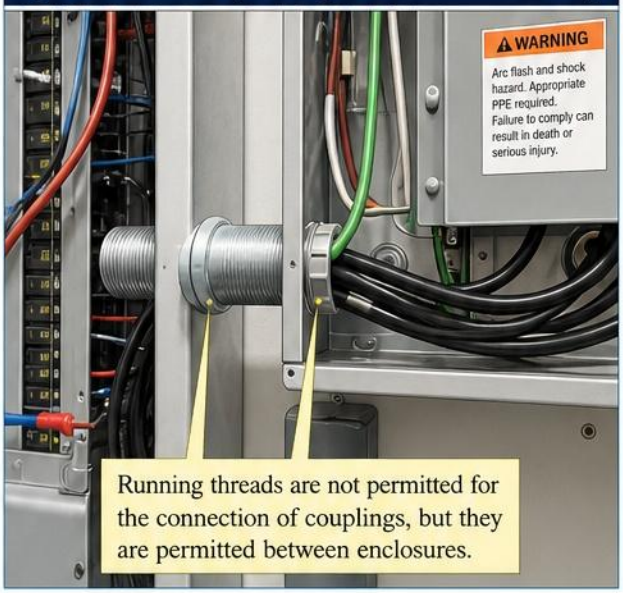


Figure 344–16 RMC, Running Threads 344.42(B)

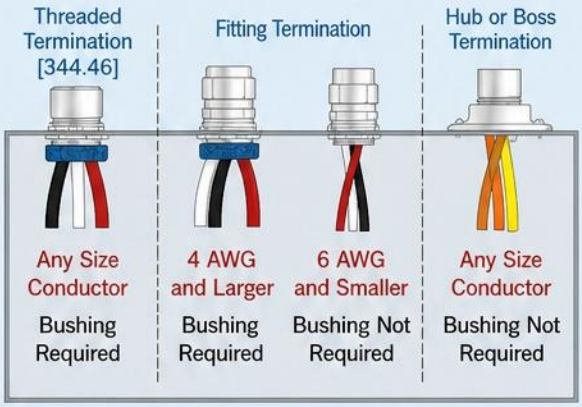


344.46 Bushings

A bushing must be installed on RMC threaded conduit to protect conductors from abrasion while exiting the RMC, unless the conduit enters a threaded entry in a box, fitting, or enclosure.

Note: Conductors 4 AWG and larger exiting a conduit connector must be protected from abrasion by a fitting that provides a smooth rounded surface in accordance with 300.6(G). Figure 344–17

Figure 344–17 RMC, Bushings Conductor Protection 344.46 Note



Conductors 4 AWG and larger exiting a conduit connector must be protected from abrasion by a fitting that provides a smooth rounded surface in accordance with 300.6(G).

344.60 Equipment Grounding Conductor

RMC can function as an equipment grounding conductor in accordance with 250.118(A)(2).

Figure 344–18: RMC, Equipment Grounding Conductor 344.60

RMC can function as an equipment grounding conductor in accordance with 250.118(A)(2).

AUTHOR'S COMMENT:

- The Steel Tube Institute and Georgia Tech provided studies that show ground-fault current paths traverse metal raceways more effectively than dedicated equipment grounding conductors. Visit https://steeltubeinstitute.org for more information.

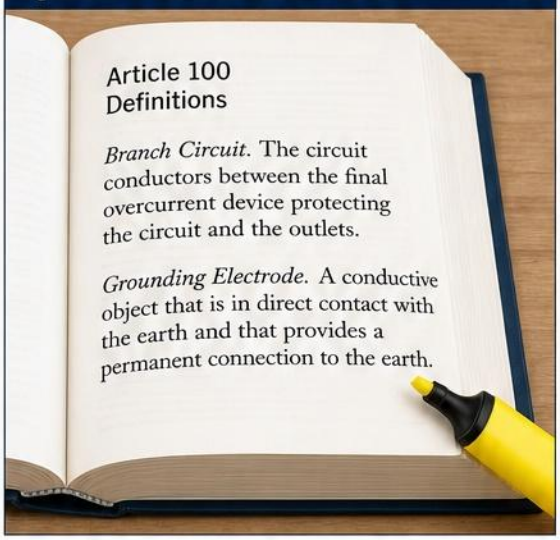
Article 100 — Definitions

Article 100 provides definitions for words and terms used throughout the NEC. Understanding these definitions is essential for correct code application.

100 Definitions. Specific technical terms are defined in Article 100. Words defined in Article 100 appear in *italics* the first time they are used in each Article.

Defined Terms. Only the technical terms defined in Article 100 are italicized. Common words or general terms are not italicized.

Figure 100–1 Technical Terms in the NEC 100



Article 100 contains the definitions of technical terms used throughout the NEC. These terms are italicized the first time they appear in each Article.

Informational Note. Informational Notes provide guidance or clarification to help understand or apply a Code rule but are not requirements.

"Shall" vs. "Should." "Shall" indicates a mandatory requirement. "Should" indicates a recommendation or that which is advised but not required.

Scope of the NEC. The NEC covers installation requirements for electrical systems and equipment to ensure practical safeguarding of persons and property from hazards arising from the use of electricity.

Article 110 — Requirements for Electrical Installations

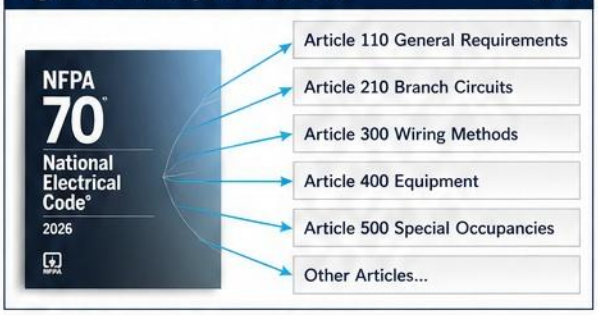
Article 110 contains general requirements that apply to all electrical installations unless modified by other Articles.

110.1 Scope. Electrical installations must comply with the requirements in this Article and in all applicable Articles of the NEC. Other sections of this Code modify or qualify these general requirements.

110.3 Approval. Equipment and materials must be listed or labeled as required in 110.3. They must be used in accordance with their listing or labeling.

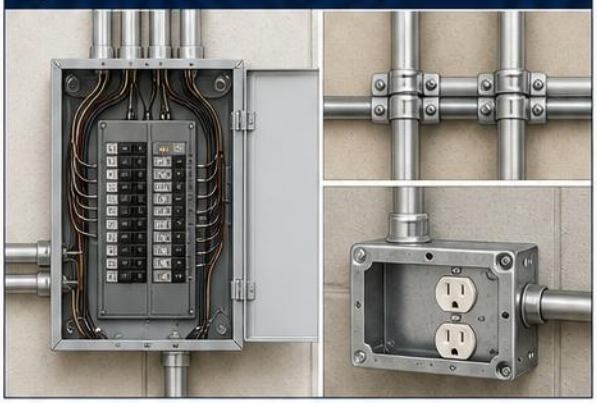
110.12 Mechanical Execution. Electrical equipment must be installed in a neat and workmanlike manner. Parts must be securely fastened and properly supported.

Figure 110–1 Scope of Article 110 110.1



Article 110 establishes general requirements that apply to all electrical installations unless modified by other Articles of the NEC.

Figure 110–2 Workmanlike Installation 110.12



Electrical equipment must be installed in a neat and workmanlike manner and securely fastened.

Safety Purpose. The purpose of Article 110 and the NEC is the practical safeguarding of persons and property from hazards that may arise from the use of electricity.

ARTICLE

348 Flexible Metal Conduit (FMC)

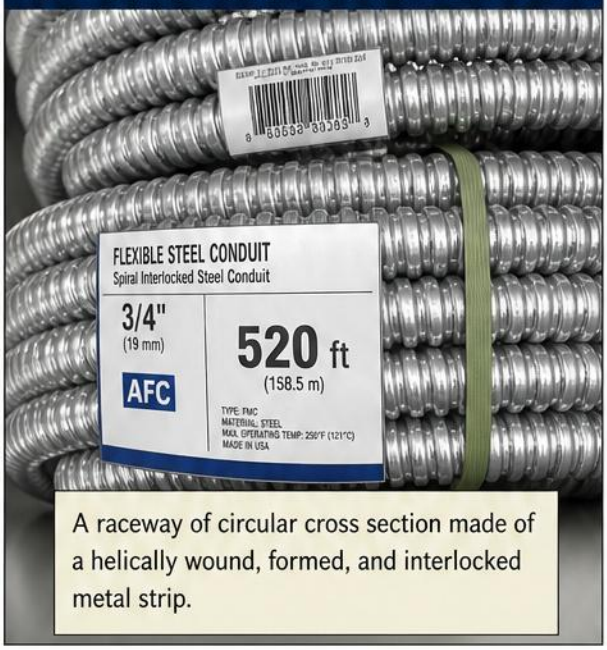
Introduction to Article 348—Flexible Metal Conduit (FMC)

Article 348 addresses the use, installation, and construction requirements for *flexible metal conduit (FMC)* and its associated fittings. FMC is a raceway made of spiral interlocked steel or aluminum strip. It is commonly referred to as "flex," and at times as "Greenfield" in honor of its inventor. FMC is primarily utilized in situations where flexibility is needed for equipment movement, vibration, or shaking.

Conduit, Flexible Metal Conduit (FMC). A raceway of circular cross section made of a helically wound, formed, and interlocked metal strip.

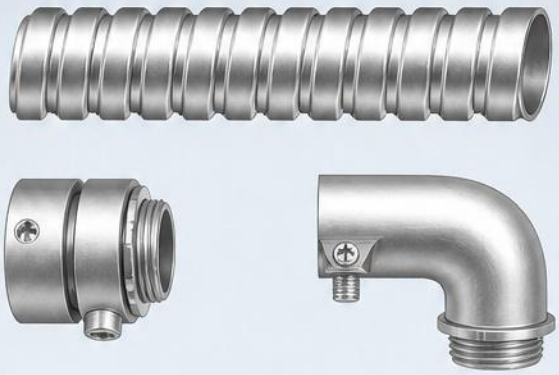
Figure 348–1

Figure 348–1 Flexible Metal Conduit (FMC) Article 100 Definition



A raceway of circular cross section made of a helically wound, formed, and interlocked metal strip.

Figure 348–2 Flexible Metal Conduit (FMC) 348.1 Scope



Article 348 sets forth the requirements for using and installing flexible metal conduit (FMC) and the associated fittings.

348.2 Listing Requirements

Flexible metal conduit and associated fittings must be listed.

Part I. General

348.1 Scope

This article contains the requirements for the use and installation of flexible metal conduit (FMC) and associated fittings.

Figure 348–2

Part II. Installation

348.10 Uses Permitted

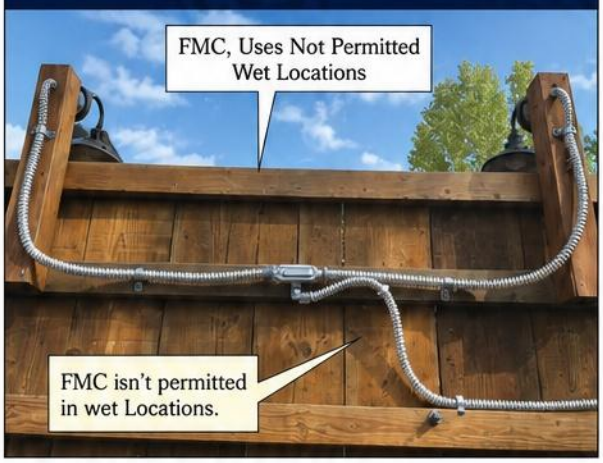
FMC is permitted to be used exposed or concealed.

348.12 Uses Not Permitted

FMC shall not be used in:

(1) Wet locations. See Figure 348–3.

Figure 348–3 FMC, Uses Not Permitted Wet Locations 348.12(1)



FMC is not permitted in wet locations.

(2) Hoistways—other than as permitted in 620.21(A)(1).

(3) Storage battery rooms.

(4) Any hazardous location, except as permitted by 501.10(B).

(5) Where the surrounding material may deteriorate the installed conductors.

(6) Underground or embedded in poured concrete. See Figure 348–4.

Figure 348–4 FMC, Uses Not Permitted Underground or in Concrete 348.12(6)

FMC is not permitted underground or embedded in poured concrete.

(7) Where subject to physical damage as determined by the AHJ.

348.20 Trade Size

(A) Minimum. The smallest trade size permitted for FMC is 1½. However, a trade size ⅜ may be used for the following applications:

(1) When enclosing motor leads.

(2) When not exceeding 6 ft for any of the following:

a. For utilization equipment.

b. As part of a listed assembly.

c. For luminaire tap connections in accordance with 410.117(C).

(5) As part of a listed assembly used to interconnect luminaires in accordance with 410.137(C).

(B) Maximum. The largest trade size permitted for FMC is 4.

348.22 Number of Conductors

The number of conductors shall not be greater than the percentage fill values shown in Chapter 9, Table 1.

Author's Comment:

- When all conductors in a raceway are the same size, same insulation type, same number of conductors permitted, or same raceway size, see Annex C, Note (1) of Chapter 9.
- For examples of how to size raceways when conductors are not all the same size, see 300.19.

Cables are permitted in the raceway if the total cross-sectional area of all cables does not exceed the allowable percentage fill values in Chapter 9, Table 1.

▶ Number of Conductors in FMC [348.22] Example

Question: *How many 6 AWG, THWN-2 conductors can be installed in 1 FMC?*

(a) 2 conductors *(b) 4 conductors*

(c) 6 conductors *(d) 8 conductors*

Answer: *(c) 6 conductors [Annex C, Table C.3]*

348.24 Bends

(A) How Made. When bending FMC, the bends must not damage or significantly change the internal diameter (no kinks) of the raceway.

(B) Degrees of Bends in One Run. The total degrees of bends (including offsets) between pull points is not permitted to exceed 360 degrees.

348.28 Trimming

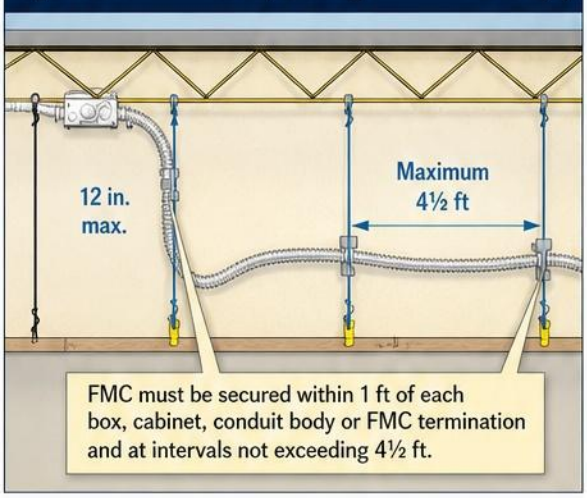
The cut ends of FMC must be trimmed to remove the rough edges but is not necessary if fittings are threaded into the convolutions.

348.30 Securing and Supporting

FMC must be securely fastened and supported in accordance with 348.30(A) and (B).

(A) Securely Fastened. FMC must be secured within 1 ft of each box, cabinet, conduit body or FMC termination. In addition, FMC must be secured at intervals not exceeding 4½ ft.
See Figure 348–5.

Figure 348–5 FMC, Securing 348.30(A)

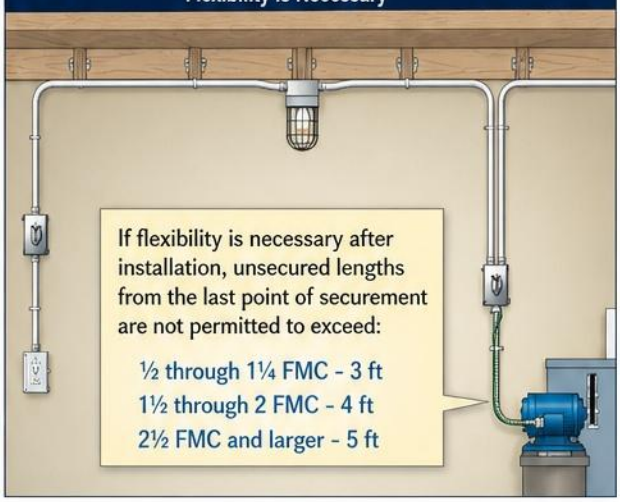


Where cable ties are used to secure FMC, they must be listed and identified for securing and supporting.

Ex 1: FMC is not required to be securely fastened or supported where fished between access points through concealed spaces and supporting is impractical.

Ex 2: If flexibility is necessary after installation as determined by the AHJ, unsecured lengths from the last point of securement are not permitted to exceed: See Figure 348–6.

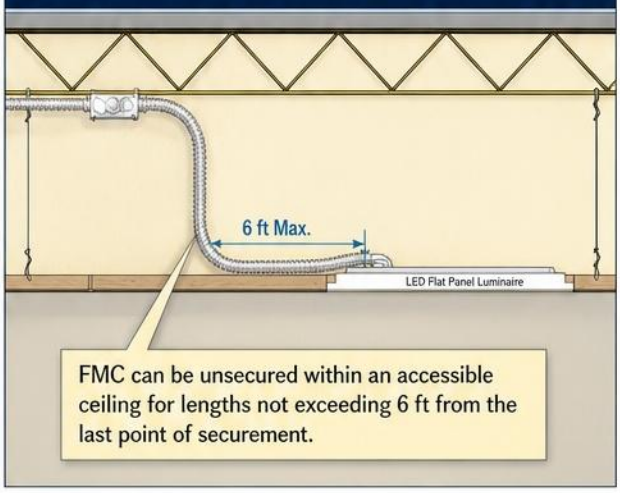
Figure 348–6 FMC, Unsecured Lengths Where Flexibility is Necessary 348.30(A) Ex 2



(1) 3 ft for trade sizes ½ through 1¼
(2) 4 ft for trade sizes 1½ through 2
(3) 5 ft for trade sizes 2½ and larger

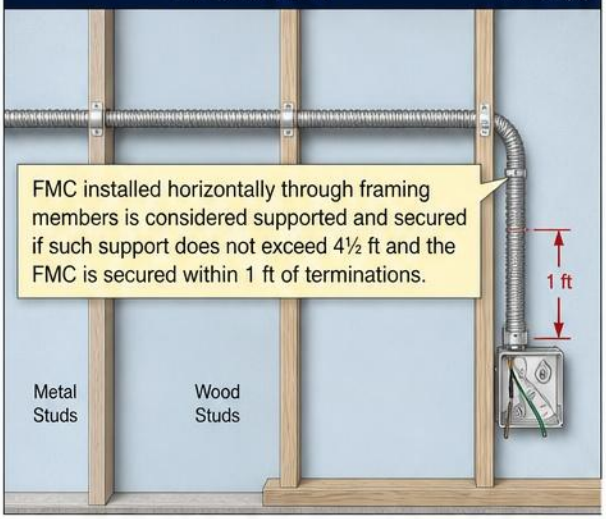
Ex 4: FMC can be unsecured within an accessible ceiling not exceeding 6 ft from the last point of securement.
See Figure 348–7.

Figure 348–7 FMC, Unsecured Accessible Ceilings 348.30(A) Ex 4



(B) Horizontal Runs. FMC installed horizontally through framing members is considered supported and secured if such support does not exceed 4½ ft and secured within 1 ft of terminations.
See Figure 348–8.

Figure 348–8 FMC, Securing and Supporting Horizontal Runs 348.30(B)



FMC is considered supported and secured when installed horizontally through framing members if support spacing does not exceed 4½ ft and the conduit is secured within 1 ft of terminations.

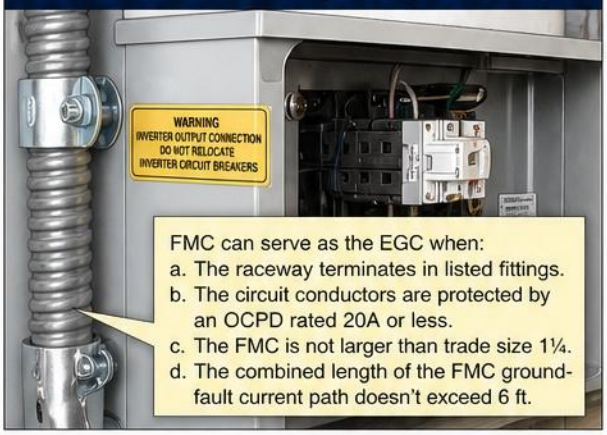
348.42 Connectors

Angle connectors are not permitted to be concealed inside drywall or concrete.

348.60 Equipment Grounding and Bonding Conductors

(A) Fixed Installation. If flexibility is not necessary after installation or vibration is not a concern, FMC can serve as an equipment grounding conductor in accordance with 250.118(A)(5). Figure 348–9.

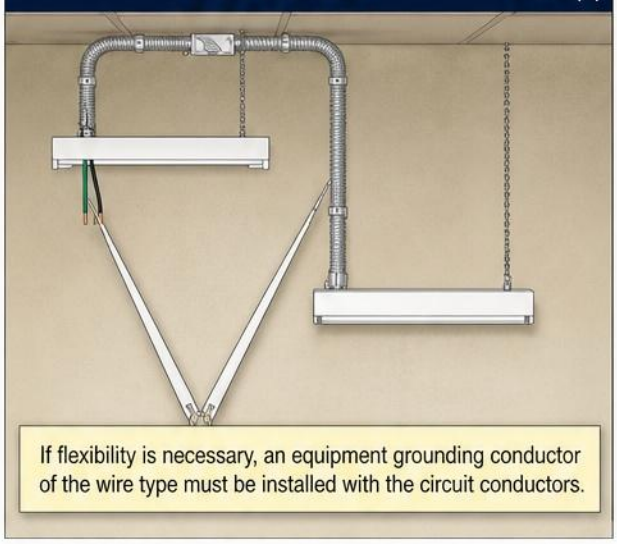
Figure 348–9 Equipment Grounding Conductor—Flexible Metal Conduit, Flexibility Not Required 250.118(A)(5)



FMC may function as an equipment grounding conductor when the conditions listed are met.

(B) Flexible Installation. If flexibility is necessary to minimize the transmission of vibration from equipment as determined by the AHJ, or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor must be installed with the circuit conductors. Figure 348–10.

Figure 348–10 FMC, Equipment Grounding Conductor Flexible Installation 348.60(B)



When flexibility is required, a wire-type equipment grounding conductor must be installed with the circuit conductors.

(D) Equipment Bonding Jumpers. The equipment bonding jumper can be installed inside or outside the flexible metal conduit. Where installed outside the FMC, the length of the equipment bonding jumper is not permitted to exceed 6 ft and must be routed with the flexible metal conduit in accordance with 250.102(E)(2).

ARTICLE

350 Liquidtight Flexible Metal Conduit (LFMC)

Introduction to Article 350—Liquidtight Flexible Metal Conduit (LFMC)

This article outlines the rules for the use, installation, and construction requirements for *liquidtight flexible metal conduit (LFMC)* and its associated connectors and fittings.

LFMC (with its associated connectors and fittings) is a flexible raceway commonly available in trade sizes ½ and larger. It is used for connections to equipment that vibrates or must be moved occasionally. LFMC is commonly called "Seal-Tite®" or "liquidtight." It serves the same purpose in use and construction as flexible metal conduit, but it has an outer liquidtight thermoplastic covering that protects against penetration by liquids and offers some resistance to corrosive environments.

Conduit, Liquidtight Flexible Metal Conduit (LFMC). A raceway of circular cross section (having an outer liquidtight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core) with connectors and fittings listed for the installation of electrical conductors.

Figure 350–1 Article 100 Definition NEC 100

A liquidtight flexible metal conduit (LFMC) protects the conductors from moisture and provides flexibility for connections to vibration-sensitive and movable equipment.

Part I. General

350.1 Scope

This article specifies the requirements for the use, installation, and construction of liquidtight flexible metal conduit (LFMC) and its associated fittings.

Figure 350–2 350.1 Scope NEC 350.1

LFMC is used to make flexible, liquidtight connections to equipment where movement or vibration may occur.

350.2 LISTING REQUIREMENTS

LFMC and its associated fittings must be listed.

Author's Comment:

- In accordance with *UL 360 Standard for Liquidtight Flexible Metal Conduit*, listed LFMC will have an internal copper strip that bonds the inner flexible metal core to each convolution of the raceway.

PART II. INSTALLATION

350.10 USES PERMITTED

LFMC is permitted to be used either exposed or concealed as follows:

(1) When flexibility is required or to provide protection from machine oils, liquids, vapors, or solids.

(2) In hazardous locations in accordance with Chapter 5.

(3) For direct burial if it is listed and marked for this purpose.

Figure 350–3 Permitted Uses – Direct Burial 350.10(3)

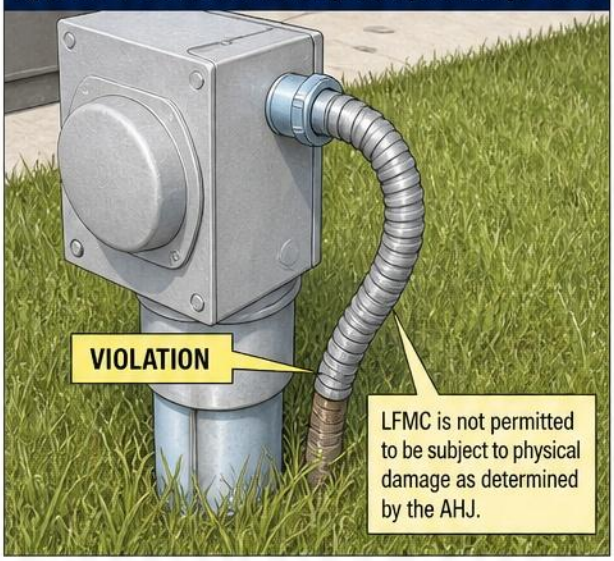
LFMC installed in direct burial next to a building foundation and HVAC unit.

(5) For encasement in concrete where it is listed and marked for direct burial and installed in accordance with 350.42.

350.12 USES NOT PERMITTED

LFMC is not permitted to be used where subject to physical damage as determined by the AHJ.

Figure 350–4 Uses Not Permitted Subject to Physical Damage 350.12



LFMC is exposed at ground level and is subject to physical damage.

350.20 TRADE SIZE

(A) Minimum. LFMC smaller than trade size ½ is not permitted to be used.

(B) Maximum. LFMC larger than trade size 4 is not permitted to be used.

350.22 NUMBER OF CONDUCTORS

(A) Raceways ½ and Larger. The number of conductors is not permitted to exceed the percentage fill specified in Chapter 9, Table 1.

Author's Comment:

- When all conductors within a raceway are the same size, same insulation type, number of conductors permitted, or raceway size, see Annex C, Note (1) of Chapter 9.
- For examples of how to size raceways when conductors are not all the same size, see 300.19.

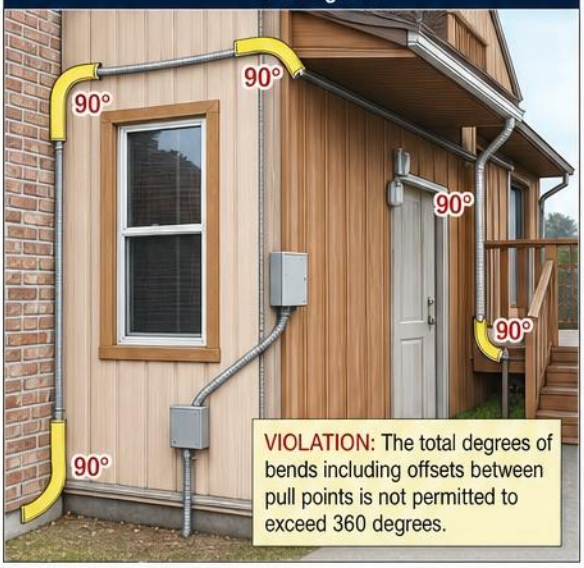
Cables are permitted in the raceway if the total area of cables does not exceed the allowable percentage fill specified in Chapter 9, Table 1.

350.24 Bends

(A) How Made. When bending LFMC, the bends must not damage or significantly change the internal diameter (no kinks) of the raceway.

(B) Degrees of Bends in One Run. The total degrees of bends including offsets between pull points is not permitted to exceed 360 degrees. ▸ Figure 350–5

Figure 350–5 LFMC, Bends in One Run 360 Degrees 350.24(B)



350.28 Trimming

Cut ends of LFMC must be trimmed inside and outside the raceway to remove rough edges.

350.30 Securing and Supporting

LFMC must be securely fastened and supported in accordance with 350.30(A) and (B).

(A) Securely Fastened. LFMC must be secured within 1 ft of each box, cabinet, conduit body, or LFMC termination. In addition, LFMC must be secured at intervals not exceeding 4½ ft. ▸ Figure 350–6

Where cable ties are used for securing LFMC, they must be listed and identified for securement and support.

Ex 1: LFMC is not required to be securely fastened or supported where fished between access points through concealed spaces and supporting is impractical.

Ex 2: If flexibility is necessary after installation, unsecured lengths from the last point of securement are not permitted to exceed: ▸ Figure 350–7

Figure 350–6 LFMC, Securing 350.30(A)

Figure 350–7 LFMC, Unsecured Lengths Where Flexibility is Necessary 350.30(A) Ex 2

(1) 3 ft for trade sizes ½ through 1¼

(2) 4 ft for trade sizes 1½ through 2

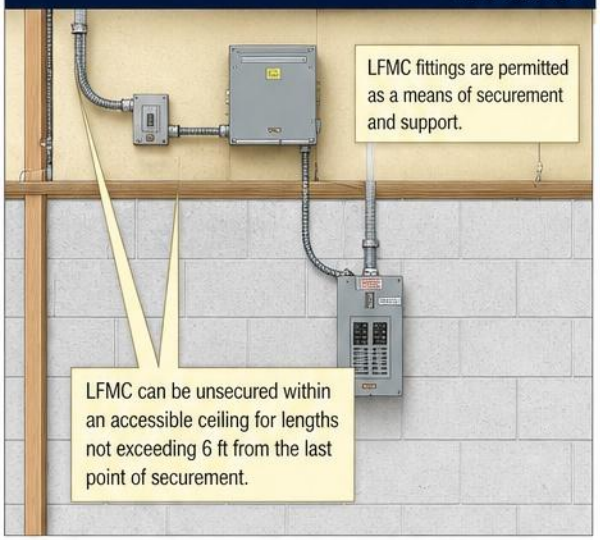
(3) 5 ft for trade sizes 2½ and larger

Ex 4: LFMC can be unsecured within an accessible ceiling not exceeding 6 ft from the last point of securement. ▸ Figure 350–8

Author's Comment:

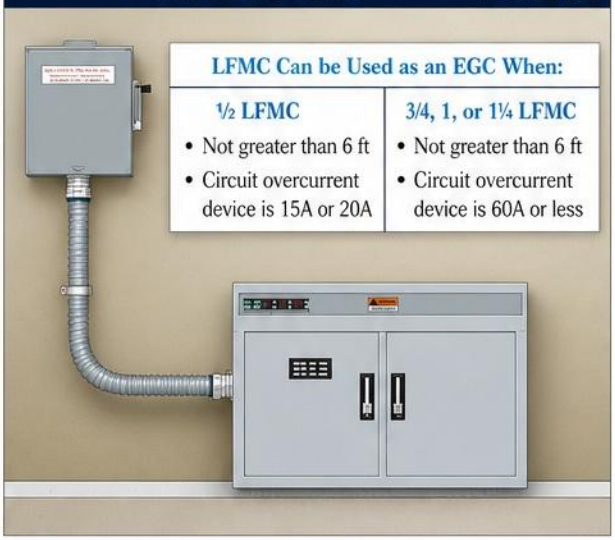
▷ This last sentence following the four exceptions means that the use of LFMC fittings as the means of securing and supporting only applies to installations made using one of the four exceptions. It should not be interpreted as permission to use these fittings to secure and support LFMC in all applications.

Figure 350–8 LFMC, Unsecured in Accessible Ceilings 350.30(A) Ex 4



LFMC is allowed to be unsecured in an accessible ceiling for runs that do not extend more than 6 ft beyond the last point at which the conduit is secured.

Figure 350–9 Equipment Grounding Conductor, LFMC, Flexibility Not Required 250.118(A)(6)



LFMC can serve as an equipment grounding conductor when the length is 6 ft or less and the overcurrent device rating matches the conditions shown.

(B) Horizontal Runs. LFMC installed horizontally through framing members is considered supported and secured if such support does not exceed 4½ ft and secured within 1 ft of termination.

350.42 Connectors

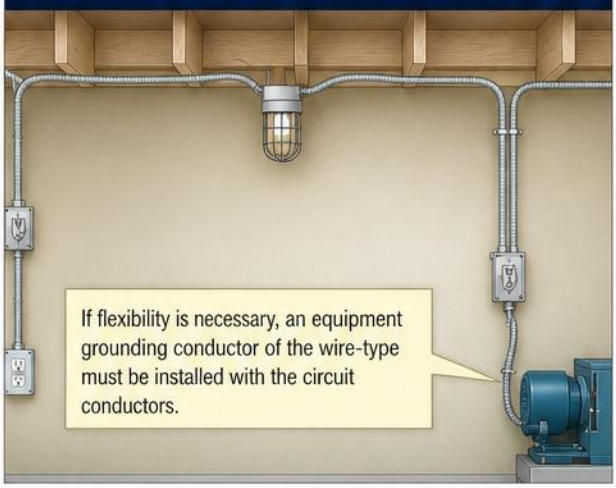
Angle connectors for LFNC cannot be concealed.

350.60 Equipment Grounding and Bonding Conductors

(A) Fixed Installations. If flexibility is not necessary after installation, and vibration is not a concern, liquidtight flexible metal conduit can serve as an equipment grounding conductor in accordance with 250.118(A)(6). **Figure 350–9**

(B) Flexible Installations. If flexibility is necessary to minimize the transmission of vibration from equipment, or to provide flexibility for equipment that requires movement after installation as determined by the AHJ, a wire-type equipment grounding conductor must be installed with the circuit conductors. **Figure 350–10**

Figure 350–10 LFMC, Equipment Grounding Conductor Flexible Installation 350.60(B)



When flexibility is needed, a separate wire-type equipment grounding conductor must be installed with the circuit conductors.

(D) Equipment Bonding Jumper. The equipment bonding jumper can be installed inside or outside the liquidtight flexible metal conduit (LFMC). Where the bonding jumper is installed outside the LFMC, the length of the equipment bonding jumper cannot exceed 6 ft, and it must be routed with the LFMC in accordance with 250.102(E)(2).

ARTICLE

352 Rigid Polyvinyl Chloride Conduit (PVC)

Introduction to Article 352—Rigid Polyvinyl Chloride Conduit (PVC)

Article 352 addresses the use, installation, and construction requirements for rigid polyvinyl chloride conduit (PVC) and listed associated fittings.

PVC is a rigid, nonmetallic conduit that is available in trade sizes ½ and up to 6.

Two wall thickness options, known as "schedules," are available. Schedule 40 PVC is used in most applications where it will not be subject to physical damage. Schedule 80 PVC (which has the same outside diameter but a thicker wall) is used where added resistance to physical damage is necessary. This type of conduit is inexpensive, lightweight, and easy to install.

Conduit, Rigid Polyvinyl Chloride Conduit (PVC). A rigid nonmetallic raceway of circular cross section that is joined with couplings, connectors, and fittings for the installation of electrical conductors and cables.

See Figure 352–1.

Figure 352–1 Definition

A rigid nonmetallic raceway of circular cross section that is joined with couplings, connectors, and fittings for the installation of electrical conductors and cables.

Part I. General

352.1 Scope

This article addresses the use, installation, and construction requirements for polyvinyl chloride conduit (PVC) and listed associated fittings.

See Figure 352–2.

Figure 352–2 352.1 Scope

This article addresses the use, installation, and construction requirements for polyvinyl chloride conduit (PVC) and listed associated fittings.

352.2 Listing

PVC, factory elbows, and associated fittings are required to be listed. ▶ Figure 352–3

Figure 352–3 Rigid Polyvinyl Chloride Conduit (PVC) Listing 352.2

PVC, factory elbows, and associated fittings are required to be listed.

Author's Comment:

- Raceway support hardware is not considered an associated PVC fitting and is not required to be listed. However, support hardware must be constructed of materials suitable for the environment for which they are to be installed, see 300.8.

Part II. Installation

352.10 Uses Permitted

PVC is permitted to be used under the following conditions:

Note: In extreme cold, PVC can become brittle and more susceptible to physical damage.

(A) Concealed. PVC is permitted to be concealed within walls, floors, or ceilings.

(B) Encased in Concrete. PVC is permitted to be encased in concrete. ▶ Figure 352–4

(C) Corrosive Influences. PVC is permitted to be used in areas subject to severe corrosion for which the material is specifically approved by the authority having jurisdiction (AHJ).

Figure 352–4 PVC, Uses Permitted Encased in Concrete 352.10(B)

PVC is permitted to be encased in concrete.

(E) Wet Locations. PVC is permitted to be used in wet locations (such as dairies, laundries, canneries, car washes, and other areas frequently washed) and outdoor locations. Support fittings (such as straps, screws, and bolts) must be made of corrosion-resistant materials or protected with a corrosion-resistant coating in accordance with 300.8(A).

(F) Dry and Damp Locations. PVC is permitted to be used in dry and damp locations except where limited in 352.12.

(G) Exposed. PVC is permitted to be used in exposed locations as determined by the AHJ. ▶ Figure 352–5

Figure 352–5 PVC, Uses Permitted Exposed Work 352.10(G)

PVC is permitted to be used in exposed locations where not subject to physical damage as determined by the AHJ.

(H) Underground. PVC is permitted to be direct buried and encased in concrete underground.

(K) Physical Damage. Install Schedule 80 PVC where the likelihood of physical damage, as determined by the AHJ, exists. See **352–6.**

Figure 352–6 Physical Damage **352.10(K)**

Use Schedule 80 PVC when the authority having jurisdiction (AHJ) determines that physical damage is likely to occur.

Note: All listed PVC fittings are suitable for connection to Schedule 40 and Schedule 80 PVC.

352.12 Uses Not Permitted

PVC shall not be used under the following conditions:

(A) Hazardous Locations. Hazardous locations, except as permitted by 501.10(A)(1)(1) Ex, 501.10(B)(1)(6), 502.10(B)(7), 503.10(A)(1), 504.20, 514.8 Ex 2, and 515.8(A).

(B) Support of Luminaires. PVC shall not be used to support luminaires or other equipment.

(C) Physical Damage. PVC shall be subject to physical damage as determined by the AHJ, unless installed in Schedule 80 PVC in accordance with 352.10(K).

(D) Ambient Temperature. PVC shall not be used if the ambient temperature exceeds 50°C (122°F).

352.20 Trade Size

(A) Minimum. PVC smaller than trade size ½ is not permitted.

(B) Maximum. PVC larger than trade size 6 is not permitted. See **Figure 352–8.**

Figure 352–7 Physical Damage **352.12(C)**

PVC is not allowed to be subject to physical damage unless it is installed in Schedule 80 PVC in accordance with 352.10(K).

Figure 352–8 Trade Size Limits **352.20(A) and (B)**

A size smaller than trade size ½ is not allowed.
A size larger than trade size 6 is not allowed.

Example: PVC greater than trade size 6 is not allowed under any of the following situations:

(1) No portion of the conduit is installed aboveground.

(2) The conduit is installed underground in accordance with 300.7(F).

(3) The conduit does not pass through, or enter, a Class I, Division 1 (hazardous) location.

(4) The percentage of cross-sectional area of the conduit for conductors and cables does not exceed the limits in Chapter 9, Table 1.

352.22 NUMBER OF CONDUCTORS

The number of conductors is not permitted to exceed the percentage fill specified in Chapter 9, Table 1.

AUTHOR'S COMMENT:

- When all conductors within a raceway are the same size, same insulation type, number of conductors permitted, or raceway size, see Annex C, Note (1) of Chapter 9.
- For examples of how to size raceways when conductors are not all the same size, see 300.19.

Cables are permitted in the raceway if the total area of the cables does not exceed the allowable percentage fill specified in Chapter 9, Table 1.

EXAMPLE: NUMBER OF CONDUCTORS IN PVC SCH 40 [352.22]

Question: How many 4/0 AWG, THWN conductors can be installed in 2 Schedule 40 PVC? ▶ Figure 352–9

(a) 2 conductors (b) 4 conductors

(c) 6 conductors (d) 8 conductors

FIGURE 352–9 PVC, Schedule 40 Number of Conductors 352.22 Example 352.22

Four 4/0 THWN conductors are allowed in 2 PVC Sch 40.

AUTHOR'S COMMENT:

- Schedule 80 PVC has the same outside diameter as Schedule 40, but the wall thickness is greater which results in a reduced interior area for conductor fill.

EXAMPLE: NUMBER OF CONDUCTORS IN PVC SCHEDULE 80 [352.22]

Question: How many 4/0 AWG, THWN conductors can be installed in 2 Schedule 80 PVC? ▶ Figure 352–10

(a) 2 conductors (b) 3 conductors

(c) 4 conductors (d) 5 conductors

FIGURE 352–10 PVC, Schedule 80 Number of Conductors 352.22 Example 352.22

Only three 4/0 THWN conductors are allowed in 2 PVC Sch 80.

Answer: (b) 3 conductors [Annex C, Table C.10]

352.24 BENDS

(A) HOW MADE. When bending PVC, the bends must not damage or significantly change the internal diameter (no kinks) of the raceway.

AUTHOR'S COMMENT:

- PVC can be bent by hand, with a heat gun, or a heat box. Just make sure you do not damage the PVC.

(B) DEGREES OF BENDS IN ONE RUN. The total degrees of bends including offsets between pull points is not permitted to exceed 360 degrees. ▶ Figure 352–11

Figure 352–11: PVC, Bends in One Run 360 Degrees 352.24(B)

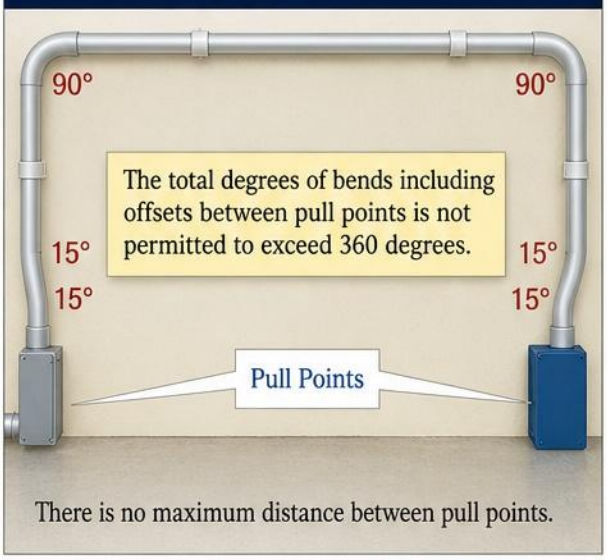
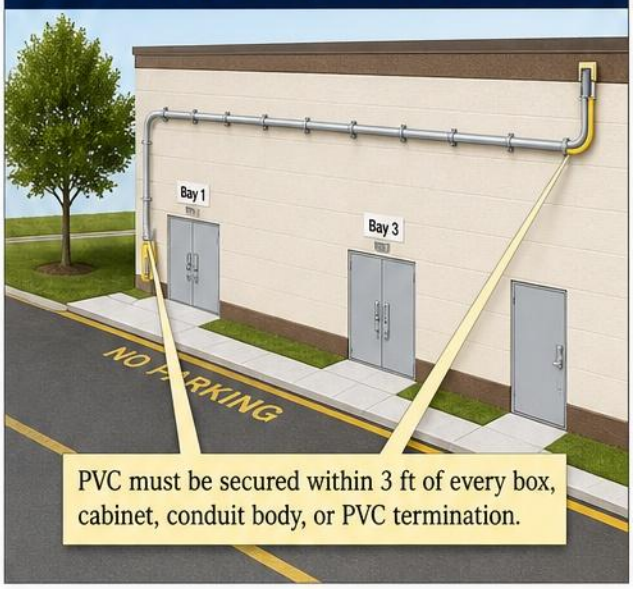


Figure 352–12: PVC, Securing Within 3 Feet 352.30(A)



352.28 Trimming

The cut ends of PVC must be trimmed (inside and out) to remove the burrs and rough edges.

Author's Comment:

- Trimming PVC is quite easy since most of the burrs will rub off with your fingers, and a knife will smooth the rough edges.

352.30 Securing and Supporting

PVC must be fastened and supported in accordance with 352.30(A) and (B) to permit movement from thermal expansion and contraction.

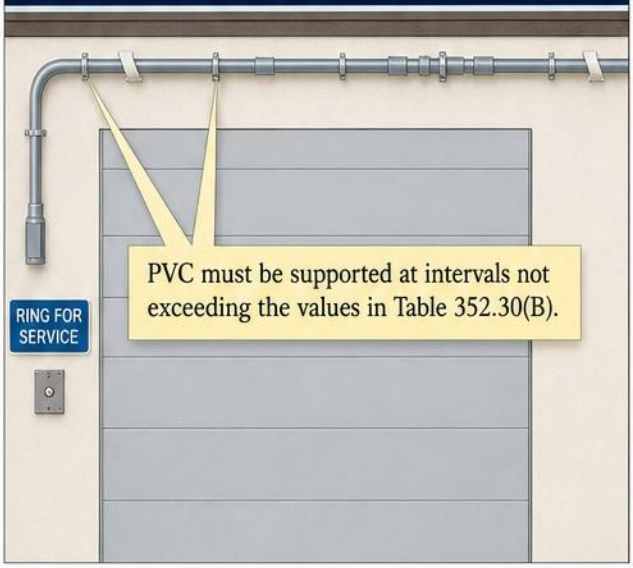
(A) Securely Fastened. PVC must be secured within 3 ft of every box, cabinet, conduit body, or PVC termination. → Figure 352–12

(B) Supports. PVC must be supported at intervals not exceeding the values in Table 352.30(B). → Figure 352–13

Table 352.30(B) Support of Rigid PVC

Trade Size	Support Spacing
½–1	3 ft
1¼–2	5 ft
2½–3	6 ft
3½–5	7 ft
6	8 ft

Figure 352–13: PVC, Support at Intervals 352.30(B)



Author's Comment:

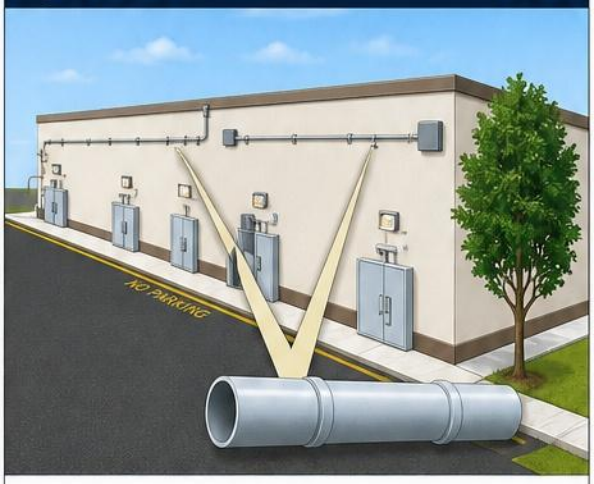
- PVC raceways must be securely fastened in a manner that permits movement from thermal expansion or contraction.

Horizontal Runs. PVC installed horizontally through framing members is considered supported and secured if such support does not exceed Table 352.30(B) requirements and secured within 3 ft of termination.

352.44 EXPANSION FITTINGS

Thermal expansion and contraction must be accommodated. Expansion fittings are required whenever the expected change in the length of a run, as shown in Table 352.44, is ¼ in. or greater in a straight run between securely mounted boxes, cabinets, elbows, or other PVC terminations. Refer to Figure 352–14.

Figure 352–14 352.44



Provide expansion fittings when the expected change in length of the run is ¼ in. or greater in a straight run between securely mounted boxes, cabinets, elbows, or other PVC terminations.

AUTHOR'S COMMENT

Before selecting the quantity and location of expansion fittings, review the manufacturer's documentation. As an example, follow the instructions for Carlon® expansion fittings for PVC conduit where direct sunlight exposure occurs; when the ambient temperature is 30°F, an allowance for high ambient temperature must be included.

352.46 BUSHING OR ADAPTER

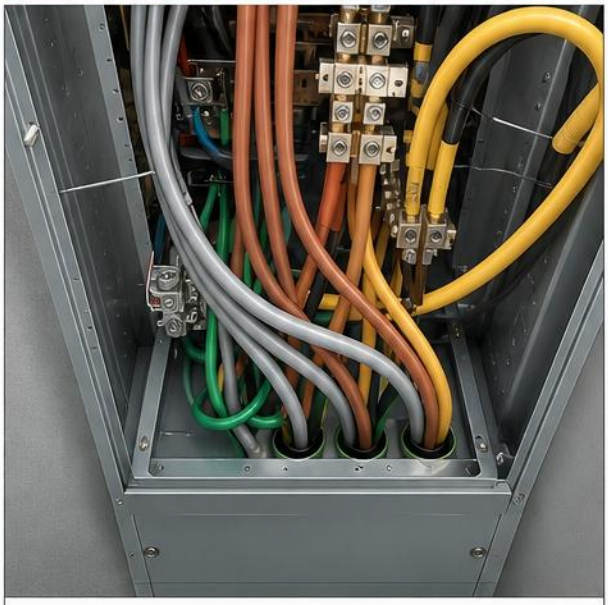
A bushing or adapter must be installed on PVC to shield the conductors from abrasion when the conduit enters a threaded opening in equipment, a fitting, or an enclosure. See Figure 352–15.

Table 352.44 Expansion Characteristics of PVC Rigid Nonmetallic Conduit Coefficient of Thermal Expansion

Temperature Change (°C)	Length of Change of PVC (mm/m)	Temperature Change (°F)	Length Change of PVC (in./100 ft)
5°C	0.30	5°F	0.20
10°C	0.61	10°F	0.41
15°C	0.91	15°F	0.61
20°C	1.22	20°F	0.81
25°C	1.52	25°F	1.01
30°C	1.83	30°F	1.22
35°C	2.13	35°F	1.42
40°C	2.43	40°F	1.62
45°C	2.74	45°F	1.83
50°C	3.04	50°F	2.03
55°C	3.35	55°F	2.23
60°C	3.65	60°F	2.43
65°C	3.95	65°F	2.64
70°C	4.26	70°F	2.84
75°C	4.56	75°F	3.04
80°C	4.87	80°F	3.24
85°C	5.17	85°F	3.45
90°C	5.48	90°F	3.65
95°C	5.78	95°F	3.85
100°C	6.08	100°F	4.06

Note: Conductors 4 AWG and larger exiting a conduit connector must be protected from abrasion by a fitting that provides a smooth, rounded, insulating surface in accordance with 300.6(G). See Figure 352–16 and Figure 352–17.

Figure 352–15 **352.46**
PVC, Bushings Conductor Protection



A bushing or adapter must be installed on PVC to protect conductors from abrasion exiting the PVC, unless the conduit enters a threaded entry in a box, fitting, or enclosure.

Figure 352–16 **352.46**
PVC, Bushings Conductor Protection *Note and 300.6(G)*

Conductors 4 AWG and larger exiting a conduit connector must be protected from abrasion by a fitting that provides a smooth, rounded, insulating surface in accordance with 300.6(G).

Figure 352–17 **352.46**
PV Bushings, Conductor Protection *Note and 300.6(G)*

Conductors 4 AWG and larger exiting a conduit connector must be protected from abrasion by a fitting that provides a smooth, rounded, insulated surface in accordance with 300.6(G).

Notes

ABOUT THIS BOOK

This reference is designed to help electrical professionals understand and apply the 2026 National Electrical Code® (NEC®). It explains code requirements in clear, practical terms with real-world examples, illustrations, and tips from field experience.

While this book simplifies complex topics, it does not replace the NEC or official interpretations. Always use the NEC as the authoritative source and consult your local Authority Having Jurisdiction (AHJ) for specific requirements.

HOW TO USE THIS BOOK

Each chapter focuses on a specific area of the NEC. Topics are organized by Article and include:

- Code summaries in plain language
- Practical examples and illustrations
- Key changes in the 2026 NEC
- Expert tips and best practices

Use the table of contents or index to quickly find the information you need. This book is ideal for studying, on-the-job reference, or exam preparation.

KEY FEATURES

- Written by experienced electrical professionals
- Based on the 2026 NEC
- Up-to-date and field tested
- Focused on real-world application
- Visual learning with detailed illustrations

IMPORTANT NOTES

- NEC requirements can vary by location due to local amendments.
- Always follow manufacturer instructions for installation and listing.
- This book does not provide legal advice. When in doubt, consult the NEC and your AHJ.

STAY CURRENT

Codes and standards change over time. Visit trusted sources and Michael Hayes' website for updates, training, and additional resources to stay current with the 2026 NEC and beyond.

Thank you for trusting Michael Hayes as your partner in electrical education and safety.

Figure 1—Typical Electrical Service Arrangement **NEC 230.2(A)**

This illustration shows a typical utility service connection, including the service drop, weatherhead, service-entrance conductors, meter, service disconnecting means, panelboard, and grounding electrode system in accordance with NEC Article 230.

ARTICLE 356

Liquidtight Flexible Nonmetallic Conduit (LFNC)

Introduction to Article 356—Liquidtight Flexible Nonmetallic Conduit (LFNC)

This article establishes the requirements for the use, installation, and construction specifications of *liquidtight flexible nonmetallic conduit* (LFNC) and associated fittings. LFNC has an inner flexible core with an outer liquidtight, nonmetallic, sunlight-resistant jacket. It is available in trade sizes ½ to 4 and is sometimes referred to as "Carflex®."

Conduit, Liquidtight Flexible Nonmetallic Conduit (LFNC). A raceway of circular cross section designated as follows:

(1) A smooth, seamless inner core and cover bonded together and having one or more reinforcement layers between the core and covers, designated as LFNC-A

(2) A smooth inner surface with integral reinforcement within the raceway wall, designated as LFNC-B

(3) A corrugated internal and external surface without integral reinforcement within the raceway wall, designated as LFNC-C

▸ **Figure 356–1**

Figure 356–1 Article 100 Definition **Article 100**

A circular raceway having an outer liquidtight, nonmetallic, sunlight-resistant jacket over a flexible nonmetallic inner core.

Part I. General

356.1 Scope

This article sets forth the requirements for the use and installation of liquidtight flexible nonmetallic conduit (LFNC) and associated fittings.

▸ **Figure 356–2**

Figure 356–2 Scope **356.1**

Liquidtight Flexible Nonmetallic Conduit (LFNC)
356.1 Scope

Photo/Illustration: Michael Hayes

Article 356 sets forth the requirements for the use and installation of liquidtight flexible nonmetallic conduit (LFNC) and associated fittings.

356.2 Listing Requirements

LFNC and its associated fittings must be listed.

Part II. Installation

356.10 Uses Permitted

Listed LFNC is permitted (either exposed or concealed) at any of the following purposes and locations:

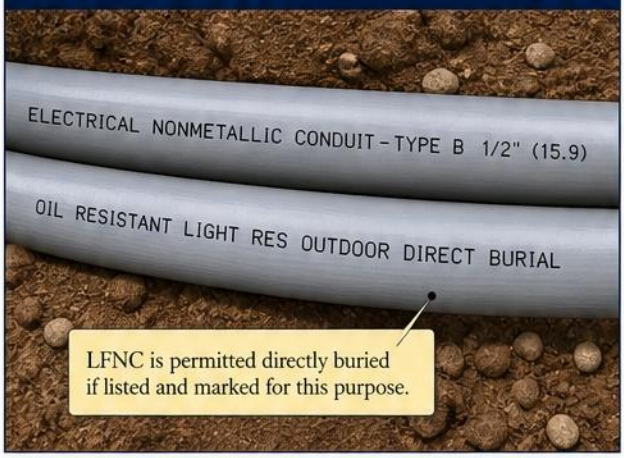
(1) Flexibility is required.

(2) Protection from liquids, vapors, machine oils, or solids is required.

(3) Outdoors—if listed and marked for this purpose.

(4) Directly buried if listed and marked for this purpose. Figure 356–3

Figure 356–3: Direct Burial **356.10(4)**



LFNC marked "OUTDOOR DIRECT BURIAL" and listed for direct burial may be installed directly in the earth.

(5) Installed in lengths over 6 ft if secured in accordance with 356.30. Figure 356–4

Figure 356–4: Secured in Lengths Over 6 Feet **356.10(5)**

LFNC runs exceeding 6 ft in length must be supported and secured as required by 356.30.

(7) Encasement in concrete if listed for direct burial.

(8) In locations subject to severe corrosive influences as covered in 300.8 where listed for exposure to specific chemicals.

Note: Extreme cold can cause some types of nonmetallic conduits to become brittle and more susceptible to damage from physical contact.

356.12 Uses Not Permitted

LFNC cannot be used under the following conditions:

(1) Where subject to physical damage as determined by the AHJ.

(2) If the ambient temperature and/or conductor temperature exceeds its listing.

(4) In any hazardous location, except as permitted by 501.10(B)(2), 502.10(A)(2) and (B)(2), and 504.20.

356.20 Trade Size

(A) Minimum. LFNC smaller than trade size ½ is not permitted.

(B) Maximum. LFNC larger than trade size 4 is not permitted.

356.22 Number of Conductors

The number of conductors is not permitted to exceed the percentage fill specified in Chapter 9, Table 1.

Author's Comment:

- When all conductors within a raceway are the same size, same insulation type, number of conductors permitted, or raceway size, see Annex C, Note (1) of Chapter 9.
- For examples of how to size raceways when conductors are not all the same size, see 300.19.

Cables are permitted in the raceway if the total area of the cables does not exceed the allowable percentage fill specified in Chapter 9, Table 1.

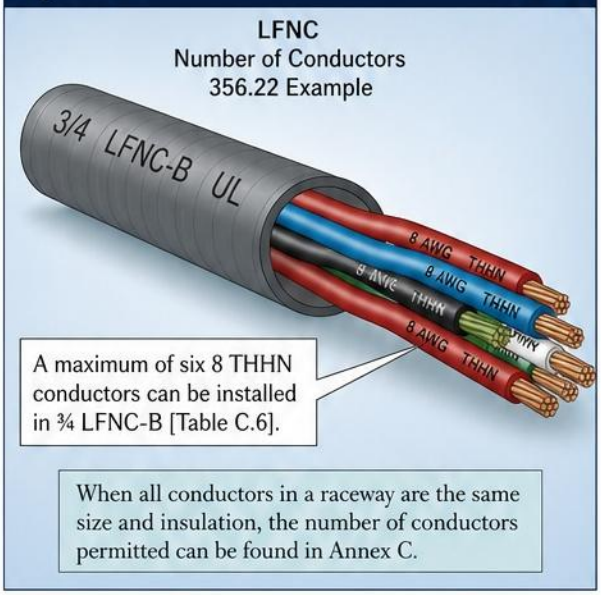
Number of Conductors in LFNC [356.22] Example

Question: *How many 8 AWG, THHN conductors can be installed in ¾ LFNC-B?*
Figure 356–5

(a) *2 conductors* (b) *4 conductors*

(c) *6 conductors* (d) *8 conductors*

Figure 356–5 **356.22**



Answer: *(c) 6 conductors [Annex C, Table C.6]*

356.24 Bends

(A) How Made. When bending LFNC, the bends must not damage or significantly change the internal diameter (no kinks) of the raceway.

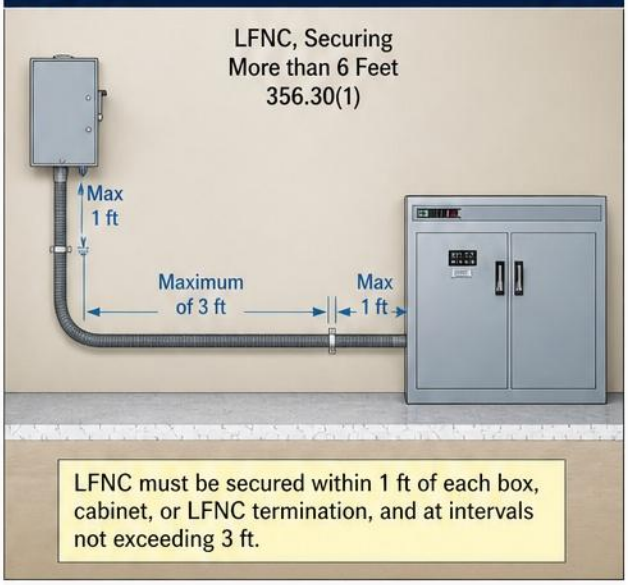
(B) Degrees of Bends in One Run. The total degrees of bends including offsets between pull points is not permitted to exceed 360 degrees.

356.30 Securing and Supporting

LFNC must be securely fastened and supported in accordance with any of the following:

(1) LFNC in lengths up to 6 ft is not required to be secured; LFNC in lengths over 6 ft must be secured within 1 ft of each box, cabinet, or LFNC termination, and at intervals not exceeding 3 ft
Figure 356–6

Figure 356–6 **356.30**



(2) Securing or supporting is not required if LFNC is fished or installed in lengths not exceeding 3 ft at terminals if flexibility is required

(3) Runs of LFNC installed horizontally through framing members are considered supported and secured if such support does not exceed 3 ft and secured within 1 ft of termination

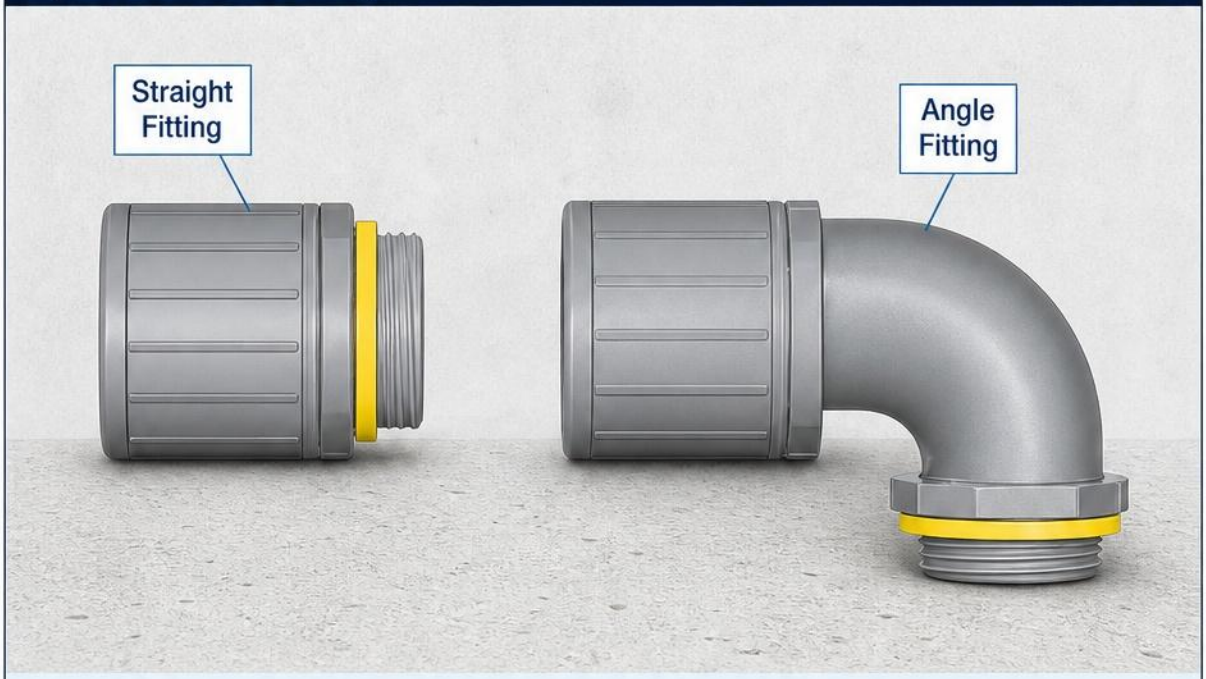
(4) Securing or supporting LFNC is not required if installed in lengths not exceeding 6 ft from the last point where the raceway is securely fastened for connections within an accessible ceiling to a luminaire or other equipment; for the purposes of this allowance, listed fittings are considered support

Where cable ties are to be used to secure LFNC, they must be listed for the application, securing, and supporting.

356.42 Fittings

Angle fittings cannot be installed where concealed. Straight LFNC fittings are permitted for direct burial or encasement in concrete.
Figure 356–7

Figure 356–7 LFNC Fittings 356.42



Angle fittings cannot be installed where concealed. Straight fittings are permitted for direct burial or encasement in concrete.

Liquidtight flexible nonmetallic conduit (LFNC) is a flexible raceway system used to protect and route conductors in a variety of electrical installations. Section 356.42 establishes specific requirements for the use of straight and angle fittings with LFNC to ensure safe and code-compliant installations.

Angle Fittings

Angle fittings for LFNC cannot be used in concealed locations. A concealed location is any location where the LFNC fitting is not accessible for inspection, maintenance, or replacement after the installation is complete.

Examples of concealed locations include behind finished walls, above suspended ceilings, within floors, or in other areas where the fitting would be covered by building materials.

This requirement helps ensure that fittings remain accessible for future inspection and that any potential damage, moisture ingress, or other issues can be identified and addressed.

Straight Fittings

Straight fittings for LFNC are permitted in installations that are in direct contact with the earth or encased in concrete.

Direct burial installations must comply with the requirements for burial depth and protection as specified elsewhere in the NEC.

Encasement in concrete must be in accordance with the applicable provisions for concrete-encased installations.

ARTICLE 358

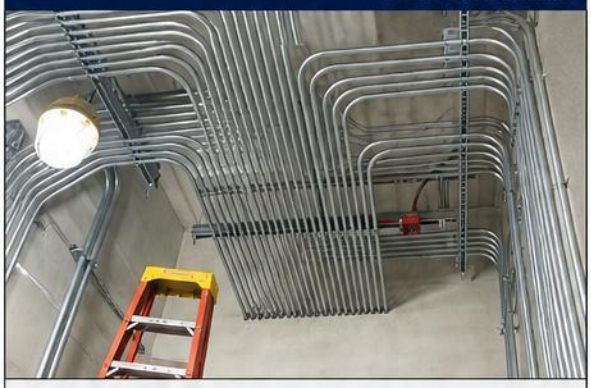
Electrical Metallic Tubing (EMT)

Introduction to Article 358—Electrical Metallic Tubing (EMT)

Article 358 addresses the utilization, installation, and construction specifications for electrical metallic tubing (EMT) and the associated fittings. EMT is a lightweight metal tubing that is easy to bend, cut, and ream—but it is not designed to be threaded. It is joined using compression or set-screw type connectors and couplings. EMT is the most common raceway used in residential, commercial, and industrial installations.

Tubing, Electrical Metallic Tubing (EMT). An unthreaded thinwall circular metallic raceway designed for the physical protection and routing of conductors. When joined together with fittings, it can be used as an equipment grounding conductor.
Figure 358–1

Figure 358–1 Electrical Metallic Tubing (EMT) Article 100 Definition



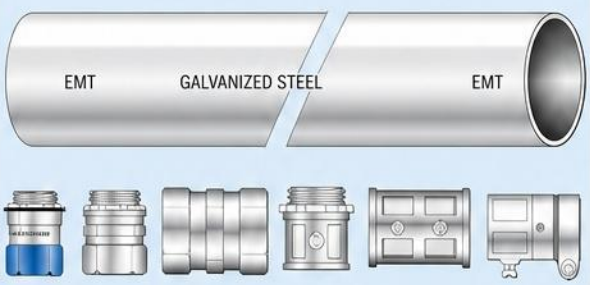
An unthreaded thinwall circular metallic raceway that when joined together with fittings can be used as an equipment grounding conductor.

Part I. General

358.1 Scope

This article outlines the requirements for the use and installation of electrical metallic tubing (EMT) and the associated fittings.
Figure 358–2

Figure 358–2 Electrical Metallic Tubing (EMT) 358.1 Scope



Article 358 specifies the requirements for the use and installation of electrical metallic tubing (EMT) and the associated fittings.

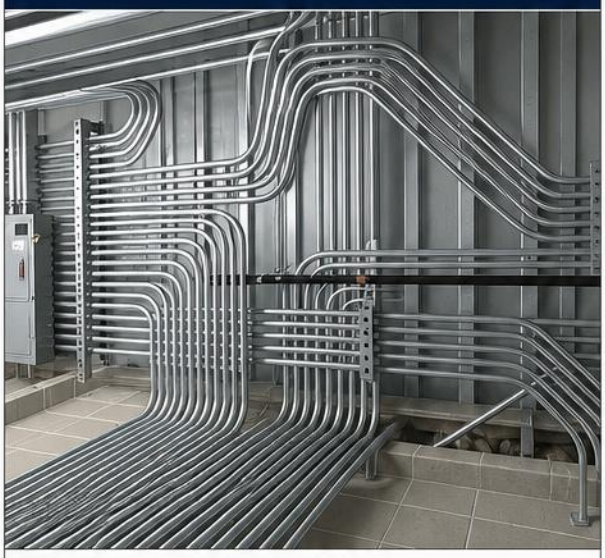
358.2 Listing Requirements

EMT and associated fittings must be listed.
Figure 358–3

Author's Comment:

- Tubing support hardware is not considered an associated EMT fitting and is not required to be listed. However, support hardware must be constructed of materials suitable for the environment for which they are to be installed, see 300.8.

Figure 358–3 EMT, Listing Requirements 358.2



EMT and associated fittings must be listed.

Figure 358–4 EMT, Uses Permitted Concrete, Direct Burial, Corrosive Areas 358.10(B)(1)

EMT, elbows, and fittings can be installed in concrete, in direct contact with the earth, or areas subject to severe corrosive influences. In addition, they must be protected by corrosion protection and approved as suitable for the condition.

Part II. Installation

358.10 Uses Permitted

(A) Exposed and Concealed. EMT is permitted to be used exposed and concealed as follows:

(1) In concrete, direct burial, or in areas subject to severe corrosive influences where installed in accordance with 358.10(B)

(2) In dry, damp, or wet locations

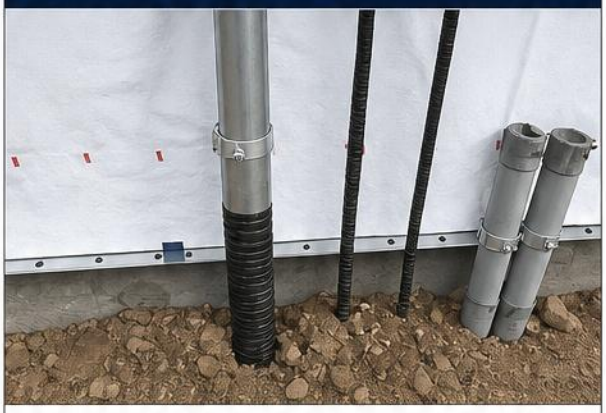
(3) In hazardous locations as permitted by other articles in this *Code*

(B) Corrosive Environments.

(1) Galvanized Steel. EMT, elbows, and fittings can be installed in concrete, in direct contact with the earth, or areas subject to severe corrosive influences. In addition, they must be protected by corrosion protection and approved as suitable for the condition. Figures 358–4 and 358–5.

Author's Comment:
In accordance with *UL Guide Information FJMX*, supplementary corrosion protection is required when EMT and associated fittings are buried. In addition, supplementary corrosion protection is required at the point where EMT transitions from concrete encasement to the soil.

Figure 358–5 EMT, Uses Permitted Concrete, Direct Burial, Corrosive Areas 358.10(B)(1)



EMT, elbows, and fittings can be installed in concrete, in direct contact with the earth, or areas subject to severe corrosive influences. In addition, they must be protected by corrosion protection and approved as suitable for the condition.

(D) Wet Locations. Support fittings (such as screws, straps, and so forth) installed in a wet location must be made of corrosion-resistant material.

Note: For protection against corrosion, see 300.8.

Author's Comment:
If installed in wet locations, fittings for EMT must be listed for use in wet locations in accordance with 314.15 [358.42].

358.12 Uses Not Permitted

EMT shall not be used for the following:

(1) Where it is subject to severe physical damage as determined by the AHJ. ▶ Figure 358–6

Figure 358–6 Uses Not Permitted 358.12(1)

(2) For support of luminaires or equipment. ▶ Figure 358–7

Figure 358–7 Support of Luminaires or Equipment 358.12(2)

358.20 Trade Size

(A) Minimum. EMT smaller than trade size ½ is not permitted.

(B) Maximum. EMT larger than trade size 6 is not permitted.

358.22 Number of Conductors

The number of conductors is not permitted to exceed the percentage fill specified in Chapter 9, Table 1.

Author's Comment:

- When all conductors within a raceway are the same size, same insulation type, number of conductors permitted, or raceway size, see Annex C, Note (1) of Chapter 9.
- For examples of how to size raceways when conductors are not all the same size, see 300.19.

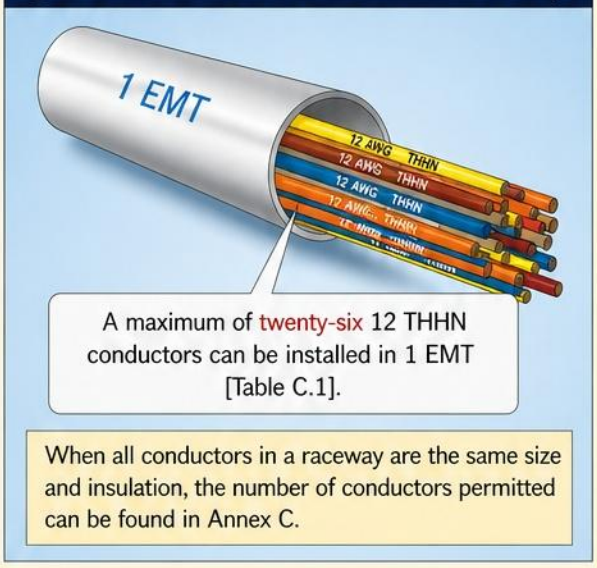
Cables are permitted in the raceway if the total area of the cables does not exceed the allowable percentage fill specified in Chapter 9, Table 1.

▶ Number of Conductors in EMT [358.22] Example

Question: *How many 12 AWG, THHN conductors can be installed in 1 EMT?* ▶ Figure 358–8

(a) 23 conductors *(b) 24 conductors*
(c) 25 conductors *(d) 26 conductors*

Figure 358–8 EMT, Number of Conductors 358.22 Example



Answer: *(d) 26 conductors [Annex C, Table C.1]*

358.24 Bends

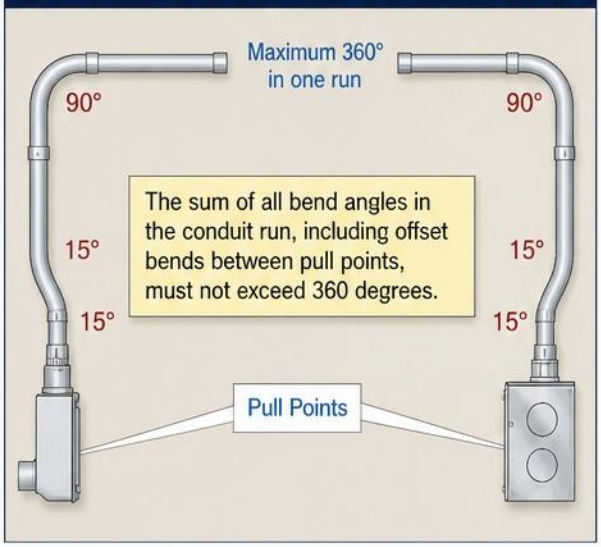
(A) How Made. When forming bends in EMT, the bend must not injure or appreciably alter the internal diameter of the raceway (no kinks).

Author's Comment:

- Typically this is not an issue since conventional EMT benders are made to meet this requirement.

(B) Degrees of Bends in One Run. The combined degrees of all bends in the run of tubing, including offset bends between pull points, must not be more than 360 degrees. **Figure 358–9**

Figure 358–9 Degrees of Bends in One Run 358.24(B)



Author's Comment:

- There is no maximum distance between pull points because this is a design issue—not a safety issue.

358.28 Reaming

(A) Reaming. Remove burrs and rough edges when the EMT is cut. **Figure 358–10**

Author's Comment:

- It is considered an accepted practice to ream EMT with a screwdriver or lineman's pliers.

Figure 358–10 Reaming 358.28(A)

Deburr and smooth rough edges inside the EMT after cutting.

Figure 358–11 Reaming Comment 358.28(A)

Reaming EMT with a screwdriver or lineman's pliers is an accepted practice.

358.30 Securing and Supporting

(A) Securely Fastened. EMT must be secured as follows: **Figure 358–12**

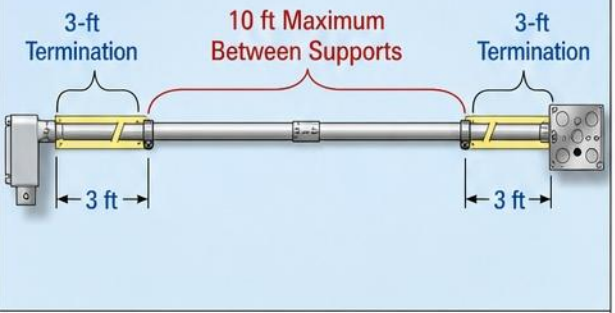
(1) At intervals not exceeding 10 ft

(2) Secured within 3 ft of each box, cabinet, conduit body, or EMT termination

Author's Comment:

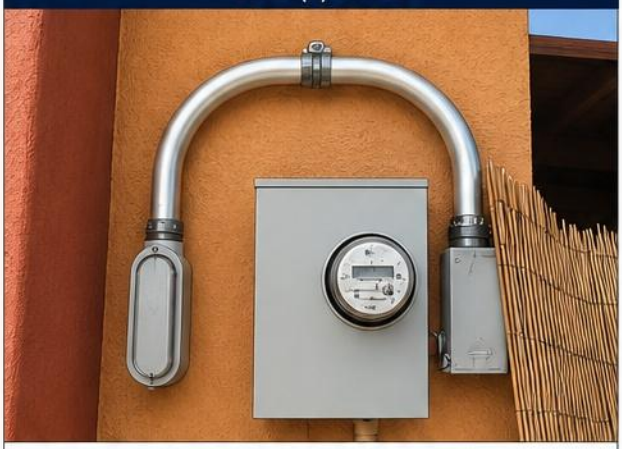
- EMTs not exceeding 3 ft are not required to be securely fastened. **Figure 358–13**

Figure 358–12 EMT, Securing 358.30(A)



EMT must be secured within 3 ft of each box, cabinet, conduit body, or EMT termination, and at intervals not exceeding 10 ft.

Figure 358–13 EMT, Securing 358.30(A) Comment



EMT in lengths not exceeding 3 feet, are not required to be securely fastened.

Figure 358–14 EMT, Securing Maximum 5 Feet *358.30(A) Ex 1*

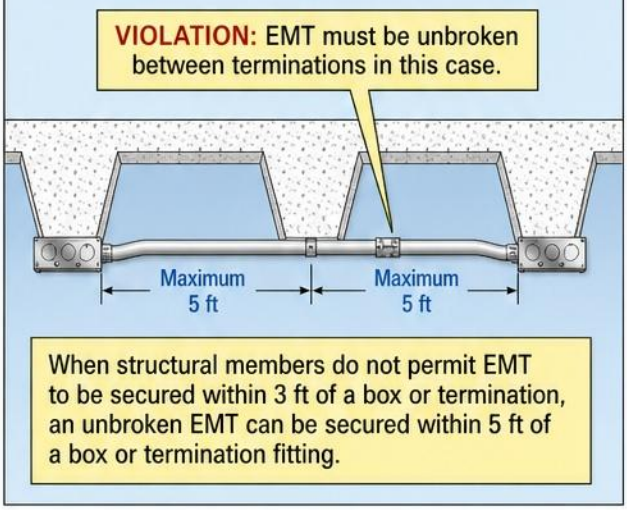
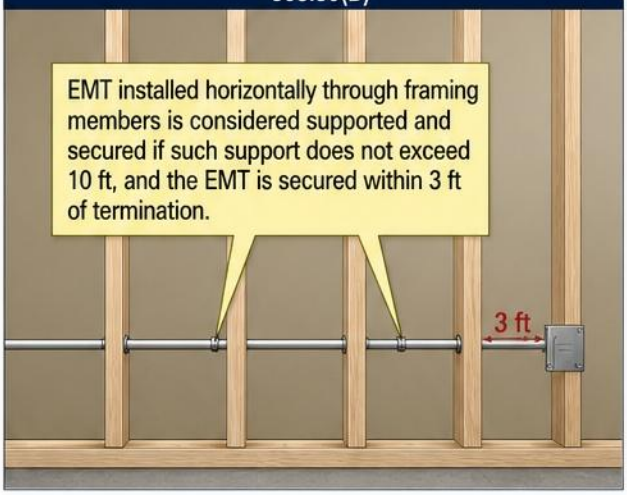


Figure 358–15 EMT, Securing and Supporting Horizontal Runs 358.30(B)



Ex 1: When structural members do not permit EMT to be secured within 3 ft of a box or termination, an unbroken EMT can be secured within 5 ft of a box or termination fitting. **(Figure 358–14)**

(B) Horizontal Runs. EMT installed horizontally through framing members is considered supported and secured if such support does not exceed 10 ft and secured within 3 ft of termination. **(Figure 358–15)**

358.42 Couplings and Connectors

Couplings and connectors must be made tight.

Author's Comment:

- Couplings and connectors must be made up tight to maintain an effective ground-fault current path to safely conduct fault current in accordance with 250.4(A)(5), 250.96(A), and 300.14.

(1) Concrete Buried. If buried in concrete, EMT couplings and connectors must be of the concrete-tight type. **(Figure 358–16)**

Figure 358–16 EMT, Couplings and Connectors Concrete Buried 358.42(1)

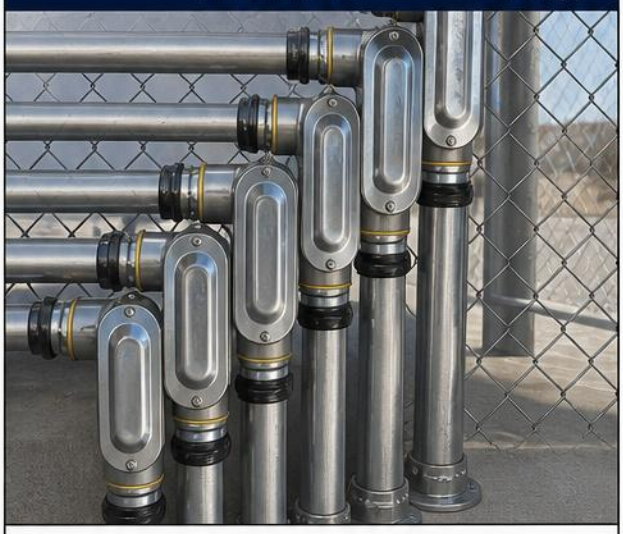
When buried in concrete, EMT couplings and connectors must be of the concrete-tight type.

Author's Comment:

Fittings suitable for use in poured concrete are indicated on the device or carton with the term "Concrete-Tight" or "Concrete-Tight When Taped," see *UL Guide Information DWTT.*

(2) Wet Locations. If installed in wet locations, EMT fittings must be listed for use in wet locations. See **Figure 358–17** and **Figure 358–18**.

Figure 358–17 EMT, Couplings and Connectors Wet Locations 358.42(2)



If installed in wet locations, EMT fittings must be listed for use in wet locations.

Figure 358–18 EMT, Couplings and Connectors Wet Locations 358.42(2)

If installed in wet locations, EMT fittings must be listed for use in wet locations.

Author's Comment:

Fittings suitable for use in a wet location are indicated on the device or carton with the term "Rain-Tight" or "Wet-Location," see *UL Guide Information DWTT.*

358.60 Equipment Grounding Conductor

EMT can serve as an equipment grounding conductor [250.118(A)(4)].

Figure 358–19

Figure 358–19 EMT, Equipment Grounding Conductor 358.60

EMT can serve as an equipment grounding conductor in accordance with 250.118(A)(4).

ARTICLE 362 Electrical Nonmetallic Tubing (ENT)

INTRODUCTION TO ARTICLE 362—ELECTRICAL NONMETALLIC TUBING (ENT)

This article sets out the rules for the use, installation, and construction requirements of *electrical nonmetallic tubing* (ENT) and the fittings that are used with it. ENT is a nonmetallic, pliable, corrugated, circular raceway. It is often called a "Smurf Pipe" or "Smurf Tube" (after the cartoon characters that share the name) because it was only offered in blue when it first became available but is now manufactured in additional colors. This type of tubing is fragile and not resistant to sunlight, so its applications are limited. ENT can be bent by hand with a reasonable amount of force and without extra tools or assistance.

Tubing, Electrical Nonmetallic Tubing (ENT). A pliable corrugated circular raceway supplied with couplings, connectors, and fittings. This tubing is made from a flame-retardant material that resists moisture and exposure to chemical atmospheres. See Figure 362–1.

Part I. General

362.1 Scope

This article establishes the rules for the use and installation of electrical nonmetallic tubing (ENT) and the fittings associated with it. See Figure 362–2.

Figure 362–1 Definition Article 100

A pliable corrugated circular raceway supplied with couplings, connectors, and fittings. This tubing is made from a flame-retardant material that resists moisture and exposure to chemical atmospheres.

Figure 362–2 Scope 362.1

This article establishes the rules for the use and installation of electrical nonmetallic tubing (ENT) and the fittings associated with it.

362.2 Listing

ENT and its associated fittings must be listed.

Author's Comment:

- ENT fittings are interchangeable with PVC fittings. The proper glue (blue) must be applied for the joints in accordance with the manufacturer's instructions.

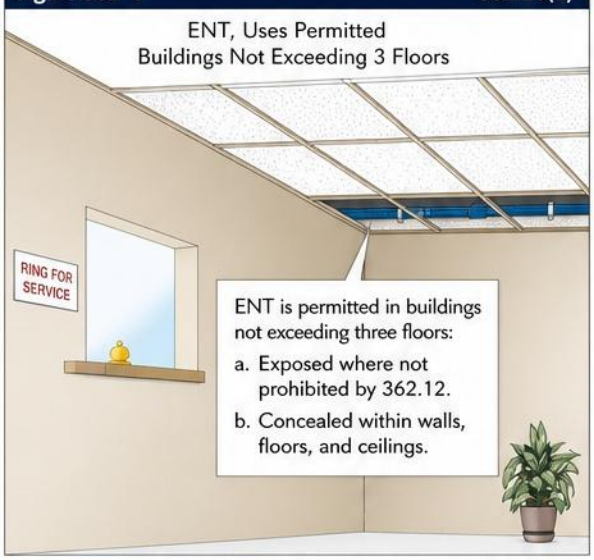
Part II. Installation

362.10 Uses Permitted

ENT is permitted to be used under the following conditions:

(1) In buildings not exceeding three floors and: Figure 362–3.

Figure 362–3 **362.10(1)**



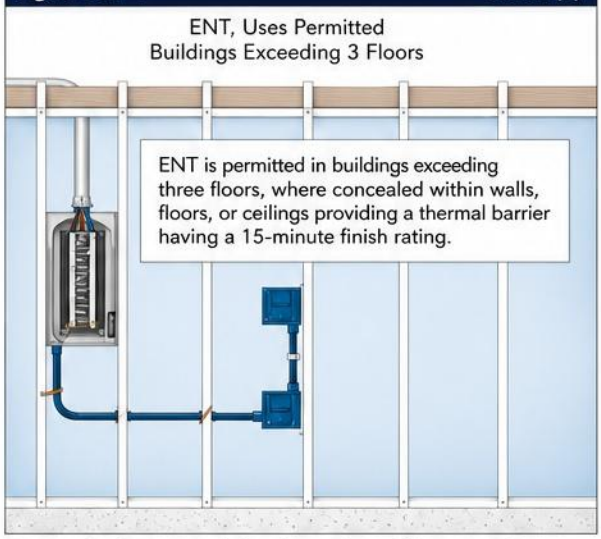
Permitted in buildings not exceeding three floors as shown.

a. Exposed—where not prohibited by 362.12.
b. Concealed within walls, floors, and ceilings

(2) In buildings exceeding three floors, where installed concealed within combustible or noncombustible walls, floors, or ceilings that provide a thermal barrier having a 15-minute finish rating, as identified in listings of fire-rated assemblies Figure 362–4.

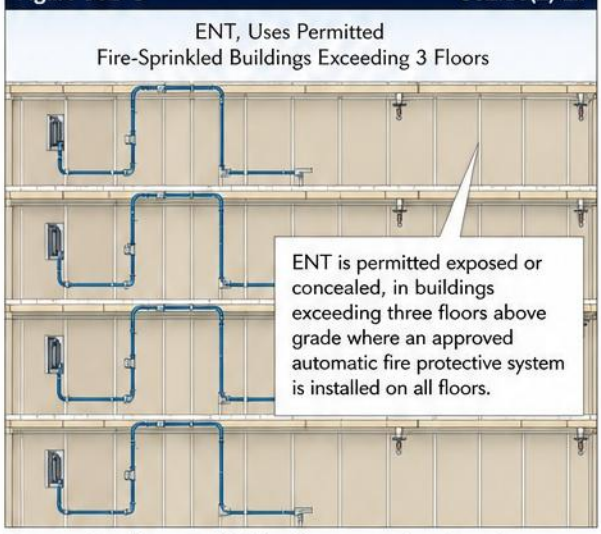
Ex to (2): Where an approved automatic fire protective system is installed on all floors, ENT shall be permitted to be exposed or concealed within walls, floors, and ceilings in buildings exceeding three floors above grade. Figure 362–5.

Figure 362–4 **362.10(2)**



Permitted when concealed within a thermal barrier with a 15-minute finish rating.

Figure 362–5 **362.10(2) Ex**



Permitted in fire-sprinkled buildings exceeding three floors.

Author's Comment:

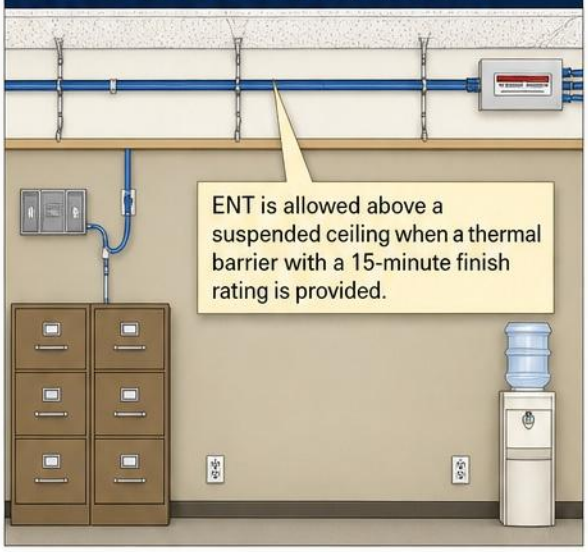
- ENT is not permitted above a suspended ceiling used as a plenum space [300.25(C)].

(3) In severe corrosive and chemical locations [300.8] when identified for this use

(4) In dry and damp concealed locations if not prohibited by 362.12

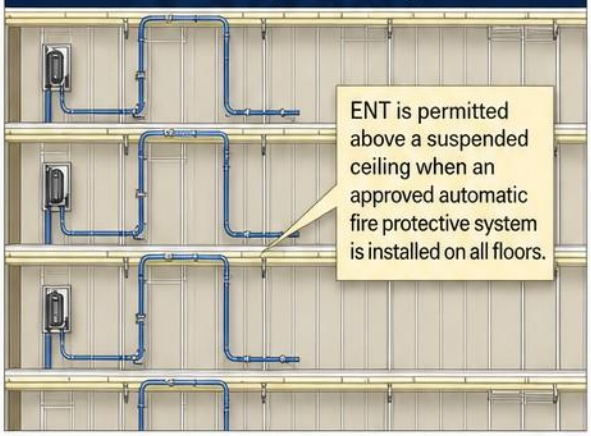
(5) Above a suspended ceiling if the suspended ceiling provides a thermal barrier having a 15-minute finish rating, as identified in listings of fire-rated assemblies Figure 362–6.

Figure 362-6 **362.10(5)**
ENT, Uses Permitted Above a Suspended Ceiling



Exception to (5): ENT may be installed above a suspended ceiling without a 15-minute finish-rated thermal barrier when an approved automatic fire protective system is provided throughout all floors. 362.10(5) Ex

Figure 362-7 **362.10(5) Ex**
ENT, Uses Permitted Fire-Sprinkled, Above a Suspended Ceiling



(6) Encased in poured concrete floors, ceilings, walls, and slabs

(7) Embedded in a concrete slab with fittings identified for the purpose are used

(8) In wet locations or in a concrete slab on or below grade with fittings listed for the purpose

362.12 Uses Not Permitted

ENT is not permitted to be used under the following conditions:

(1) In any hazardous location, except as permitted by 504.20 and 505.15(A)

(2) For the support of luminaires or equipment (see 314.23)

(3) If the ambient temperature exceeds 50°C (122°F)

(4) For direct earth burial

Author's Comment:

- ENT is permitted to be encased in concrete [362.10(6)].

(5) Exposed in buildings over three floors, except as permitted by 362.10(1) and (5) Ex

(6) In assembly occupancies, except as permitted by 518.4

(7) Exposed to the direct rays of the sun—unless identified as sunlight resistant 362.12(7)

Figure 362-8 **362.12(7)**
ENT, Uses Not Permitted Exposed to Direct Sunlight

Author's Comment:

- Extended exposure of ENT to direct sunlight may cause the material to become brittle unless it is listed to resist the effects of ultraviolet (UV) radiation.

(8) Where subject to physical damage as determined by the AHJ

Author's Comment:

- ENT is not permitted in ducts, plenum spaces [300.25(C)], and patient care space circuits in health care facilities [517.13(A)].

362.20 Trade Sizes

(A) Minimum. ENT smaller than trade size ½ is not permitted.

(B) Maximum. ENT larger than trade size 2½ is not permitted.

362.22 Number of Conductors

The number of conductors is not permitted to exceed the percentage fill specified in Chapter 9, Table 1.

Author's Comment:

- When all conductors within a raceway are the same size, same insulation type, number of conductors permitted, or raceway size, see Annex C, Note (1) of Chapter 9.
- For examples of how to size raceways when conductors are not all the same size, see 300.19.

Cables are permitted in the raceway if the total area of the cables does not exceed the allowable percentage fill specified in Chapter 9, Table 1.

▶ Number of Conductors in ENT [366.22] Example

Question: *How many 12 AWG, THHN conductors can be installed in ½ ENT?* ▶ Figure 362–9

(a) 2 conductors (b) 4 *conductors*
(c) 6 conductors (d) 8 *conductors*

Figure 362–9 Number of Conductors in ENT 362.22

A ½-inch ENT can contain up to eight 12 AWG THHN conductors based on the allowable fill in Annex C, Table C.2.

Answer: *(d) 8 conductors [Annex C, Table C.2]*

362.24 Bends

(A) How Made. When bending ENT, the bends must not damage or significantly change the internal diameter (no kinks) of the raceway.

(B) Degrees of Bends in One Run. The total degrees of bends in the tubing including offsets between pull points cannot exceed 360 degrees.

362.28 Trimming

The cut ends of ENT must be trimmed (inside and out) to remove the burrs and rough edges.

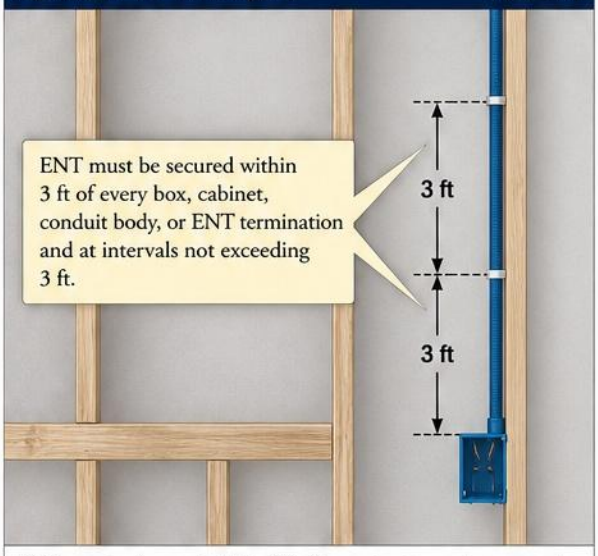
Author's Comment:

- Trimming ENT is quite easy since most of the burrs will rub off with your fingers, and then a knife will smooth the rough edges.

362.30 Securing and Supporting

(A) Securely Fastened. ENT must be secured within 3 ft of every box, cabinet, conduit body, or ENT termination. In addition, ENT must be secured at intervals not exceeding 3 ft. ▶ Figure 362–10

Figure 362–10 Securing ENT 362.30(A)



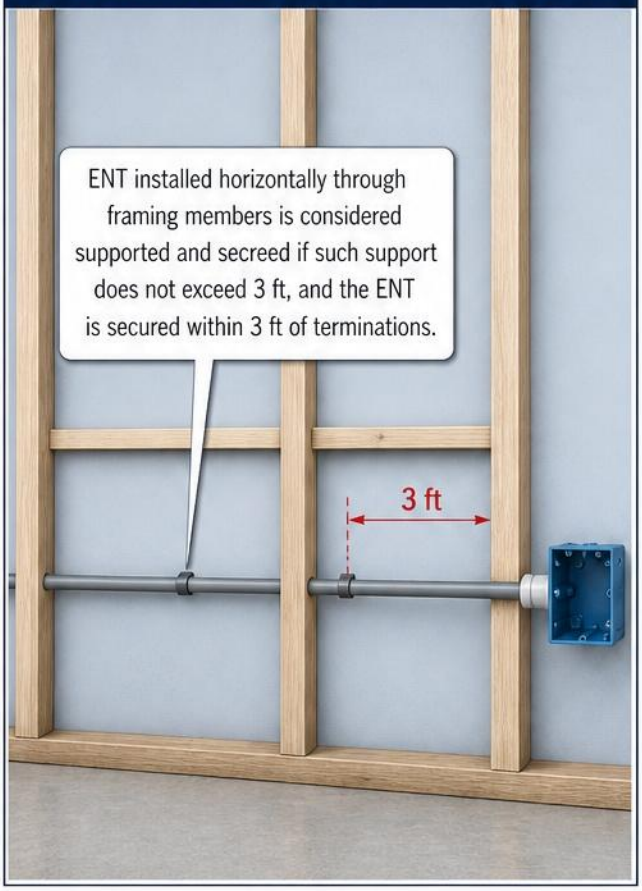
ENT must be fastened within 3 ft of a termination and supported at intervals of 3 ft or less.

Cable ties used to secure ENT must be listed as suitable for securing and supporting.

Ex 3: ENT is not required to be secured if fished between access points through concealed spaces and securing is impractical.

(B) Horizontal Runs. ENT installed horizontally through framing members is considered supported and secured if such support does not exceed 3 ft and secured within 3 ft of terminations. › Figure 362-11

Figure 362-11 Horizontal Runs of ENT *NEC 362.30(B)*



362.48 Bushings

Where ENT enters a box, fitting, or other enclosure, a bushing or adapter is required to protect the wire from abrasion, unless the box fitting or enclosure design provides equivalent protection.

Note: Conductors 4 AWG and larger that enter an enclosure must be protected from abrasion by a fitting that provides a smooth, rounded insulating surface, unless the design of the box, fitting, or enclosure provides equivalent protection in accordance with 300.6(G).

362.48 Joints

Joints such as couplings and connectors must be made in a manner approved by the authority having jurisdiction (AHJ).

ARTICLE 110 — REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

110.1 Scope

This article covers general requirements that apply to all electrical installations, including equipment, wiring methods, conductors, and raceways, unless a different article specifies otherwise.

110.2 Approval

Electrical equipment shall be listed or labeled in accordance with the appropriate standards and shall be installed and used within the conditions of its listing or labeling.

110.3 Electrical Installation Condition

Electrical equipment shall be installed in a neat and workmanlike manner and in accordance with this Code. (See Figure 1.)

Figure 1 Electrical Installation Condition 110.3

Electrical equipment installed in a neat and workmanlike manner and in accordance with this Code.

110.7 Maintenance

Electrical equipment shall be maintained in a safe operating condition. (See Figure 3.)

110.4 Use of Equipment

Electrical equipment shall be used in accordance with any instructions included in the listing or labeling and within the range of the values for which it is listed or labeled.

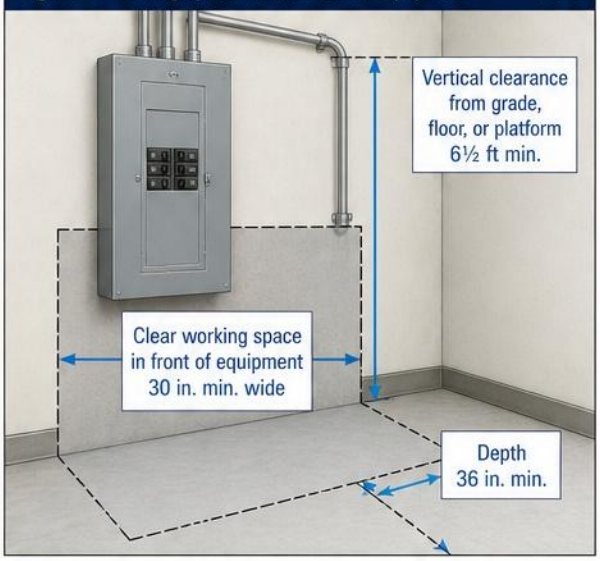
110.5 Abnormal Operating Conditions

Electrical equipment shall be suitable for the conditions of use and installed in accordance with any instructions included in the listing or labeling.

110.6 Working Space

Sufficient access and working space shall be provided and maintained about all electrical equipment to permit ready and safe operation and maintenance of such equipment. (See Figure 2.)

Figure 2 Working Space About Electrical Equipment 110.6



Sufficient access and working space shall be provided and maintained to permit ready and safe operation and maintenance of electrical equipment.

110.8 Identification

Circuits and equipment shall be identified in accordance with 110.22 to indicate their clear, evident, and permanent destinations or purposes.

ARTICLE 376 Metal Wireways

Introduction to Article 376—Metal Wireways

Article 376 specifies how metal wireways and related fittings must be used, installed, and constructed. Metal wireways are typically installed to enclose and protect conductors within a raceway when terminations, splices, or taps are needed at multiple points along a single run. These are frequently misidentified in the field as "gutters."

Wireway, Metal Wireway. A sheet metal trough with hinged or removable covers used to contain and protect electrical conductors and cable, where the conductors are installed after the raceway has been put in place.

▸ Figure 376–1

Figure 376–1 Metal Wireway — Article 100 Definition

A sheet metal trough with hinged or removable covers for housing and protecting electric wires and cable, and in which conductors are placed after the raceway has been installed.

Part I. General

376.1 Scope

This article provides the requirements for the use and installation of metal wireways and associated fittings.

▸ Figure 376–2

Figure 376–2 Metal Wireways — 376.1 Scope

This article sets out the rules for using and installing metal wireways and the fittings that go with them.

Part II. Installation

376.10 Uses Permitted

Metal wireways are allowed for use under the following conditions:

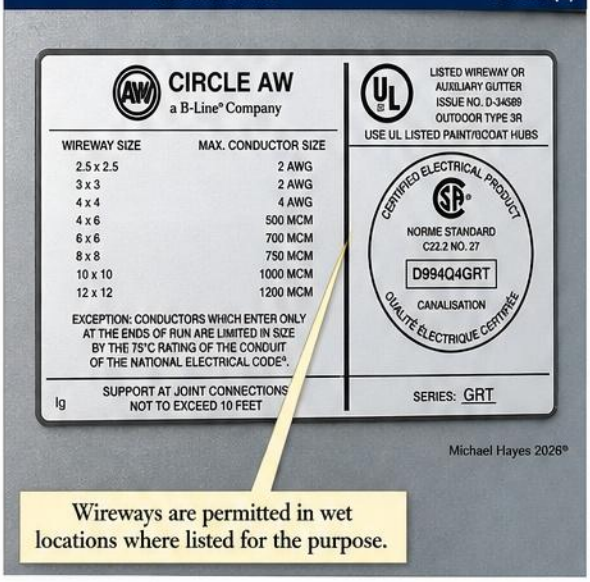
(1) Exposed

(2) In any hazardous location, as permitted by other articles in the *Code*

(3) In wet locations where listed for the purpose

▸ Figure 376–3

Figure 376–3 Metal Wireways, Uses Permitted Wet Locations 376.10(3)



Author's Comment:

- Wireways in damp or dry locations are not required to be listed.

(4) Unbroken through walls, partitions, and floors

376.12 Uses Not Permitted

Metal wireways are not allowed to be used under the following conditions:

(1) Where subject to severe physical damage as determined by the AHJ

(2) Where subject to severe corrosive environments as determined by the AHJ

376.20 Conductors Connected in Parallel

Where conductors are installed in parallel as permitted in 310.10(G), the parallel conductors in metal wireways must be installed in groups consisting of not more than one conductor per phase or neutral to prevent current imbalance in the paralleled conductors. ▸Figure 376–4

Note: The purpose of having all parallel conductor sets within the same group is to prevent current imbalance in the paralleled conductors due to inductive reactance.

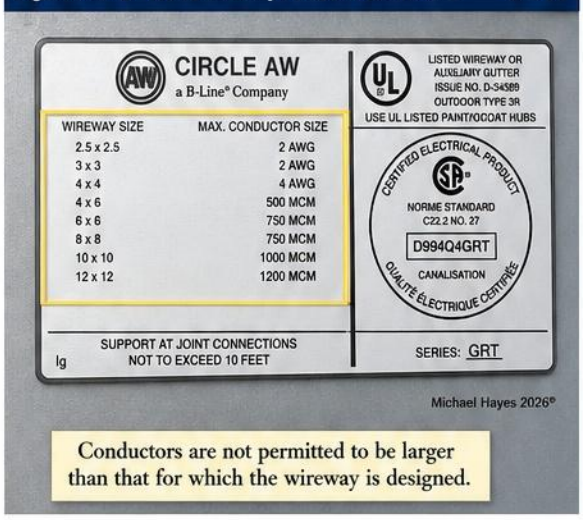
376.21 Size of Conductors

Conductors are not permitted to be larger than that for which the wireway is designed. ▸Figure 376–5

Figure 376–4 Metal Wireways Conductors Connected in Parallel 376.20

Parallel conductors in metal wireways must be installed in groups consisting of not more than one conductor per phase or neutral to prevent current imbalance in the paralleled conductors.

Figure 376–5 Metal Wireways Size of Conductors 376.21



376.22 Number of Conductors and Ampacity

(A) Number of Conductors. The maximum number of conductors permitted in a metal wireway is limited to 20 percent of the wireway's cross-sectional area. ▸Figure 376–6

Author's Comment:

- Splices and taps including conductors are not permitted to fill more than 75 percent of the wiring space at any cross section [376.56(A)].

Figure 376–6 Number of Conductors in Metal Wireways 376.22(A)

The total number of conductors allowed in a metal wireway is limited to 20% of the cross-sectional area of the wireway.

Wireway Conductor Fill [376.22(A)] Example 1

Question: What is the minimum size wireway suitable for three *500 kcmil THWN-2, one 250 kcmil THWN-2, and four 4/0 AWG THWN-2 conductors?*

(a) *4 in. × 4 in. (16 sq in.)* (b) *6 in. × 6 in. (36 sq in.)*
(c) *8 in. × 8 in. (64 sq in.)* (d) *10 in. × 10 in. (100 sq in.)*

Solution:

Step 1: Determine the conductor area [Chapter 9, Table 5].

500 kcmil THWN-2 = 0.7073 sq in. × 3 conductors
= *2.1219 sq in.*

250 kcmil THWN-2 = *0.3970 sq in.*

4/0 AWG THWN-2 = 0.3237 sq in. × 4 conductors
= *1.2948 sq in.*

Total Conductor Area = *2.1219 sq in. + 0.3970 sq in. + 1.2948 sq in. = 3.8137 sq in.*

Step 2: The wireway must not be filled to over 20 percent of its cross-sectional area [376.22(A)]. Twenty percent is equal to one-fifth, so we can multiply the required conductor area by five to find the minimum square inch area required.

Conductor Area × 5 = Required Wireway Minimum Area

3.8137 sq in. × 5 = 19.07 sq in. (less than 36 sq in.)

A 6 in. × 6 in. wireway has a cross-sectional area of *36 sq in.* and will be large enough.

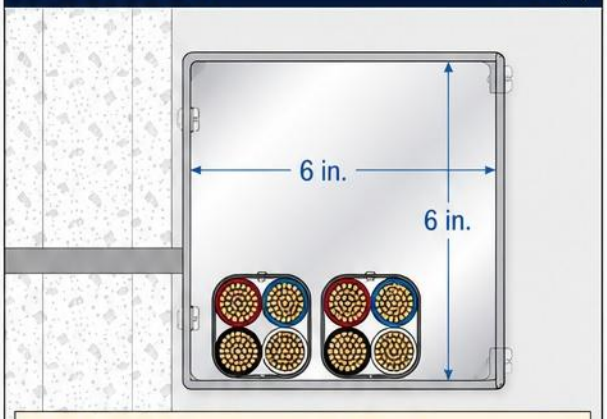
Answer: *(b) 6 in. × 6 in. (36 sq in.)*

Wireway Conductor Fill [376.22(A)] Example 2

Question: What is the maximum conductor fill permitted for a 6 in. × 6 in. wireway? Refer to Figure 376–7.

(a) *7.20 sq in.* (b) *9.20 sq in.* (c) *11.20 sq in.*
(d) *13.20 sq in.*

Figure 376–7 6 in. × 6 in. Metal Wireway Cross-Sectional Area 376.22(A)



Area of Wireway = 6 in. × 6 in. = 36 sq in.
Wireway Conductor Fill = 36 sq in. × 20% = 7.20 sq in.
Maximum Conductor Fill Permitted = 7.20 sq in.

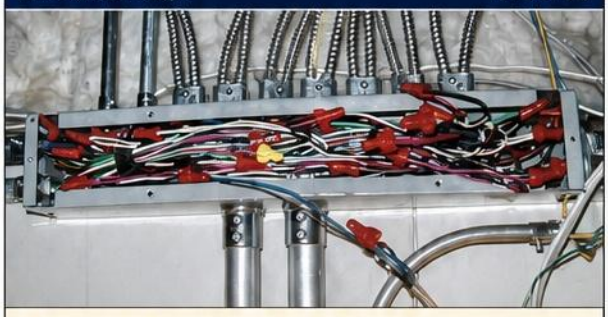
Solution:

36 sq in. × 20% = 7.20 sq in.

Answer: *(a) 7.20 sq in.*

(B) Conductor Ampacity Adjustment. When more than 30 current-carrying conductors are installed in any cross-sectional area of the metal wireway, the conductor ampacity must be adjusted in accordance with Table 310.15(C)(1). Refer to **Figure 376–8.**

Figure 376–8 Conductor Ampacity Adjustment in Metal Wireways 376.22(B)



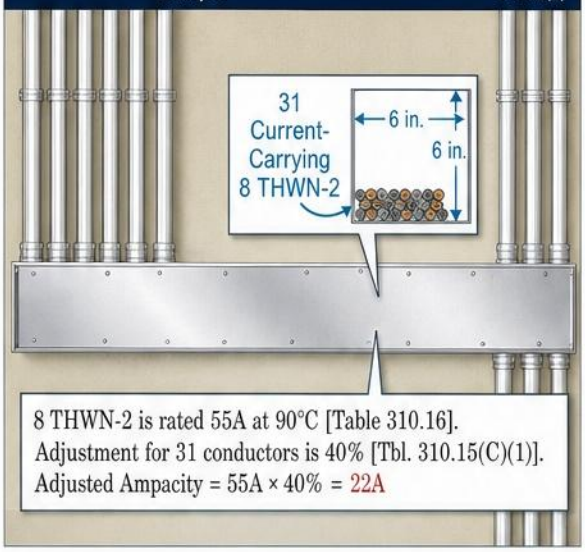
When more than 30 current-carrying conductors are present in any cross-sectional area of a metal wireway, adjust the conductor ampacity in accordance with Table 310.15(C)(1).

▶ Wireway—Conductor Ampacity Adjustment [376.22(B)] Example

Question: Suppose 31 current-carrying conductors of size 8 AWG THWN-2 are in the cross-sectional area of a wireway. What is the ampacity?
Figure 376–9

(a) 20A *(b)* 22A *(c)* 24A *(d)* 26A

Figure 376–9 *Wireway—Conductor Ampacity Adjustment Example* 376.22(B)



Solution:

Adjusted Ampacity = Table 310.16 Ampacity × Bundled Ampacity Adjustment Factor from Table 310.10.15(C)(1)

8 AWG THWN-2 is rated 55A at 90°C [Table 310.16].

The adjustment factor for thirty-one current-carrying conductors is 40 percent [Table 310.15(C)(1)].

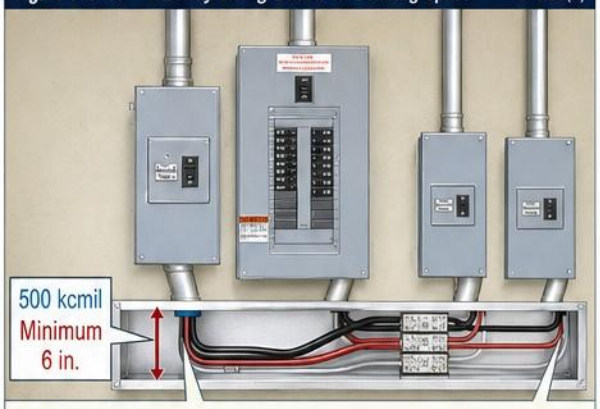
Adjusted Ampacity = 55A × 40%
Adjusted Ampacity = 22A

Answer: *(b) 22A*

376.23 Wireway Sizing

(A) Wireway Sizing. If conductors in a metal wireway are bent more than 30 degrees, the wireway must be sized to the bending space dimensions in Table 312.9(A), based on one wire per terminal. Figure 376–10

Figure 376–10 *Wireway Sizing Based on Bending Space* 376.23(A)



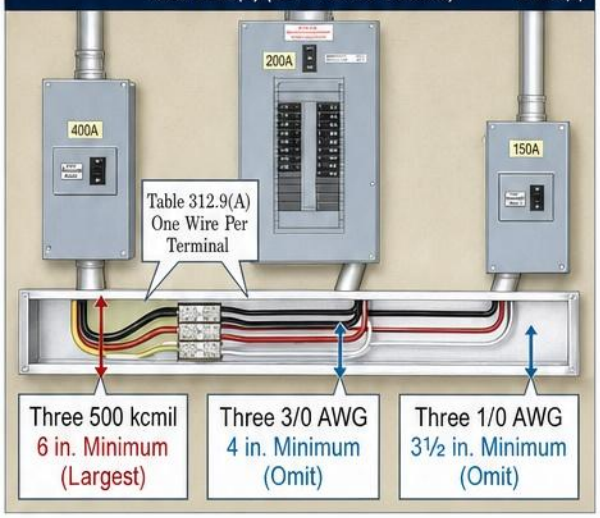
When conductors in a metal wireway are bent more than 30°, the wireway must be sized to the bending space dimensions in Table 312.9(A), based on one wire per terminal.

▶ Wireway Bending Space [376.23(A)] Example

Question: *What is the minimum wireway size suitable for three 500 kcmil THWN-2 conductors from the first disconnect, three 3/0 AWG THWN-2 conductors from the panelboard, and three 1/0 AWG THWN-2 conductors from the other disconnect?*
Figure 376–11

(a) 4 in. *(b) 6 in.* *(c) 8 in.* *(d) 10 in.*

Figure 376–11 *Wireway Bending Space Based on Table 312.9(A) (One Wire Per Terminal)* 376.23(A)



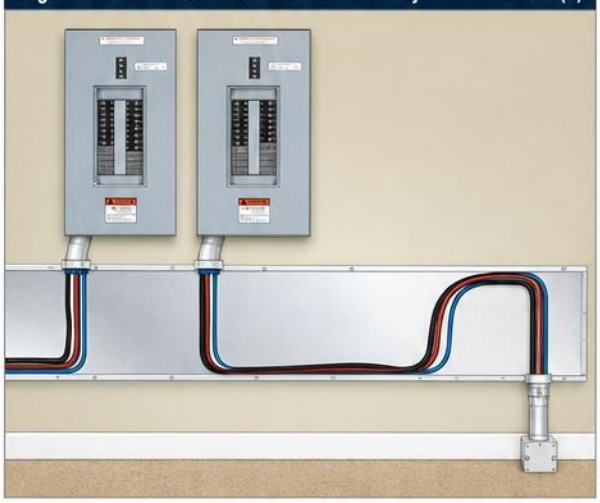
Solution:

According to Table 312.9(A), based on one wire per terminal, the wireway must be sized to accommodate the bending space required for the largest conductor. In this application, it is based on the 500 kcmil conductors [376.23(A)].

Answer: *(b) 6 in.*

(B) Distances Between Raceways. When the conductors are 4 AWG or larger, and pulled through a wireway, the spacing between raceways must comply with 314.28(A)(1) for straight pulls and 314.28(A)(2) for angle pulls. 376.56(B) ▶

Figure 376–12 Distances Between Raceways 376.23(B)



When the conductors are 4 AWG or larger and pulled through a wireway, the spacing between raceways must comply with 314.28(A)(1) for straight pulls and 314.28(A)(2) for angle pulls.

376.30 Supports

Wireways must be supported in accordance with 376.30(A) and (B).

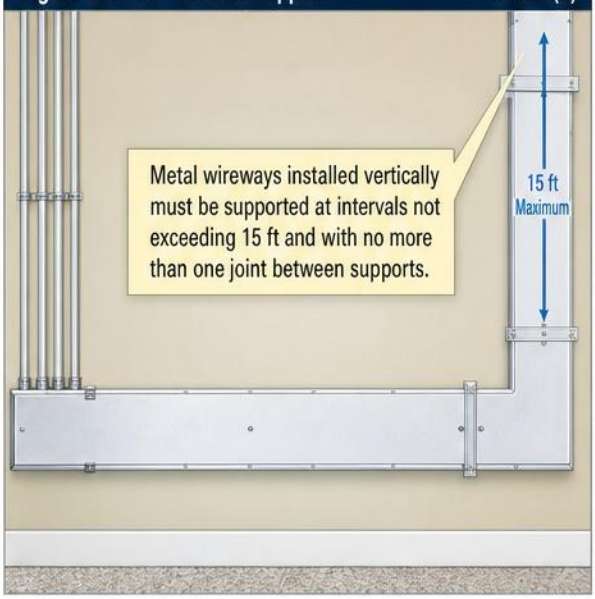
(A) Horizontal Support. Metal wireways installed horizontally must be supported at each end and at intervals not exceeding 5 ft. The distance between supports must not exceed 10 ft. 376.30(A) ▶

Figure 376–13 Horizontal Support 376.30(A)

For horizontal installations, supports are required at each end and at intervals of 5 ft or less, and the spacing between any two supports must not be more than 10 ft.

(B) Vertical Support. Metal wireways installed vertically must be supported at intervals not exceeding 15 ft with no more than one joint between supports. 376.56(B) ▶

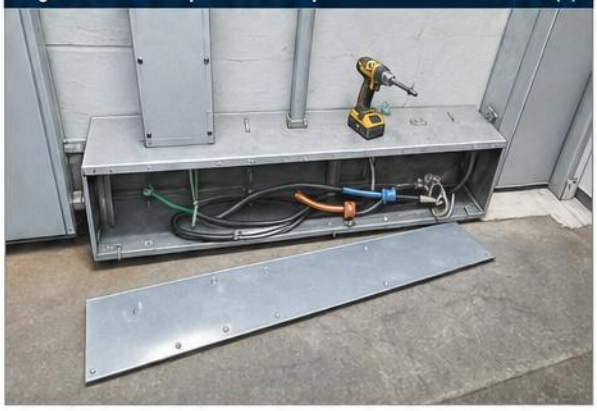
Figure 376–14 Vertical Support 376.30(B)



376.56 Splices, Taps, and Power Distribution Blocks

(A) Splices and Taps. Splices and taps in metal wireways are not permitted to exceed 75 percent of the wireway's cross-sectional area. 376.56(A) ▶

Figure 376–15 Splices and Taps 376.56(A)



Splices and taps in metal wireways are not permitted to exceed 75 percent of the wireway's cross-sectional area.

(B) Power Distribution Blocks.

(1) Installation.

Listed. Power distribution blocks installed in metal wireways must be listed.

(2) Size of Enclosure. The power distribution block in a metal wireway must not be smaller than the size specified in the instructions for the power distribution block.

(3) Wire-Bending Space. The space for bending conductors at the terminals of power distribution blocks must comply with 312.9(B).

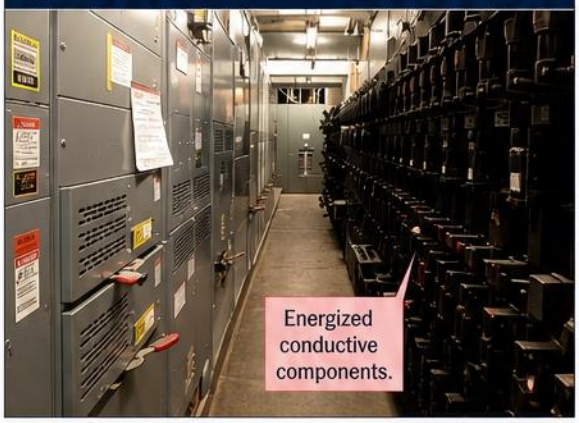
(4) Live Parts. Power distribution blocks are not allowed to have uninsulated exposed live parts whether the metal wireway cover is installed or not. Figure 376–16.

Figure 376–16 376.56(B)(4)

Power distribution blocks are not permitted to have uninsulated exposed *live parts* whether the metal wireway cover is installed or not.

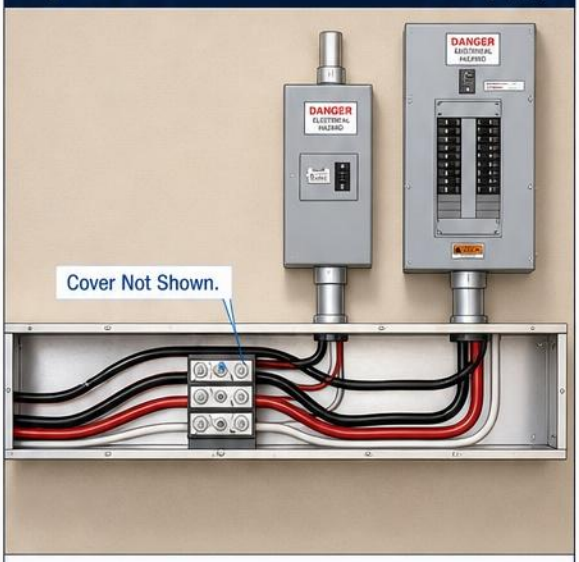
Live Parts. Energized conductive components. Figure 376–17.

Figure 376–17 Article 100 Definition



(5) Conductors. Conductors must be connected at the terminals of the power distribution block in a way that does not obstruct access. Figure 376–18.

Figure 376–18 376.56(B)(5)



Conductors must be installed so the terminals of the power distribution block aren't obstructed.

376.60 Equipment Grounding Conductor

Listed metal wireways are permitted to serve as an equipment grounding conductor in accordance with 250.118(A)(13). Figure 376–19.

Figure 376–19 376.60

Listed metal wireways are permitted to serve as an equipment grounding conductor in accordance with 250.118(A)(13).

ARTICLE
380

Multioutlet Assemblies

Introduction to Article 380—Multioutlet Assemblies

This article specifies the requirements for the use and installation of *multioutlet assemblies*. A *multioutlet assembly* is a surface, flush, or freestanding raceway designed to hold conductors and receptacles. It can be assembled in the field or at the factory.

Multioutlet Assembly. A surface, flush, or freestanding assembly containing receptacles.
▶ Figure 380–1

Figure 380–1 Multioutlet Assembly — Article 100 Definition

A surface, flush, or freestanding assembly containing receptacles.

Figure 380–2 Multioutlet Assemblies — 380.1 Scope

Article 380 contains the requirements for the use and installation of multioutlet assemblies.

Part I. General

380.1 Scope

This article sets forth the requirements for the use and installation of multioutlet assemblies.
▶ Figure 380–2

380.2 Listing Requirements

Multioutlet assemblies and associated fittings must be listed.

Part II. Installation

380.10 Uses Permitted

Multioutlet assemblies are only permitted in dry locations.

380.12 Uses Not Permitted

Multioutlet assemblies must not be used under the following conditions:

(1) When concealed.

(2) When subject to severe physical damage.

(3) If the voltage is 300V or more between conductors—unless the metal has a thickness of not less than 0.04 in.

(4) When subject to corrosive vapors.

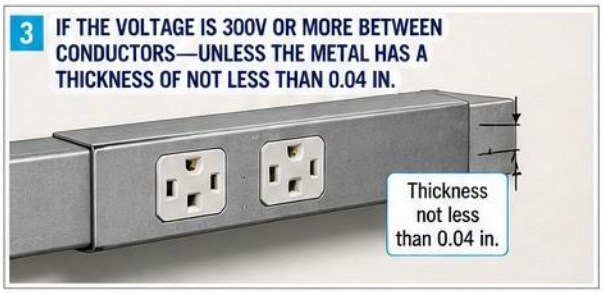
(5) In hoistways.

(6) In any hazardous location, except as permitted elsewhere in this *Code*.

(7) When cord-and-plug-connected.

380.76 Through Partitions

Metal multioutlet assemblies may pass through a dry partition, provided no receptacle is concealed in the wall, and the cover of the exposed portion of the system can be removed.



ARTICLE 386 Surface Metal Raceways

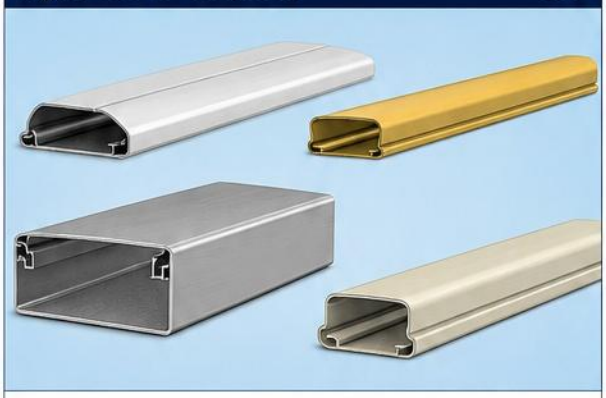
Introduction to Article 386—Surface Metal Raceways

Article 386 addresses the use, installation, and construction specifications for surface metal raceways and associated fittings. Surface metal raceways are commonly used where exposed traditional raceway systems are not visually appealing and concealment is not economically practical. Surface metal raceways are manufactured in a variety of colors and configurations and may be referred to in the field as "Wiremold®."

Raceway, Surface Metal Raceway. A metal raceway with associated fittings designed to be mounted on the surface of a structure where conductors are installed after the raceway has been installed as a complete system.

▶ Figure 386–1

Figure 386–1 Definition **100**



A metal raceway with associated fittings intended to be mounted on the surface of a structure in which conductors are placed after the raceway has been installed as a complete system.

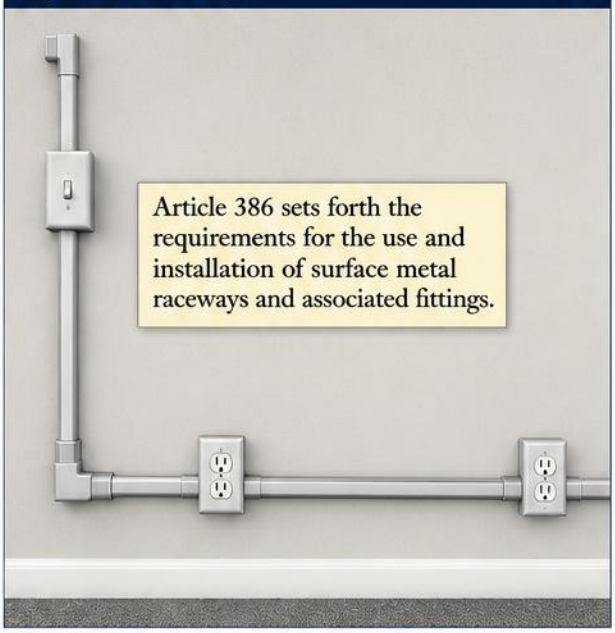
Part I. General

386.1 Scope 386.1

This article specifies the requirements for the use and installation of surface metal raceways and associated fittings.

▶ Figure 386–2

Figure 386–2 Scope **386.1**



This section defines the scope of Article 386.

Author's Comment

- Surface metal raceways are available in different shapes or sizes, and can be mounted on walls, ceilings, or floors.

386.2 Listing Requirements 386.2

Surface metal raceways and associated fittings must be listed.

Author's Comment:

- Enclosures for switches, receptacles, luminaires, and other devices are identified by the markings on their packaging. The markings specify the type of surface metal raceway that can be used with the enclosure.

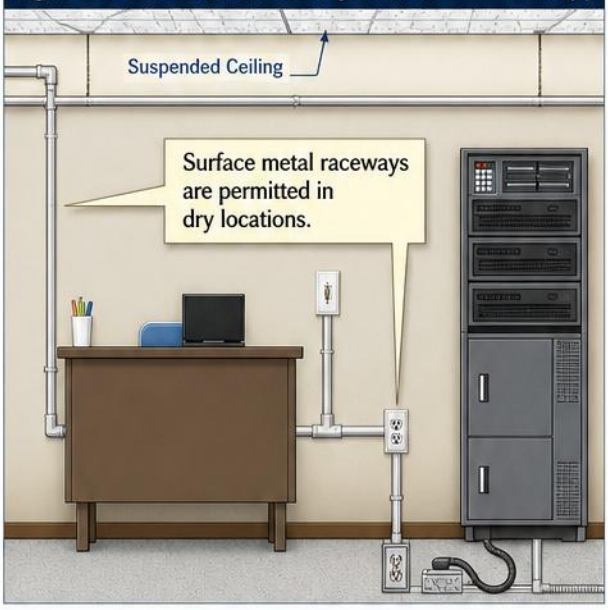
Part II. Installation

386.10 Uses Permitted

Surface metal raceways are permitted to be used as follows:

(1) In dry locations ▸Figure 386–3

Figure 386–3: Uses Permitted in Dry Locations 386.10(1)



Surface metal raceways may be used in dry locations as shown above.

(2) In Class I, Division 2 locations 501.10(B)(3)

(3) Under raised floors in accordance with 645.5(E)(2)

(4) Through walls and floors, if access to the conductors is maintained on both sides of the wall, partition, or floor

386.12 Uses Not Permitted

Surface metal raceways cannot be used under the following conditions:

(1) Where subject to severe physical damage unless approved by the authority having jurisdiction

(2) If the voltage is 300V or more between conductors—unless the metal has a thickness of not less than 0.04 in.

(3) Where subject to corrosive vapors

(4) In hoistways

(5) If concealed, except as permitted in 386.10

386.21 Size of Conductors

The maximum size conductor permitted in a surface metal raceway cannot be larger than that for which the raceway is designed.

386.22 Number of Conductors

Number of Conductors. The number of conductors installed in a surface metal raceway must not be more than the number for which the raceway is designed.

Author's Comment:

- The size and number of conductors permitted is marked on the raceway itself or the package.

Conductor Ampacity. Ampacity adjustment factors of Table 310.15(C)(1) do not apply to conductors installed in surface metal raceways if all the following conditions are met: ▸Figure 386–4

Figure 386–4: Surface Metal Raceway Conductor Ampacity 386.22

The ampacity adjustment factors of Table 310.15(C)(1) don't apply where all the following conditions are met:

(1) The cross-sectional area exceeds 4 sq in.,

(2) The number of current-carrying conductors doesn't exceed 30, and

(3) The conductor fill doesn't exceed 20% of the interior cross-sectional area of the raceway.

When all three conditions shown are met, the ampacity adjustment factors of Table 310.15(C)(1) do not need to be applied.

(1) Cross-sectional area of the raceway exceeds 4 sq in.

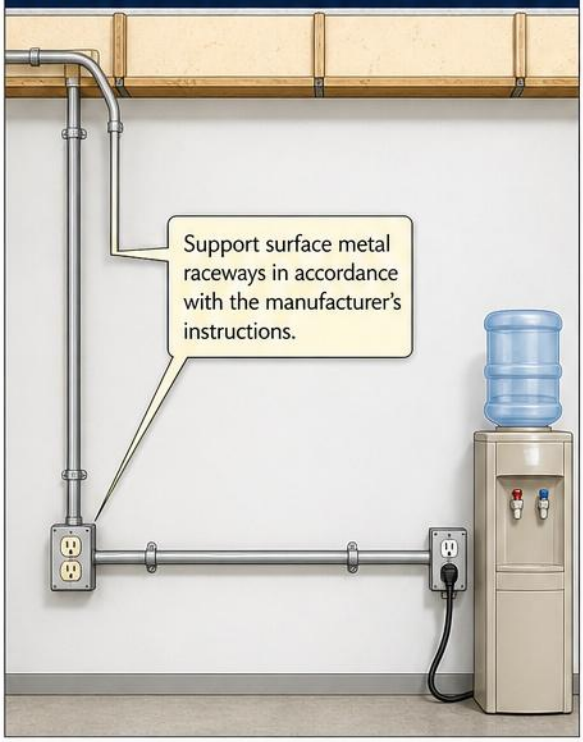
(2) Number of current-carrying conductors does not exceed 30

(3) Sum of the cross-sectional areas of all contained conductors does not exceed 20 percent of the interior cross-sectional area of the raceway

386.30 Supporting

Surface metal raceways must be supported in accordance with the manufacturer's instructions.

Figure 386–5 Surface Metal Raceways, Supporting 386.30



Surface metal raceways must be supported in accordance with the manufacturer's instructions.

386.56 Splices and Taps

Splices and taps must be accessible and must not occupy more than 75 percent of the cross-sectional area of the raceway.

386.60 Equipment Grounding Conductor

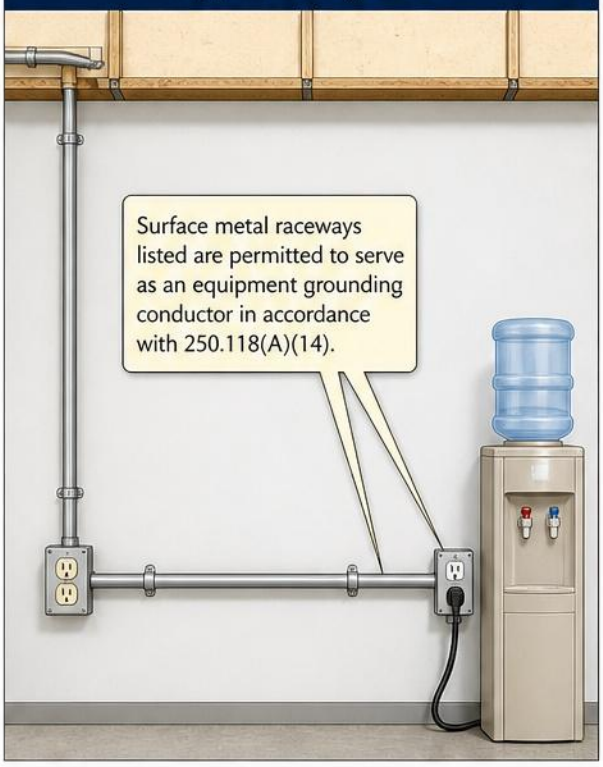
Surface metal raceways that allow a transition to another wiring method (such as knockouts for connecting raceways) must have a means for the termination of an equipment grounding conductor.

Author's Comment:

- Surface metal raceways listed are suitable for use as an equipment grounding conductor in accordance with 250.118(A)(14).

  See Figure 386–6.

Figure 386–6 Surface Metal Raceways, Equipment Grounding Conductor 386.60



Surface metal raceways listed are permitted to serve as an equipment grounding conductor in accordance with 250.118(A)(14).

ARTICLE 230 Service

Article 230 covers the general requirements for electric services, including the conductors, overcurrent protection, switching, and equipment necessary to deliver electrical power from the serving utility to the premises wiring system.

230.1 Scope

This article applies to the conductors and equipment for services supplied by electric utilities, and to the conductors and equipment on the load side of the service disconnecting means.

230.2 Service Conductors

Service conductors are those conductors that extend from the serving utility distribution system to the service overcurrent device or to the service disconnecting means, whichever is supplied first. Service conductors can be overhead or underground.

- Overhead service conductors shall comply with 230.24.
- Underground service conductors shall comply with 230.43.

230.24 Overhead Service Conductors

Overhead service conductors shall have minimum clearances as specified in 230.24(B). The minimum height above finished grade for service conductors over areas accessible to pedestrians is 10 ft.

- Over streets, alleys, roads, and driveways: 18 ft.
- Over roofs not intended for occupancy: 8 ft.
- Over roofs intended for occupancy: 3 ft.

A messenger wire is permitted to be used where approved by the serving utility. The messenger, if used, shall be considered a service conductor and shall comply with the same clearance requirements.

230.43 Underground Service Conductors

Underground service conductors shall comply with the following.

- The minimum depth of burial shall be 24 in. below grade, unless greater depth is required by other articles of the NEC.
- They shall be installed in a raceway, unless a cable or approved direct-burial conductors are used.
- The raceway shall extend from the point of entrance at the building to a point at least 18 in. below grade, unless otherwise permitted by the NEC.
- Where the raceway emerges from the ground, it shall be securely fastened to the building or other approved structure.

230.70 Service Disconnecting Means

A disconnecting means shall be provided to disconnect all ungrounded conductors from the source of supply.

- The disconnecting means shall be located within sight from, and not more than 50 ft from, the point of entrance of the service conductors.
- It shall be accessible to authorized persons only.
- The disconnect shall be suitable for the available fault current.

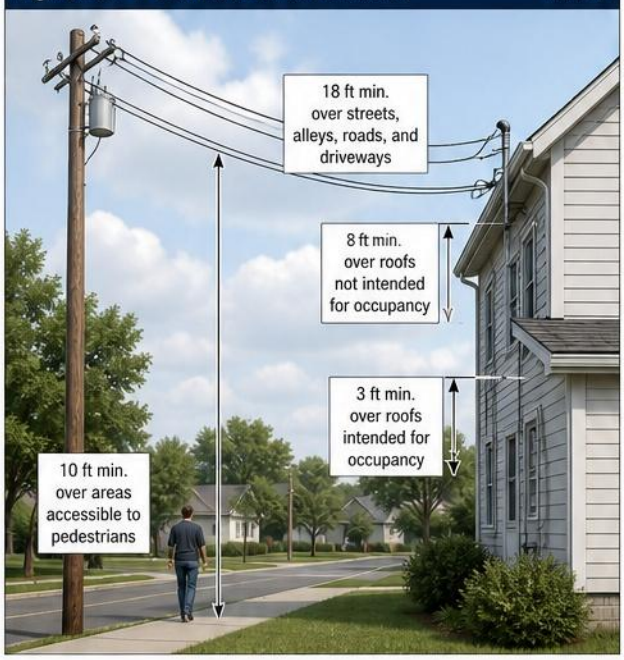
The service disconnecting means may be a circuit breaker, fused switch, or other approved means.

230.71 Service Disconnects in Dwelling Units

For one- and two-family dwellings, the service disconnecting means shall be located either outside the dwelling or in a readily accessible location.

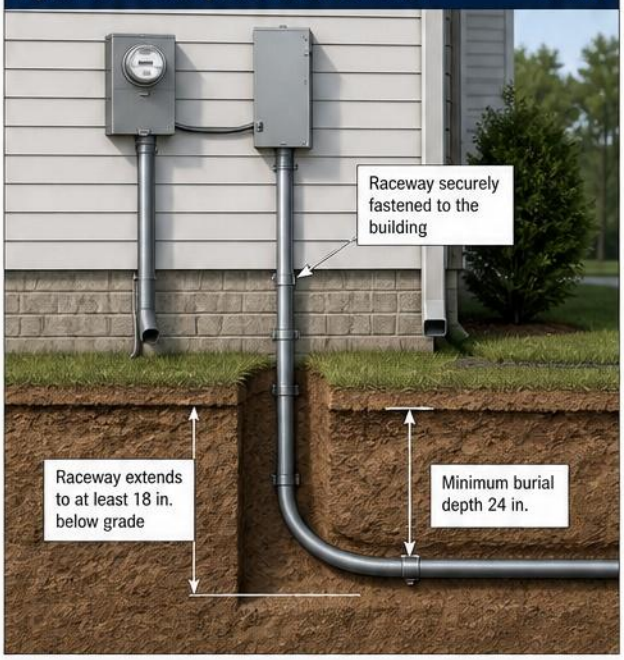
- The service disconnect shall not be located in a bathroom or over a sink.

Figure 230–1 Overhead Service Conductors 230.24



Overhead service conductors must maintain the minimum clearances specified in 230.24(B) to ensure safe conditions for pedestrians, vehicles, and buildings.

Figure 230–2 Underground Service Conductors 230.43



Underground service conductors must be installed in a raceway to the required depth and properly secured where it emerges from the ground.

ARTICLE

392 Cable Trays

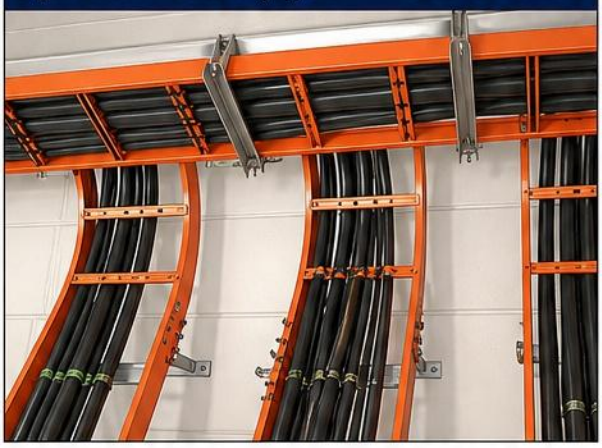
Introduction to Article 392—Cable Trays

This article establishes the requirements for cable tray systems, including ladder, ventilated trough, ventilated channel, solid bottom, and other comparable structures. A cable tray system is a unit (or an assembly of units or sections with associated fittings) that forms a structural system used to securely fasten or support cables and raceways.

Cable Tray System. A unit or assembly of units or sections with associated fittings that forms a structural system used to securely fasten or support cables and raceways.

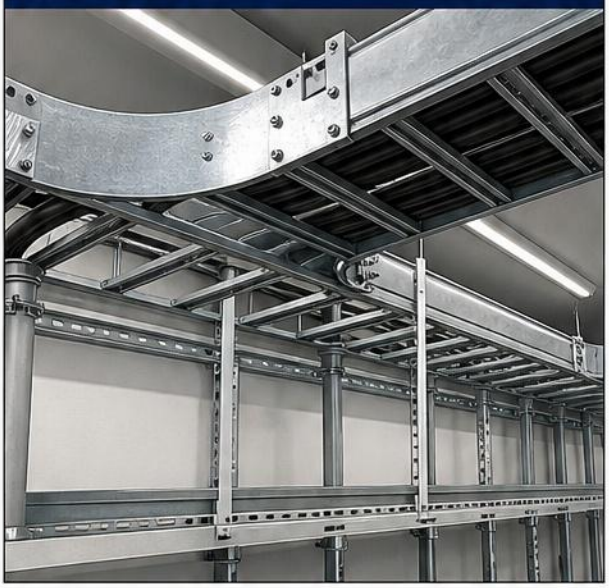
▸ Figure 392–1

Figure 392–1 Cable Tray System — Article 100 Definition



A unit or assembly of units or sections with associated fittings that forms a structural system used to securely fasten or support cables and raceways.

Figure 392–2 Cable Trays — 392.1 Scope



Article 392 sets out the rules for cable tray systems, including ladder, ventilated trough, ventilated channel, solid bottom, and other comparable structures.

Part I. General

392.1 Scope

Article 392 specifies the requirements for cable tray systems, including ladder, ventilated trough, ventilated channel, solid bottom, and other comparable structures.

▸ Figure 392–2

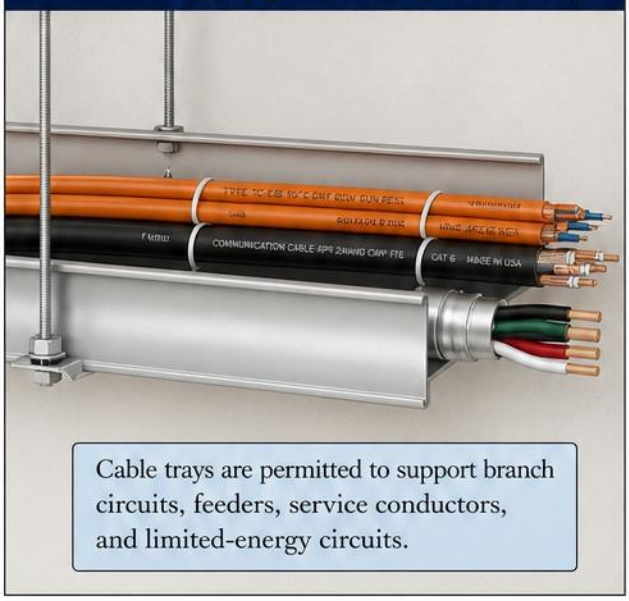
Part II. Installation

392.10 Uses Permitted

Wiring Methods. A cable tray is permitted to support system service conductors, feeders, branch circuits, control circuits, and signaling circuits.

▸ Figure 392–3

Figure 392–3 Cable Trays, Uses Permitted Support System for Wiring Methods 392.10



Cable trays are permitted to support branch circuits, feeders, service conductors, and limited-energy circuits.

Single Conductor Cables and Conductors. Only single-conductor cables and conductors are permitted in cable trays when installed in accordance with 392.10(B)(1).

AUTHOR'S COMMENT:

- Service conductors in cable trays must be installed in accordance with 230.44.

(A) Wiring Methods. The following wiring methods may be used in a cable tray:

(1) Armored cables
(2) Coaxial cables
(3) Class 2 and Class 3 cables
(4) Class 4 cables
(5) Communications cables
(6) Communications raceways
(7) Electrical metallic tubing
(8) Electrical nonmetallic tubing
(9) Fire alarm cables
(10) Flexible metal conduit
(11) Flexible metallic tubing
(12) Instrumentation tray cable
(13) Intermediate metal conduit
(14) Liquidtight flexible metal conduit
(15) Liquidtight flexible nonmetallic conduit
(16) Metal-clad cables
(17) Mineral-insulated, metal-sheathed cables
(18) Network-powered broadband communications cables
(19) Nonmetallic-sheathed cables
(20) Nonpower-limited fire alarm cables
(22) Other factory-assembled, multiconductor control, signal, or power cables that are specifically approved for installation in cable trays
(23) Power and control tray cables
(24) Power-limited fire alarm cables
(25) Power-limited tray cables
(26) Rigid metal conduit
(27) Rigid polyvinyl chloride conduit
(28) Reinforced thermosetting resin conduit
(29) Service-entrance cables
(30) Underground feeder and branch-circuit cables

AUTHOR'S COMMENT:

- Metal cable trays can be used in environmental air spaces (plenums) only when the wiring methods they support are permitted in accordance with 300.25(C).

(B) In Industrial Establishments.

(1) **Single-Conductor Cables and Conductors.**

(a) **1/0 AWG and Larger.** Where conditions of maintenance and supervision ensure that only qualified persons service the installed cable tray system, single-conductor cables, and conductors can be installed in accordance with the following:

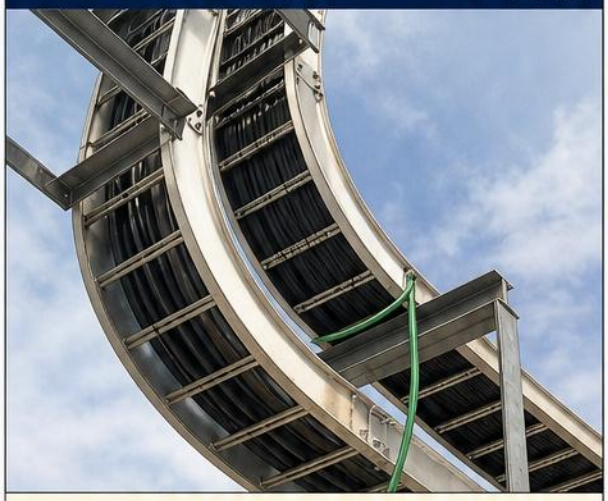
- Figure 392–4

(a) 1/0 AWG and larger listed and marked for use in cable trays

(c) Equipment grounding conductors must be 4 AWG and larger

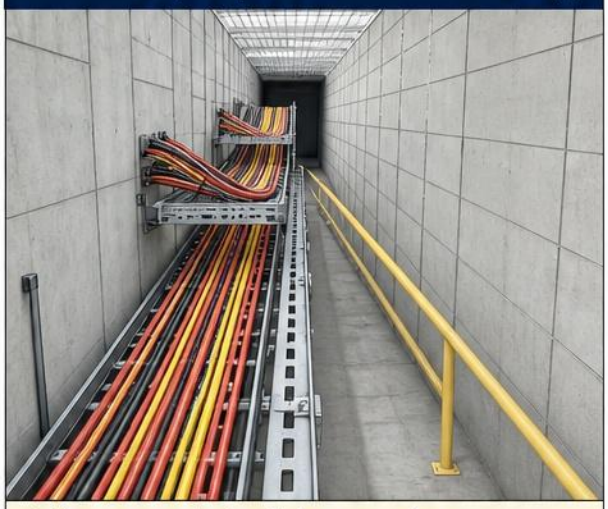
(C) Hazardous Locations. Cable trays in hazardous locations must contain only the cable types and raceways permitted by this *Code* for the application.

Figure 392–4 Cable Trays, Single Conductors 1/0 AWG and Larger 392.10(B)(1)(a)



Conductors 1/0 AWG and larger listed and marked "CT" for use in cable trays can be installed where conditions of maintenance and supervision ensure that only qualified persons service the cable tray.

Figure 392–5 Cable Tray Installations Complete Systems 392.18(A)



Cable trays must be installed as a complete system, except mechanically discontinuous segments between cable tray runs or between cable tray runs and equipment are permitted.

AUTHOR'S COMMENT:

- For permitted cable types in hazardous locations, see 501.10, 502.10, 503.10, 504.20, and 505.15.

392.12 USES NOT PERMITTED

Cable tray systems are not permitted in hoistways or where subject to severe physical damage.

392.18 CABLE TRAY INSTALLATIONS

(A) Complete System. Cable trays must be installed as a complete system, except mechanically discontinuous segments between cable tray runs or between cable tray runs and equipment are permitted. **Figure 392–5.**

(B) Completed Before Installation. Each run of cable tray must be completed before the installation of cables.

(D) Through Partitions and Walls. Cable trays can extend through partitions, walls, or vertically through platforms and floors, if the installation is made in accordance with the firestopping requirements of 300.23.

(E) Exposed and Accessible. Cable trays must be exposed and accessible, except as permitted by 392.18(D).

(F) Access. A minimum space of 12 in. of access above cable trays must be provided and maintained to permit access for installing and maintaining the cables.

Ex 1: Where the installation complies with 645.5 for IT equipment room.

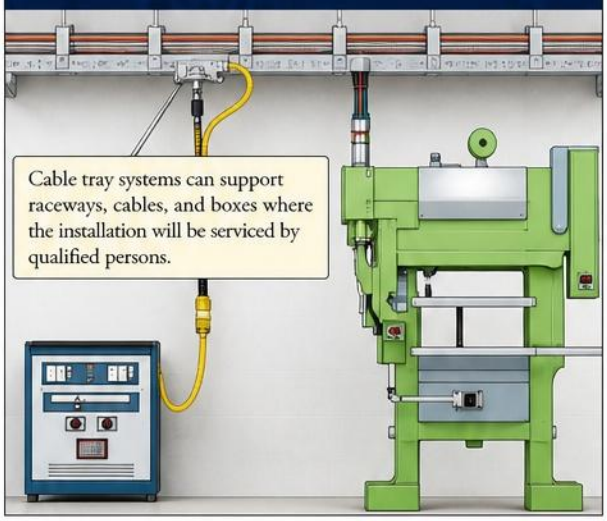
Ex 2: In industrial establishments, where conditions of maintenance and supervision ensure that only qualified persons service the installed cable tray.

Ex 3: By special permission, smaller distance spaces may be permitted.

Ex 4: For equipment crossing at any angle.

(G) Raceways, Cables, and Boxes Supported from Cable Trays. Support of Raceways, Cables, and Boxes. In industrial facilities where conditions of maintenance and supervision ensure only qualified persons will service the installation, cable tray systems can support raceways, cables, and boxes. **Figure 392–6.**

Figure 392–6 Cable Trays, Support of Raceways, Cables, and Boxes 392.18(G)



Raceway Termination. For raceways terminating at a cable tray, a listed cable tray clamp or adapter must be used to securely fasten the raceway to the cable tray system.

Raceways or cables running parallel to a cable tray system can be attached to the bottom or side of the cable tray system. The raceway or cable must be fastened and supported in accordance with the appropriate raceway or cable article.

Boxes attached to the bottom or side of a cable tray system must be fastened in accordance with 314.23.

392.20 Cable and Conductor Installation

(C) Connected in Parallel. Where conductors are installed in parallel as permitted in 310.10(G), the parallel conductors must be installed in groups consisting of not more than one conductor per phase or neutral to prevent current imbalance in the paralleled conductors.

(D) Single Conductors.

Single Layer. Single conductors 1/0 AWG through 4/0 AWG must be installed in a single layer.

Conductors Bound Together. Conductors that are bound together to comprise each circuit group are permitted in other than a single layer.

392.30 Securing and Supporting

(A) Cable Trays. Cable trays must be supported at intervals in accordance with the manufacturer's instructions.

(B) Cables and Conductors. Cables and conductors must be secured to the cable tray system in accordance with the following:

(4) Cable ties must be listed and identified for the application and for securement and support.

392.44 Expansion Splice Plates

Expansion splice plates must be provided where necessary to compensate for thermal expansion and contraction of the cable tray system.

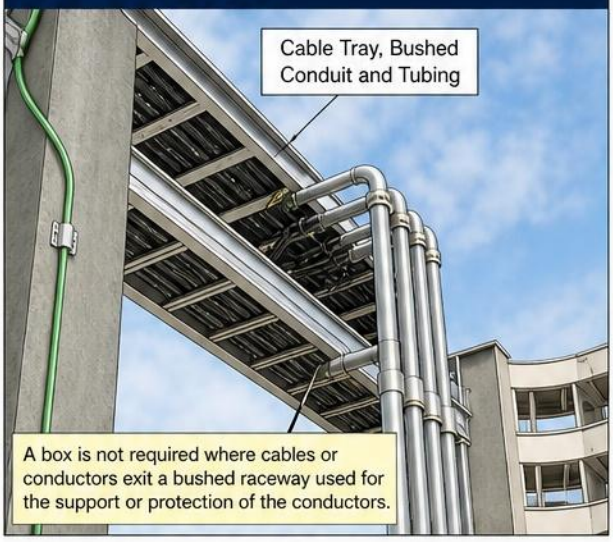
Author's Comment:

- Without the installation of raceway expansion joints, thermal expansion is an issue and often overlooked. For the cable tray system to properly serve its function, it must be able to expand—as well as contract—and expansion joints provide the ability to do so.
- This *Code* section gives no guidance as to how to determine the need for an expansion splice plate, but there is a National Electrical Manufacturers Association (NEMA) document, *NEMA VE2, Cable Tray Installation Guidelines,* available as a free download that may assist.

392.46 Bushed Conduit and Tubing

A box is not required where cables or conductors are installed in a bushed raceway used for support, protection against physical damage, or where conductors or cables transition to a raceway from the cable tray.

Figure 392–7 | 392.46



A box is not required where cables or conductors are installed in a bushed raceway used for support, protection, or where conductors or cables transition from the cable tray.

(A) Through Bushed Conduit or Tubing. Individual conductors or multiconductor cables with nonmetallic sheaths can enter enclosures where they are terminated through nonflexible bushed conduit or tubing installed for their protection, if they are secured at the cable tray transition point and sealed at the outer end. To seal, use an approved means to prevent debris from entering the equipment through the raceway.

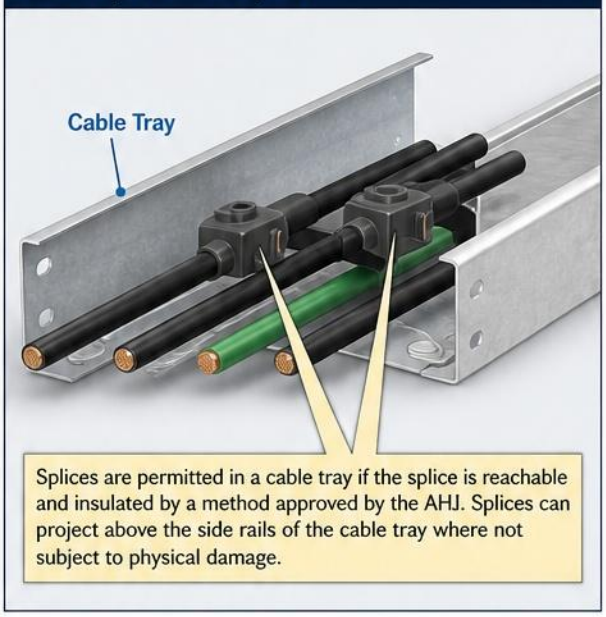
(B) Flanged Connections. Single-conductor or multi-conductor cables with entirely nonmetallic jackets can enter enclosures through openings that are fitted with flanges from the cable tray at the point where the tray attaches, provided the flange is mounted directly to the equipment. The openings must be constructed so the conductors are shielded from mechanical wear and must be sealed or otherwise covered to stop debris from getting into the enclosure.

Note: A reliable method to stop debris from entering an enclosure is to seal the opening or the outer end of the raceway with a duct seal.

392.56 Cable Splices

Splices are allowed in a cable tray only when they are reachable and insulated in accordance with a method recognized by the authority having jurisdiction (AHJ). Splices may extend past the side rails of the cable tray if they are not subject to physical damage. Figure 392–8

Figure 392–8 392.56
Cable Tray Conductor Splices



ARTICLE 230 — GROUNDING AND BONDING

Scope and Purpose

Article 230 establishes the requirements for grounding electrical installations to provide a low-impedance path to earth for fault currents and to limit voltage to ground on the electrical system, equipment, and exposed metal parts. It also specifies the necessary bonding of non–current-carrying metal parts and systems to ensure electrical safety.

The intent of grounding and bonding is to reduce the risk of electric shock, fire, and equipment damage by ensuring that fault current has an effective path to ground and that exposed metal parts do not become energized.

230.4 — Grounding of Systems and Equipment

(A) All electrical systems, circuits, and equipment likely to become energized shall be grounded in accordance with this article.

(B) The grounding electrode system shall be installed in accordance with Part III of this article.

Figure 230.4 — Grounding of Electrical System **NEC 230.4**

All electrical systems and equipment that can become energized shall be connected to an equipment grounding conductor and to the grounding electrode system.

230.5 — Grounding Electrode System

(A) The grounding electrode system shall be installed and used to provide an effective ground-fault current path.

(B) The grounding electrode system shall consist of one or more of the grounding electrodes specified in 250.52(A)(1) through (A)(8), or other electrodes approved for use, and shall be installed in accordance with Part III of this article.

(C) The grounding electrode conductor shall be connected to the grounding electrodes in accordance with 250.64.

230.6 — Bonding

(A) Non–current-carrying metal parts of equipment likely to become energized shall be bonded to the equipment grounding conductor.

(B) Metal raceways, enclosures, and equipment shall be bonded to establish electrical continuity and reduce the impedance of the fault current path.

(C) Bonding shall be done in accordance with 250.102.

Figure 230.6 — Bonding **NEC 230.6**

Bonding ensures that metal enclosures and raceways remain at the same electrical potential, providing an effective path for fault current.

230.24 — Service Equipment

(A) The frame of service equipment shall be connected to the grounding electrode system by an equipment grounding conductor.

(B) Service neutral conductors shall be connected to the grounding electrode system in accordance with 250.24.

CHAPTER 3

REVIEW QUESTIONS

Please use the 2026 *Code* book to answer the following questions.

1. Where a cable is installed through bored holes in joists, rafters, or wood members, the holes shall be bored so that the edge of the hole is _____ the edges of the wood member.

Figure 1 NEC 300.4(B)

(a) not less than 1¼ in. from
(b) adjacent to
(c) not less than ½ in. from
(d) none of these

2. A listed expansion/deflection fitting or other approved means shall be used where a raceway crosses a structural joint intended for _____.

Figure 2 NEC 300.7(A)

(a) expansion
(b) contraction
(c) deflection
(d) any of these

3. Electrical metallic tubing under a two-family dwelling driveway shall have at least _____ of cover.

Figure 3 NEC 300.5(D)

(a) 6 in.
(b) 12 in.
(c) 18 in.
(d) 24 in.

4. Elaceways may be used as a means of _____ Class 2 power-limited cables that are solely for the purpose of connection to the equipment control circuits.

Figure 4 NEC 725.136(A)

(a) supporting
(b) securement
(c) strapping
(d) none of these

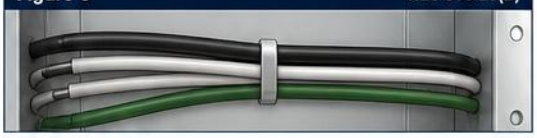
5. _____ used to provide support or protection of cables from physical damage shall not be required to be mechanically continuous.

Figure 5 NEC 300.4(E)

(a) AC Cable
(b) MC Cable
(c) Short sections of raceways
(d) any of these

6. Conductors carrying alternating current installed in ferrous metal raceways or enclosures shall be arranged to avoid heating the surrounding ferrous metal by induction. To accomplish this, the _____ shall be grouped together.

Figure 6 NEC 300.20(B)



(a) phase conductors
(b) grounded conductors
(c) equipment grounding conductors
(d) all of these

7. In accordance with Table 310.4(1), USE-2 cable is _____ resistant.

Figure 7 NEC 338.10(B)

(a) heat
(b) moisture
(c) sunlight
(d) heat and moisture

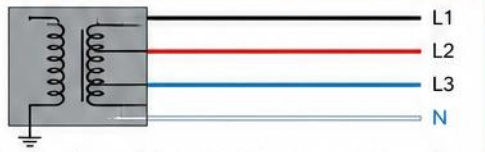
8. Where installed in raceways, conductors _____ and larger shall be stranded, unless specifically permitted or required elsewhere in the *NEC*.

Figure 8 NEC 310.10(H)

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

9. A neutral conductor of a 3-wire circuit consisting of two ungrounded conductors and one neutral conductor from a 4-wire, three-phase _____ system shall be considered a current-carrying conductor.

Figure 3–9 Three-Phase, 4-Wire System 200.6(A)



Neutral conductor of a 3-wire circuit is a current-carrying conductor.

(a) wye-connected
(b) delta-connected
(c) zigzag-connected
(d) open delta-connected

10. Enclosures for overcurrent protective devices are allowed to have conductors feeding through where the wiring space is not filled to more than _____ of the cross-sectional area of the space.

Figure 3–10 Wiring Space Fill 240.17(C)

(a) 20 percent
(b) 30 percent
(c) 40 percent
(d) 60 percent

11. Nonmetallic boxes are permitted with _____ in accordance with 250.109(b).

Figure 3–11 Nonmetallic Box Connection 250.109(B)

Nonmetallic boxes are permitted with listed metal conduit or metal armored cable.

(a) metal conduit
(b) metal armored cable
(c) metal conduit or metal armored cable
(d) none of these

12. Boxes, conduit bodies, and fittings installed in wet locations shall be listed for use in _____ locations.

Figure 3–12 Wet Location Fitting 314.10(C)

(a) wet
(b) damp
(c) dry
(d) corrosive

13. The number of 12 AWG conductors permitted in a 4 × 1½ square box is _____.

Figure 3–13 Conductor Fill (12 AWG) 314.16(B)

(a) 7
(b) 9
(c) 11
(d) 13

14. Enclosures can be secured to suspended-ceiling framing members by mechanical means such as _____, or by other means identified for use with the suspended-ceiling framing member(s).

Figure 3–14 Securing Enclosure to Ceiling Frame 410.36(A)

(a) bolts
(b) screws
(c) rivets or clips
(d) any of these

15. A connection to a pendant box equipped with a hub shall be made with a(n) _____ cord grip attachment fitting marked for use with a threaded hub.

Figure 3–15 Pendant Box with Hub 314.27(C)

(a) approved
(b) listed
(c) marked
(d) identified

16. Boxes used to support luminaire outlets in a ceiling shall be designed so that a luminaire can be attached and the boxes shall be required to support a luminaire weighing a minimum of _____.

Figure 3–16 Luminaire Outlet Box 410.27(A)

(a) 20 lb
(b) 30 lb
(c) 40 lb
(d) 50 lb

17. Outlet boxes used as the sole support of a ceiling-suspended (paddle) fan shall be listed and marked by their manufacturer on the _____ of the box.

Figure 3–17 Ceiling Fan Outlet Box 314.27(B)

(a) interior
(b) exterior
(c) outside
(d) any of these

18. The minimum distance from the raceway entry to the opposite wall of a pull or junction box for a U pull with two 3 in. raceways is _____.

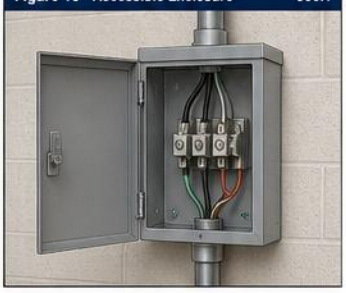
Figure 3–18 U Pull in Box 314.28(A)

(a) 16 in.
(b) 15 in.
(c) 18 in.
(d) 21 in.

19. Boxes, conduit bodies, and handhole enclosures shall be installed so that wiring and devices contained in the boxes, conduit bodies, or handhole enclosures can be rendered _____.

(a) accessible
(b) readily accessible
(c) exposed
(d) none of these

Figure 19 Accessible Enclosure 300.1



Enclosure installed for access to wiring and devices.

20. Underground boxes and handhole enclosures shall be be installed so they are sidewalks, pavings, used to establish the finished grade.

(a) accessible
(b) readily accessible
(c) exposed
(d) seen

Figure 20 Readily Accessible 300.5

Handhole installed for ready access at grade level.

21. Article 320 covers the use, installation, and construction specifications for _____.

(a) flexible metal cable
(b) metal-clad cable
(c) armored cable
(d) nonmetallic cable

Figure 21 Metal-Clad Cable Article 320

Metal-clad cable (Type MC).

22. AC cable is not permitted to be installed _____.

(a) in damp or wet locations
(b) where subject to physical damage
(c) where exposed to corrosive conditions
(d) all of these

Figure 22 AC Cable Limitations 330.10

AC cable is not permitted in damp or wet locations, where subject to physical damage, or where exposed to corrosive conditions.

23. Exposed runs of AC cable shall be permitted to be installed on the underside of joists where _____ at each joist.

(a) supported
(b) strapped
(c) sustained
(d) braced

Figure 23 AC Cable on Underside of Joists 330.30

AC cable supportted at each joist.

24. _____ covers the use, installation, and construction specifications of metal-clad cable, Type MC.

(a) Article 300
(b) Article 310
(c) Article 320
(d) Article 330

Figure 24 Metal-Clad Cable (MC) Article 320

Article 320 specifies metal-clad cable (Type MC).

25. MC cable is not permitted to be installed _____.

(a) where subject to physical damage
(b) directly buried in the earth or embedded in concrete unless identified for direct burial
(c) exposed to cinder fills, strong chlorides, caustic alkalis, or vapors of chlorine or hydrochloric acids
(d) all of these

Figure 25 MC Cable Limitations 330.12

MC cable not permitted where subject to physical damage, directly buried or embedded in concrete (unless for direct burial), or exposed to cinder fills, strong chlorides, caustic alkalis, or vapors of chlorine or hydrochloric acids.

26. NM cable used for exposed work shall be protected from physical damage by _____.

(a) electrical metallic tubing
(b) Schedule 80 PVC
(c) rigid metal conduit
(d) any of these

Figure 26 Protecting NM Cable 334.15

NM cable protected by rigid metal conduit.

27. Where NM cable is run at angles with joists in unfinished basements and crawl spaces, it is permissible to secure cables not smaller than _____ conductors directly to the lower edges of the joist.

(a) three, 6 AWG
(b) four, 8 AWG
(c) four, 10 AWG
(d) two 6 AWG or three 8 AWG

Figure 27 NM Cable at Joist Angles 334.30

NM cable secured to the lower edge of the joist where run at angles.

28. TC cable, cable ties, cable cleats, staples, straps, hangers, and fittings used to connect TC cable to boxes, cabinets, or equipment shall be _____.

(a) marked
(b) approved
(c) listed and identified
(d) labeled

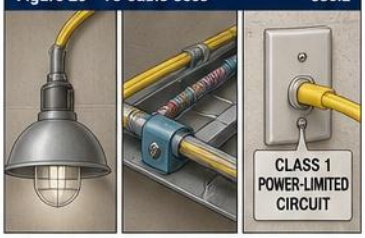
Figure 28 TC Cable Fittings 336.10

Fittings used with TC cable shall be listed and identified.

29. TC cable is permitted to be used _____.

(a) for power, lighting, control, and signal circuits
(b) in cable trays including those with mechanically discontinuous segments up to 1 ft
(c) for Class 1 power-limited circuits in accordance with Article 724
(d) all of these

Figure 29 TC Cable Uses 336.2



TC cable permitted for power, lighting, control, and signal circuits; in cable trays (discontinuous segments up to 1 ft); and for Class 1 power-limited circuits per Article 724.

30. TC cable shall be permitted for use in hazardous (classified) locations where specifically _____ by other articles in this Code.

Figure 30 | Type TC Cable in Hazardous Locations NEC 330.10

(a) required
(b) permitted
(c) approved
(d) identified

31. For flat SE cables, the _____ diameter dimension of the cable shall be used to determine the bending radius when bending on the flat side of the SE cable.

Figure 31 | Flat SE Cable—Bending Radius NEC 336.24

(a) minor
(b) major
(c) interior
(d) exterior

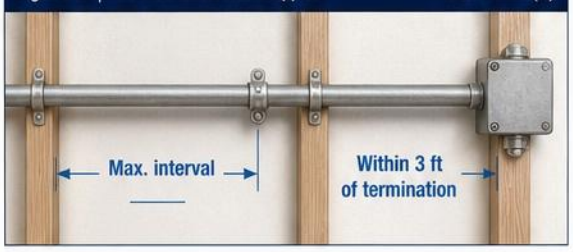
32. Intermediate metal conduit larger than _____ shall not be used.

Figure 32 | IMC Trade Size Limitation NEC 342.3

(a) trade size 4
(b) trade size 6
(c) trade size 8
(d) trade size 10

33. Horizontal runs of intermediate metal conduit supported by openings through framing members at intervals not exceeding _____ and securely fastened within 3 ft of terminations shall be permitted.

Figure 33 | IMC Horizontal Run Support NEC 342.30(A)



(a) 5 ft
(b) 8 ft
(c) 10 ft
(d) 15 ft

34. Running threads shall not be used on intermediate metal conduit for connection at _____.

Figure 34 | Prohibited Running Threads NEC 342.13

(a) couplings
(b) terminal adapters
(c) enclosures
(d) threadless connectors

35. All rigid metal conduit support fittings, bolts, straps, screws, and so forth, in wet locations shall be constructed of _____ or protected by corrosion-resistant coatings.

Figure 35 | Corrosion Protection in Wet Locations NEC 344.50

(a) weatherproof materials
(b) stainless steel
(c) aluminum
(d) corrosion-resistant materials

36. Where structural members do not readily permit fastening within 3 ft, rigid metal conduit may be fastened within _____ of each conduit termination.

Figure 36 | Conduit Fastening When 3 ft Not Readily Possible NEC 344.30

(a) 3 ft
(b) 4 ft
(c) 5 ft
(d) 8 ft

37. If buried in masonry or concrete, rigid metal conduit fittings shall be the _____ type.

Figure 37 | Rigid Metal Conduit Fittings in Concrete NEC 344.60

(a) raintight
(b) wet and damp location
(c) nonabsorbent
(d) concrete-tight

42. The ampacity adjustment factors in 310.15(C)(1) shall be applied to a metal wireway only where the number of current-carrying conductors exceeds _____ in any cross section of the wireway.

(a) 30
(b) 40
(c) 50
(d) 60

Figure 42 — 310.15(C)(1)

Adjustment factors apply only when the number of current-carrying conductors exceeds the specified limit in the wireway cross section.

43. Where conductors are deflected within a metal wireway, the wireway shall be sized to meet the bending requirements corresponding to _____ per terminal in Table 312.9(A).

(a) one wire
(b) two wires
(c) three wires
(d) four wires

Figure 43 — 312.9(A)

Size the wireway for the bending requirement corresponding to the specified number of wires per terminal.

44. A multioutlet assembly is permitted to be installed in _____ locations.

(a) dry
(b) damp
(c) damp and wet
(d) dry and damp

Figure 44 — 406.5(A)

Multioutlet assemblies are allowed in dry and damp locations.

45. Metal multioutlet assemblies can extend through (not run within) dry partitions if arrangements are made for removing the cap or cover on all _____ portions and no outlet is located within the partitions.

(a) exposed
(b) concealed
(c) uninsulated
(d) none of these

Figure 45 — 406.5(B)

Assemblies may pass through dry partitions when covers on all exposed parts can be removed and no outlets are within the partition.

46. No conductor larger than that for which the raceway is _____ shall be installed in a surface metal raceway.

(a) designed
(b) identified
(c) listed
(d) approved

Figure 46 — 358.36(A)

Install only conductors up to the size for which the raceway is designed.

47. The ampacity adjustment factors of 310.15(C)(1) shall not apply to conductors installed in surface metal raceways where the _____.

(a) cross-sectional area exceeds 4 sq in.
(b) current-carrying conductors do not exceed 30 in number
(c) total cross-sectional area of all conductors does not exceed 20 percent of the interior cross-sectional area of the raceway
(d) all of these

Figure 47 — 310.15(C)(1)

All listed conditions must be met for adjustment factors not to apply.

48. Cable tray systems, including ladder, ventilated trough, ventilated channel, solid bottom, and similar structures are covered within _____.

(a) Article 358
(b) Article 362
(c) Article 366
(d) Article 392

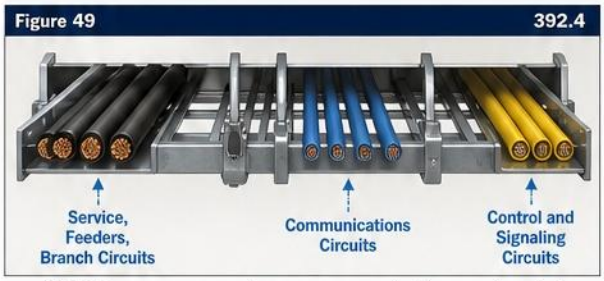
Figure 48 — Article 392

Cable tray systems are addressed in Article 392.

49. Cable trays are permitted to be used as a support system for _____.

(a) service conductors, feeders, and branch circuits
(b) communications circuits
(c) control and signaling circuits
(d) all of these

Figure 49 — 392.4



Cable trays may support power, communications, and control or signaling conductors.

50. In industrial facilities where conditions of maintenance and supervision ensure that only qualified persons will service the installation, cable tray systems can be used to support _____.

(a) raceways
(b) cables
(c) boxes and conduit bodies
(d) all of these

Figure 50 — 392.6

Under qualified supervision and maintenance, trays may support raceways, cables, and boxes or conduit bodies.

Article 702
Optional Standby Systems

Article 702 covers the installation requirements for optional standby systems.

702.1 General. Optional standby systems shall comply with one of the following:

(1) An optional standby system shall comply with Article 690.

(2) An optional standby system shall comply with Article 702.

702.2 Optional Standby Systems in Other Than One- and Two-Family Dwellings. Optional standby systems in other than one- and two-family dwellings shall comply with 702.2(A) through (E), inclusive.

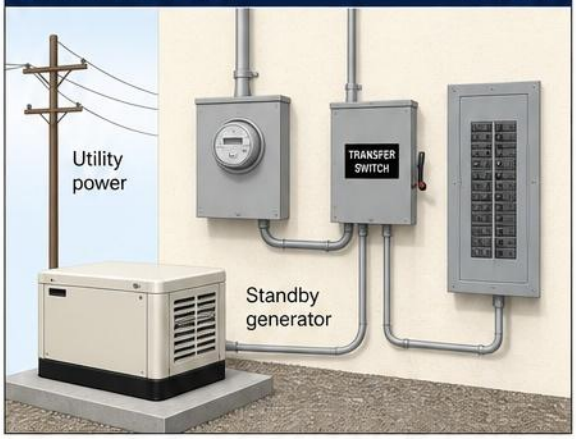
702.2(A) Transfer Equipment. A transfer switching equipment shall be used to prevent feedback to the normal power source. See Figure 1.

702.2(B) Wiring. The wiring for optional standby systems shall be permitted to be installed in accordance with 702.2(B)(1) or 702.2(B)(2).

(1) Alternate Source Conductors. The conductors of the optional standby system shall be permitted to be installed in accordance with Article 700.

(2) Existing Wiring. Existing wiring shall be permitted to be used in accordance with 702.2(B)(2)(a) through (c).

Figure 1 Transfer Equipment Prevents Feedback to the Utility **702.2(A)**



The transfer switch isolates the building from the utility system when the standby generator is in use to prevent feedback to the normal power source.

702.2(B)(2)(a) Existing Wiring to Be Used. Existing wiring shall be permitted to be used for optional standby systems where the wiring complies with all of the following.

(1) The wiring is suitable for operation at the voltage provided by the alternate source.

(2) The wiring is suitable for the load connected.

(3) The wiring type and its installation methods meet the requirements of this Code.

(4) The wiring is inspected and approved.

702.2(B)(2)(b) Longer Than 30 m (100 ft). Existing wiring longer than 30 m (100 ft) shall be permitted to be used for optional standby systems where the voltage drop does not exceed 5% at the farthest outlet, utilization equipment, or other point of use.

702.2(B)(2)(c) Figured in Volt-Amperes. The rating of existing wiring shall be permitted to be figured in volt-amperes.

Figure 2 Existing Wiring Longer Than 30 m (100 ft) — Voltage Drop Limited to 5% **702.2(B)(2)(b)**

Existing wiring longer than 30 m (100 ft) may be used for optional standby systems where the voltage drop does not exceed 5% at the farthest outlet, utilization equipment, or other point of use.

CHAPTER 4

EQUIPMENT FOR GENERAL USE

Introduction to Chapter 4—Equipment for General Use

Chapter 4 of the NEC covers equipment commonly used in a wide range of electrical installations. The articles included in this chapter establish requirements for cords, switches, wiring devices, panelboards, lighting, appliances, heating equipment, motor circuits, air-conditioning equipment, and generators. Each article addresses specific applications, installation conditions, and protection requirements to help ensure safe and reliable electrical systems.

Article 400—Flexible Cords

This article sets forth the general requirements, uses, and construction criteria for flexible cords that have two or more insulated conductors within a flexible outer covering.

Article 406—Wiring Devices

This article contains the requirements for wiring devices such as attachment plugs, receptacles, general-use snap switches, pendant switches, surface switches, dimmers, electronic control switches, and lighting control switches.

Article 410—Luminaires

This article includes the rules for luminaires—equipment used to illuminate spaces or objects—and also supports visual tasks, activities, aesthetics, or security.

Article 422—Appliances

This article contains the requirements for electric appliances such as clothes washing, air-conditioning, food mixing, deep frying, and vending machines.

Article 430—Motor Circuits, Controllers, and Adjustable-Speed Drives

This article contains the specific rules for conductor sizing, overcurrent protection, control circuit conductors, controllers, and disconnects for electric motors, controllers, and adjustable-speed drives.

Article 445—Generators

This article contains the requirements for generators, which are machines that convert mechanical energy by means of a prime mover into

Article 404—Switches

This article applies to general-use switches, including motor-circuit switches, isolating switches, pullout switches, circuit breakers used as switches, and molded-case switches.

Article 408—Switchboards and Panelboards

This article covers the requirements for switchboards and panelboards. Switchboards are large single panel, frame, or assembly of panels that contain switches, overcurrent, and other protective devices, buses, and instruments. Panelboards are assemblies with buses and overcurrent protective devices intended for installation in a cabinet or enclosure.

Article 411—Low-Voltage Lighting

This article covers lighting systems that operate at no more than 30Vac or 60Vdc.

Article 424—Fixed Electric Space-Heating Equipment

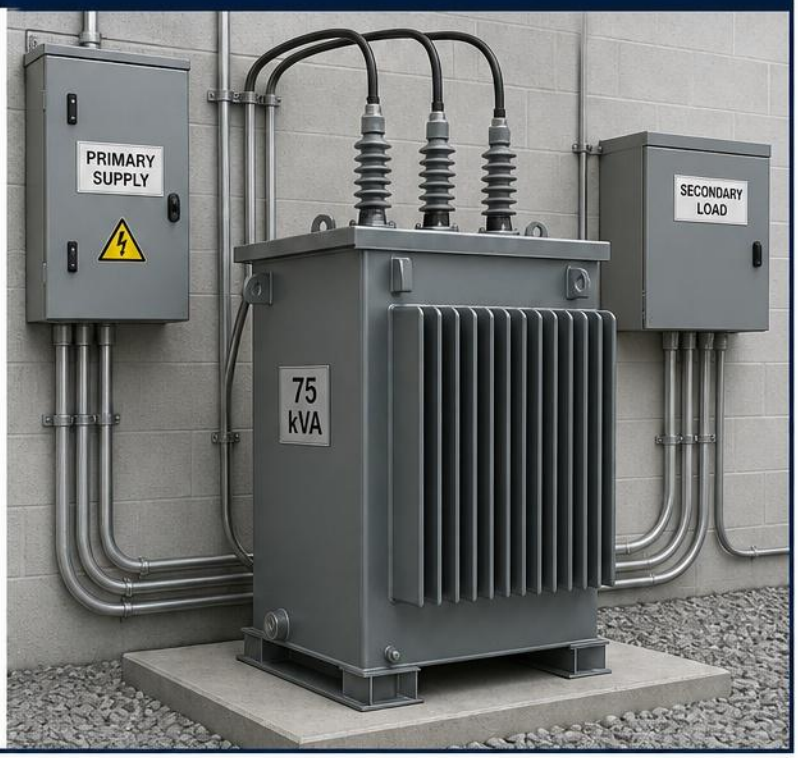
This article covers fixed electric equipment used for space heating (such as heating cables, unit heaters, boilers, central heating systems) and other fixed electric space-heating equipment.

Article 440—Air-Conditioning and Refrigeration Equipment

This article applies to air-conditioning and refrigeration equipment with a hermetic compressor and motor that are enclosed in the same housing and immersed in refrigerant.

ARTICLE 450—TRANSFORMERS

This article sets out the requirements for transformers—equipment that uses electromagnetic induction to convert current and voltage in a primary circuit into current and voltage in a secondary circuit.



ARTICLE 480—STORAGE BATTERIES

This article establishes the requirements for stationary batteries (greater than 1 kWh) that spend the majority of the time on continuous float charge, or in a high state of charge, in readiness for a discharge event.

ARTICLE

400 Flexible Cords

Introduction to Article 400—Flexible Cords

Article 400 covers the general requirements, permitted uses, and construction specifications for *flexible cords* as contained in Table 400.4. Flexible cords are not considered a Chapter 3 wiring method because they are not intended for permanent wiring of a building or structure. Instead, they're used for the connection of portable equipment, appliances, or luminaires where flexibility is necessary.

Cord, Flexible Cord. Two or more insulated conductors enclosed in a flexible covering. ▶ Figure 400–1

Figure 400–1 **Definition**

Two or more flexible insulated conductors enclosed in a flexible covering.

400.1 Scope

This article contains the general requirements and applications for flexible cords as contained in Table 400.4. ▶ Figure 400–2

Figure 400–2 **Scope**

Article 400 contains the general requirements and applications for flexible cords as contained in Table 400.4.

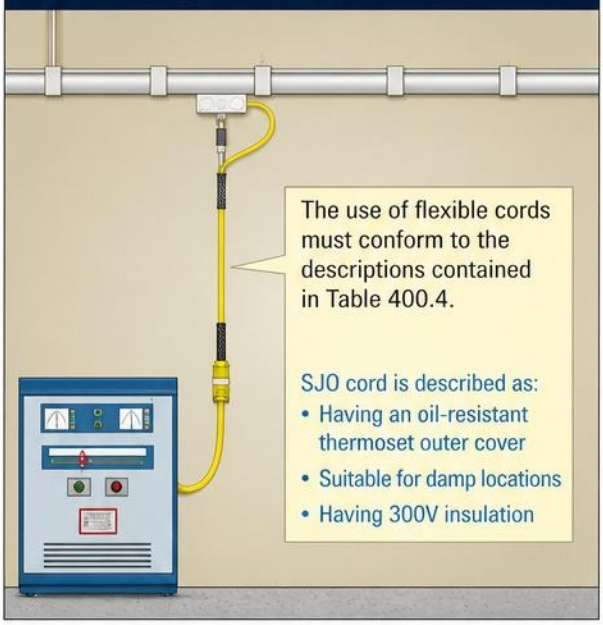
400.4 Flexible Cords Types

The use of flexible cords must conform to the descriptions in Table 400.4. ▶ Figure 400–3

Author's Comment:

- The suffix "W" at the end of a flexible cord type designates that it is sunlight resistant and suitable for wet locations [Table 400.4, Note 9].

Figure 400–3 Types of Flexible Cords 400.4



Flexible cords must comply with the descriptions provided in Table 400.4.

400.5 FLEXIBLE CORD AMPACITY

(A) Ampacity Tables. Table 400.5(A)(1) lists the ampacities for manufactured flexible cords.

400.7 SUITABILITY

Flexible cords and their associated fittings must be suitable for the use and location.

Figure 400–4 Flexible Cords Suitability 400.7

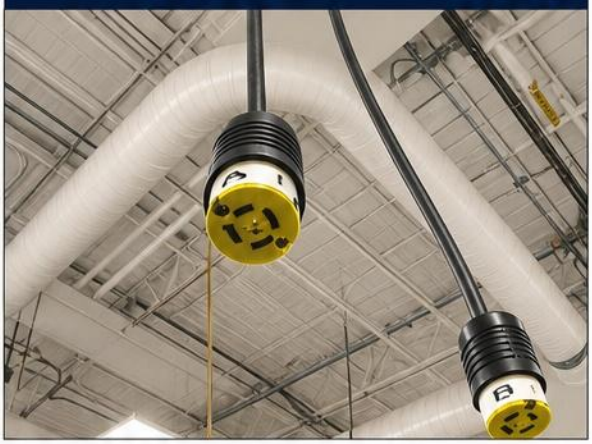
Flexible cords and their associated fittings must be suitable for the use and location.

400.10 USES PERMITTED

(A) Uses Permitted. Flexible cords are permitted for the following:

(1) Pendant boxes [314.23(H)(1)], pendant luminaires and pendant receptacles [210.50(A)]

Figure 400–5 Flexible Cords, Use Permitted—Pendant Receptacles 400.10(A)(1)



Flexible cords are permitted to be used for pendant receptacles.

(2) Wiring of luminaires [410.24(A) and 410.62(B)]

(3) Connection of portable luminaires, portable signs, or portable appliances

Figure 400–6 Flexible Cords, Uses Permitted—Portable Equipment 400.10(A)(3)

Flexible cords are permitted to connect portable luminaires, portable signs, or portable appliances.

(4) Elevator cables

(5) Wiring of cranes and hoists

(6) Connection of utilization equipment to facilitate frequent inter-change [422.16]

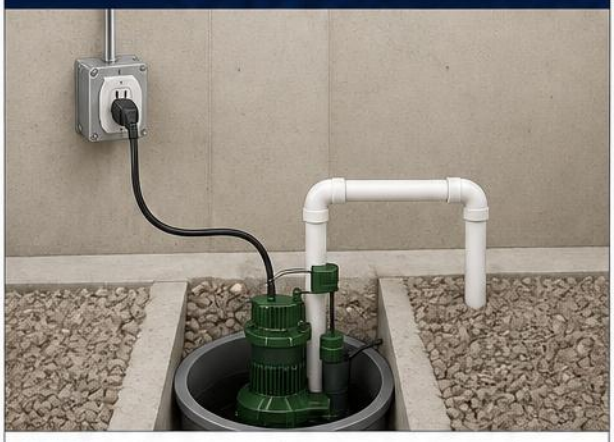
Figure 400–7 Flexible Cords, Uses Permitted—Utilization Equipment 400.10(A)(6)

Flexible cords may be used to connect utilization equipment to facilitate frequent interchange.

(7) Prevention of the transmission of noise or vibration [422.16]

(8) Connection of appliances if the appliance is identified for flexible cord connections [422.16], utilization equipment to facilitate its frequent interchange [400.10(A)(6) and 422.16], and appliances specifically designed to permit ready removal for maintenance and repair and identified for flexible cord connection [400.10(A)(8) and 422.16].

Figure 400–8 Flexible Cords, Uses Permitted—Identified for Appliances 400.10(A)(8)



Flexible cords are permitted to connect appliances if the appliance is identified for flexible cord connections.

AUTHOR'S COMMENT

▶ Household storage-type water heaters over 5 gallons or rated over 120V cannot be cord-and-plug-connected. See *UL 174, Section 11.*

(9) Connection of moving parts

Figure 400–9 Flexible Cords, Uses Permitted—Identified for Appliances 400.10(A)(8)

Flexible cords are permitted to connect appliances if the appliance is identified for flexible cord connections.

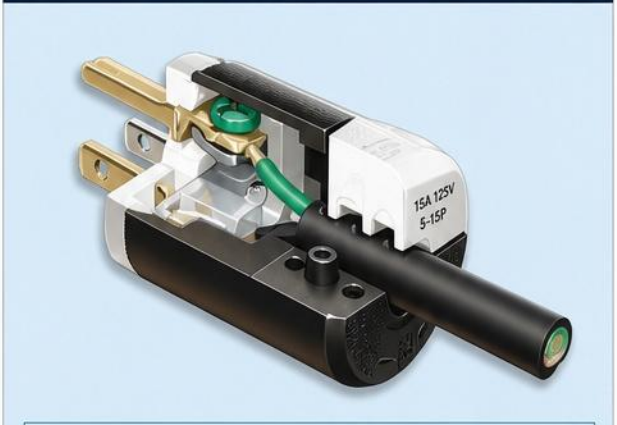
(B) Attachment Plugs. Attachment plugs are required for flexible cords used on portable luminaires, portable/mobile signs, or appliances [400.10(A)(3) and 422.16], utilization equipment to facilitate its frequent interchange [400.10(A)(6) and 422.16], and appliances specifically designed to permit ready removal for maintenance and repair and identified for flexible cord connection [400.10(A)(8) and 422.16]. **Figure 400–10**

Figure 400–10 Flexible Cords—Attachment Plugs 400.10(B)

Flexible cords must have an attachment plug for:
- Portable luminaires or appliances
- Equipment to facilitate its frequent interchange
- Appliances identified for flexible cord usage

Attachment Plug. A wiring device at the end of a flexible cord inserted into a receptacle to make an electrical connection. **Figure 400–11**

Figure 400–11 Attachment Plug *Article 100 Definition*



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

400.12 Uses Not Permitted

Unless specifically permitted in 400.10, flexible cords, *cord sets* (extension cords), and *power-supply cords* are not permitted for the following:

(1) Substitute for fixed wiring

Figure 400–12 Cord Set, Uses Not Permitted 400.12(1)

(2) Run through holes in walls, ceilings, or floors

(3) Run through doors, windows, or similar openings

(4) Attached to building surfaces

Ex to (4): Flexible cords used for temporary wiring [590.4] may be attached to building surfaces.

Figure 400–13 Power-Supply Cords, Uses Not Permitted 400.12(2)

(5) Concealed by walls, floors, or ceilings, or above suspended or dropped ceilings ▸ **Figure 400–14**

Figure 400–14 Power-Supply Cords, Uses Not Permitted Concealed by Walls, Floors, or Ceilings 400.12(5)

(6) Installed in raceways, except as permitted by 400.17

(7) Where they are subject to physical damage as determined by the AHJ

Cord Set. A flexible cord having an attachment plug at one end and a cord connector at the other end. ▸ **Figure 400–15**

Power-Supply Cord. A flexible cord with an attachment plug connected to utilization equipment. ▸ **Figure 400–16**

Figure 400–15 Cord Set—*Article 100 Definition*

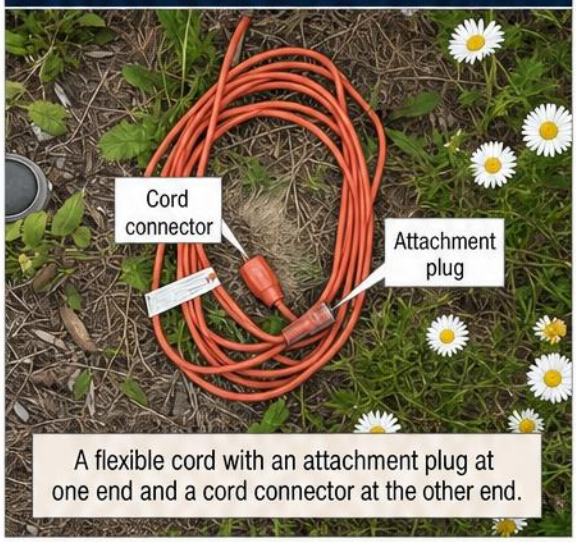


Figure 400–16 Power-Supply Cord—*Article 100 Definition*

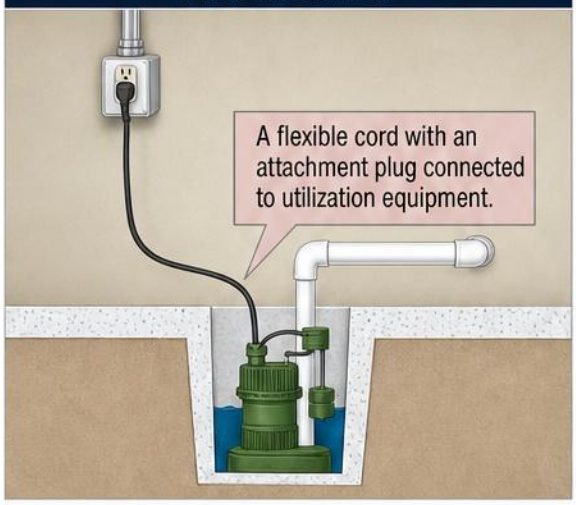
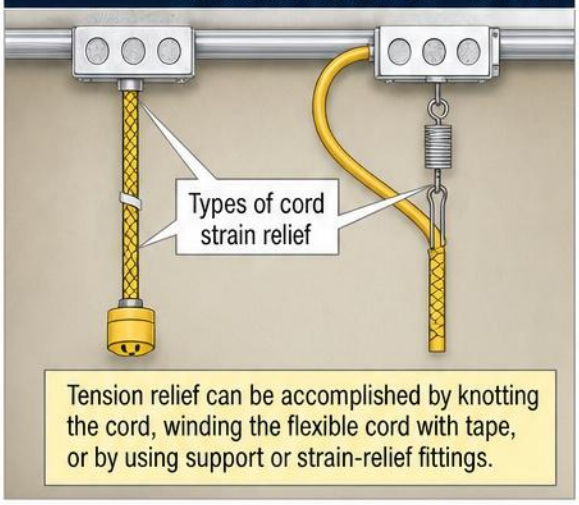


Figure 400–17 Flexible Cords—Pull at Joints and Terminals *400.14*

Figure 400–18 Flexible Cords and Flexible Cables—Pull at Joints and Terminals *400.14 Note*



400.13 Splices

Flexible cords must be installed without splices or taps.

400.14 Pull at Joints and Terminals

Flexible cords must be connected to devices and fittings so tension is not transmitted to joints or terminals. **Figure 400–17**

Note: Tension relief can be accomplished by knotting the cord, winding it with tape, or using support or strain-relief fittings. **Figure 400–18**

400.17 Protection from Damage

Flexible cords must be protected by bushings or fittings where passing through holes in covers, outlet boxes, or similar enclosures.

Notes

The 2026 *National Electrical Code* (NEC) continues to emphasize electrical safety through updated requirements that address modern installations, emerging technologies, and lessons learned from field experience. Understanding the intent behind these rules helps electricians apply them correctly and make informed decisions in the field.

This section provides explanatory notes and practical guidance for select code changes and key technical requirements. The goal is to clarify application, highlight common issues, and support compliance with the NEC.

Reading the Notes

Each note is organized around a specific code topic or change. The notes:

- Paraphrase the rule in everyday language.
- Explain the reasoning and intent.
- Offer field examples or applications.
- Highlight related requirements or limitations.

Always consult the NEC for complete requirements and exceptions.

Key Updates in the 2026 NEC

The 2026 NEC includes revisions that reflect evolving technology, improved safety practices, and harmonization with related standards. Key areas of focus include:

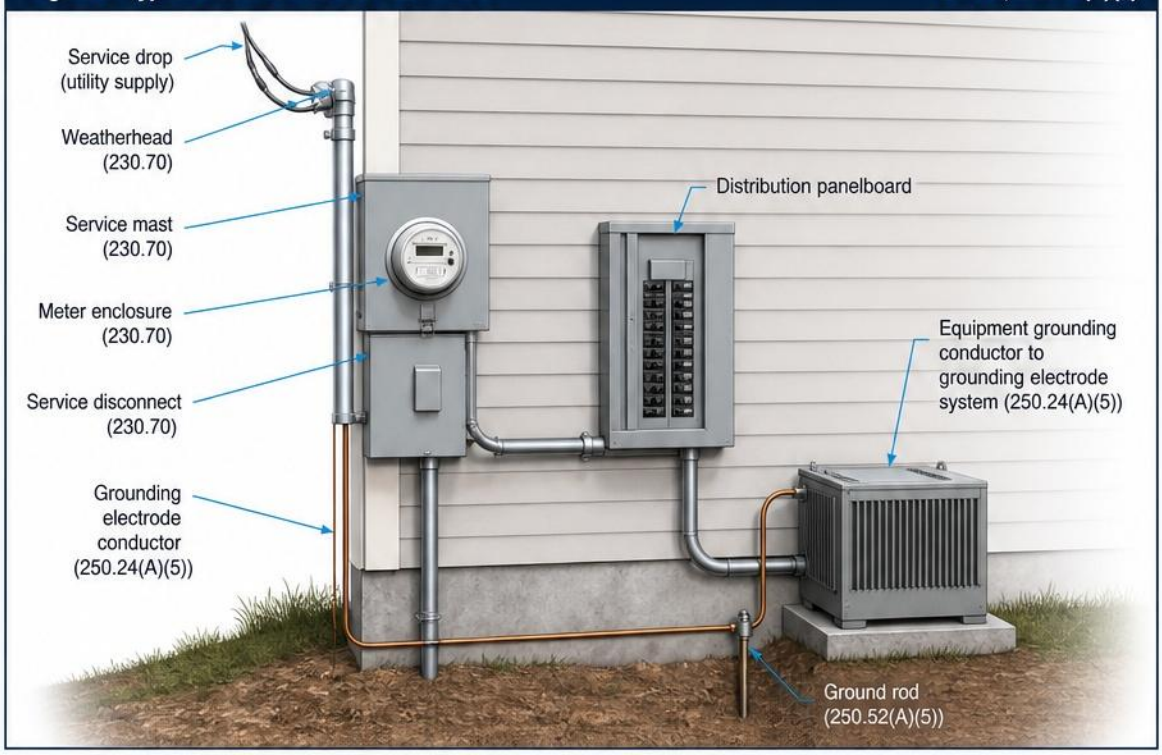
- Electrical vehicle (EV) infrastructure
- Energy management systems
- Surge protection
- Arc-fault and ground-fault protection
- Updated wiring methods and installation requirements
- Clarifications to definitions and general requirements

Application and Enforcement

Electrical installations must comply with the rules in effect at the time of installation. Local amendments may apply.

When questions arise, the AHJ (Authority Having Jurisdiction) has the final authority on interpretation.

Figure 1 Typical Electrical Service Installation **230.70, 250.24(A)(5)**



A typical service installation includes the service drop, weatherhead, service mast, meter enclosure, service disconnect, distribution panelboard, and grounding electrode system. All components must comply with the applicable requirements in Article 230 and Article 250.

ARTICLE 404 Switches

Introduction to Article 404—Switches

This article applies to general-use switches, *motor-circuit switches*, *isolating switches*, pullout switches, circuit breakers used as switches, and molded-case switches. These switching devices are intended for control and isolation in general distribution and capable of interrupting their rated current at their rated voltage. For *Code* users familiar with previous editions of the *Code*, the common snap switches used for lighting circuits are now covered by Article 406—Wiring Devices.

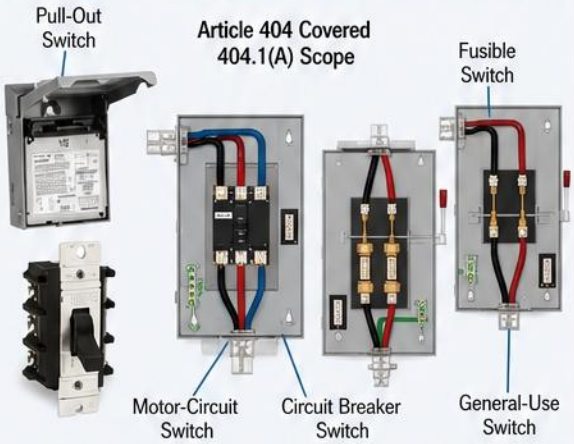
Part I. Installation

404.1 Scope

(A) Covered. This article covers general-use switches, motor-circuit switches, isolating switches, pull-out switches, molded case switches, and circuit breakers used as switches.

Figure 404-1

Figure 404-1 Article 404 Covered 404.1(A) Scope

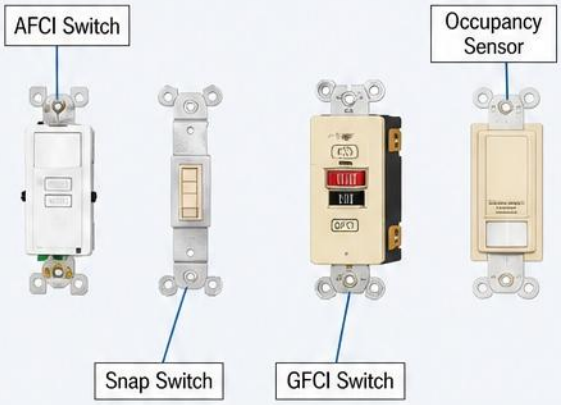


Article 404 covers general-use switches, motor-circuit switches, isolating switches, pull-out switches, molded case switches, and circuit breakers used as switches.

(B) Not Covered. This article does not cover:

(2) Wiring devices Figure 404-2

Figure 404-2 Article 404 Not Covered—Wiring Device 404.1(B)(2) Scope



Article 404 does not cover wiring devices.

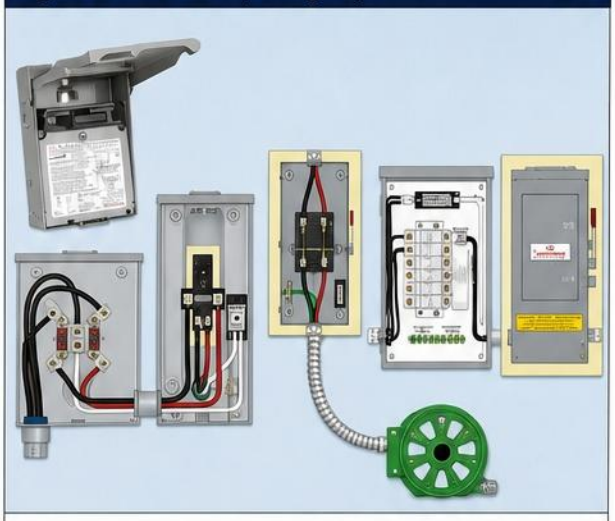
Note: See Article 406 for the requirements of general-use snap switches and other wiring devices.

404.2 Listing Requirements

General-use switches, motor-circuit switches, isolating switches, pull-out switches, molded case switches, and circuit breakers used as switches must be listed.

Figure 404-3

Figure 404–3 Switches, Listing Requirements 404.2



General-purpose switches, motor-circuit switches, isolating-switches, pull-out switches, molded case switches, and circuit breakers used as switches must be listed.

Figure 404–4 Switches, Damp or Wet Locations, Surface-Mounted 404.6(A)

A surface-mounted switch or circuit breaker in a damp or wet location must be installed in a weatherproof enclosure.

404.5 Switch and Circuit Breaker Enclosures

(B) Used as a Raceway, Taps, or Splices. Switch and circuit breaker enclosures cannot be used as junction boxes and raceways for conductors feeding through or tapping—unless the enclosure complies with the following:

Splices and Taps. Switch and circuit-breaker enclosures can contain splices and taps if the cross-sectional area of all conductors, splices and taps do not fill more than 75 percent of any cross section of the wiring space in accordance with 312.11.

Used as Raceway. Switch and circuit-breaker enclosures can have feed-through conductors if the cross-sectional area of all conductors does not fill more than 40 percent of any cross section of the wiring space in accordance with 312.11.

404.6 Damp or Wet Locations

(A) Surface-Mounted Switches or Circuit Breakers. Surface-mounted switches or circuit breakers in *damp locations* or *wet* locations must be installed in a *weatherproof* enclosure.

Location, Damp Location. Locations protected from weather and not subject to saturation with water or other liquids, but subject to moderate degrees of moisture.

Figure 404–5 Damp Location *Article 100 Definition*

Location, Wet Location. A location that is one of the following:

(1) Unprotected and exposed to weather

(2) Subject to saturation with water or other liquids

(3) Underground

(4) Concrete slabs or masonry in direct contact with the earth

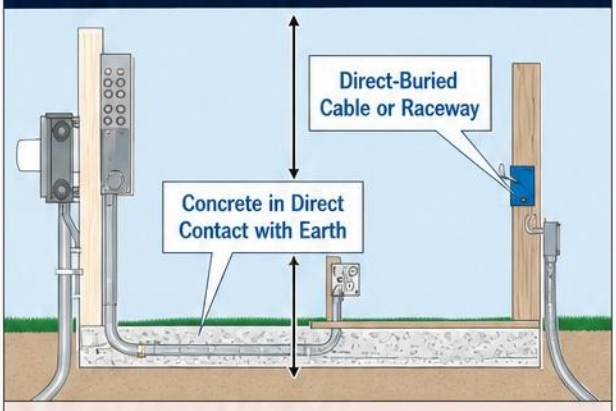
▶ Figure 404–6 ▶ Figure 404–7

Weatherproof. Constructed or protected so exposure to the weather will not interfere with successful operation.

Figure 404–6 Wet Location Article 100 Definition

A location that is one of the following:
(1) Unprotected and exposed to weather
(2) Subject to saturation with water or other liquids
(3) Underground
(4) In concrete slabs or masonry in direct contact with the earth

Figure 404–7 Wet Location Article 100 Definition



A location that is one of the following:
(1) Unprotected and exposed to weather
(2) Subject to saturation with water or other liquids
(3) Underground
(4) In concrete slabs or masonry in direct contact with the earth

Author's Comment:

- According to Table 110.28, Note 1, any NEMA Type 3 enclosure is identified as rainproof, raintight, or watertight, therefore it's considered weatherproof and suitable for this purpose.

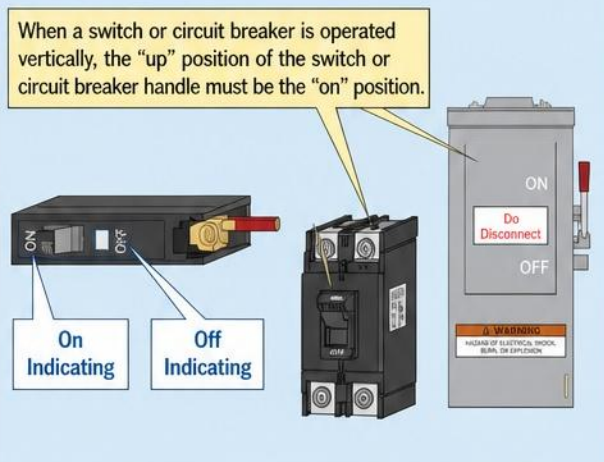
(B) Flush-Mounted Switches or Circuit Breakers. Flush-mounted switches or circuit breakers in damp or wet locations must have a weatherproof cover.

404.9 Indicating

Marking. Switches must be marked to indicate if the switch is in the "on" or "off" position.

Operated Vertically. When a switch or circuit breaker is operated vertically, the "up" position of the switch or circuit breaker handle must be the "on" position. ▸ 404.8

Figure 404–8 Switches, Indicating 404.9



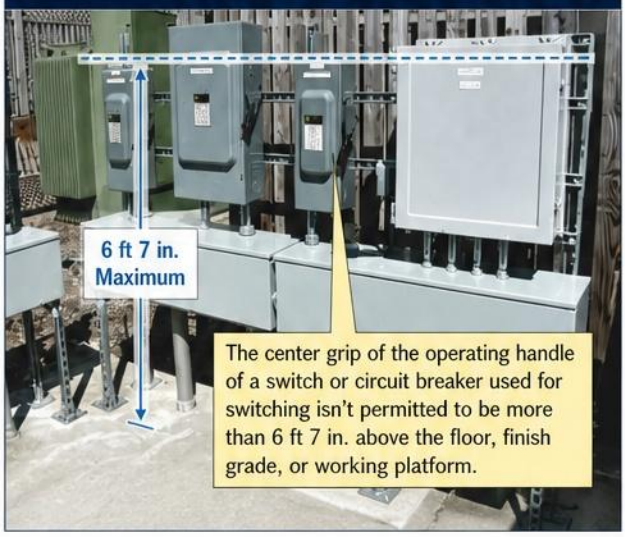
404.10 Accessibility and Grouping

(A) Location.

(1) Readily Accessible. Switches and circuit breakers used for switching must be capable of being operated from a readily accessible location.

(2) Maximum Height. The center of the grip of the operating handle of a switch or circuit breaker used for switching when in its highest position is not permitted to be more than 6 ft 7 in. above the floor, finish grade, or working platform except as follows: ▸ 404.9

Figure 404–9 Switches and Circuit Breakers Used as Switches Maximum Height Above Floor, Grade, or Platform 404.10(A)(2)



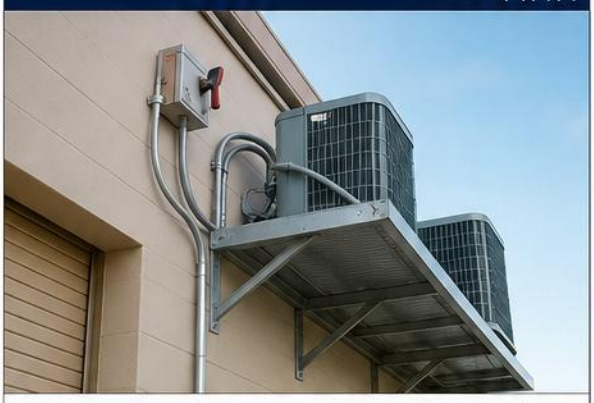
(1) Switches or circuit breakers used for switching on busways are allowed to be installed at the same elevation as the busway, provided there is a suitable means supplied to operate the switch from floor level. ▶Figure 404–10

Figure 404–10 Switches and Circuit Breakers Used as Switches 404.10(A)(2)(1)

Switches or circuit breakers used for switching on busways are allowed to be installed at the same elevation as the busway, provided there is a suitable means supplied to operate the switch from floor level.

(2) Switches and circuit breakers used for switching are allowed to be located higher than 6 ft 7 in. above the floor, finish grade, or working platform if placed next to motors, appliances, or equipment they supply. ▶Figure 404–11

Figure 404–11 Switches and Circuit Breakers Used as Switches 404.10(A)(2)(2)



Switches and circuit breakers used for switching are allowed to be located higher than 6 ft 7 in. above the floor, finish grade, or working platform if placed next to motors, appliances, or equipment they supply.

404.12 Bonding of Enclosures

Metal enclosures for switches and circuit breakers must be connected to an equipment grounding conductor of a type recognized in 250.118(A). ▶Figure 404–12 and ▶Figure 404–13

Figure 404–12 Switches, Bonding of Metal Enclosures 404.12

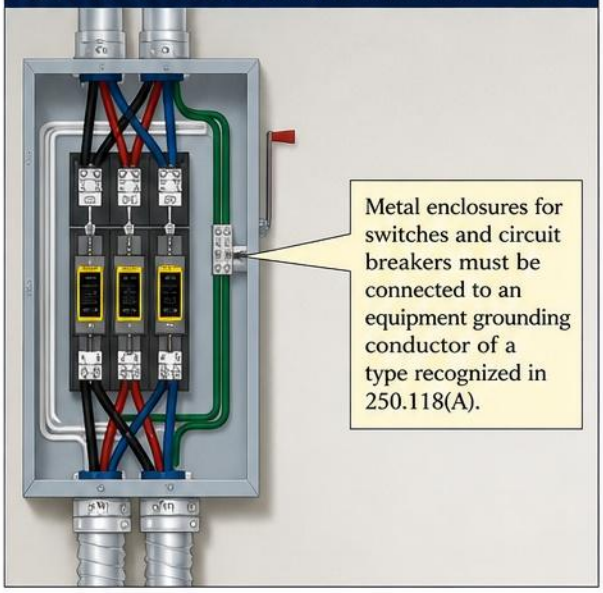
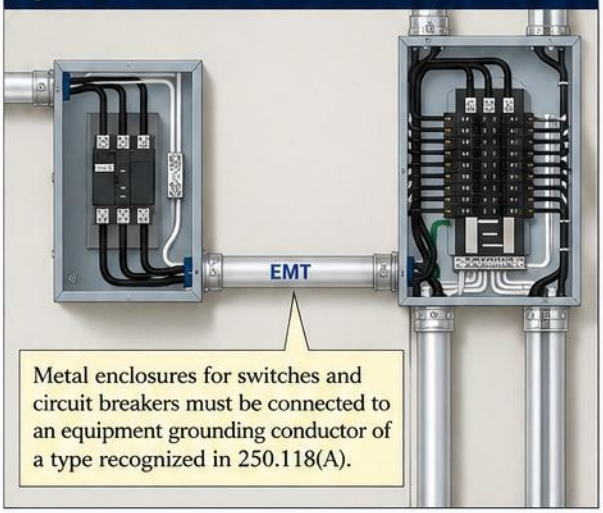


Figure 404–13 Switches, Bonding of Metal Enclosures 404.12



Nonmetallic enclosures for switches and circuit breakers must be installed with a wiring method that provides or includes an equipment grounding conductor. ▶Figure 404–14

Part II. Construction Specifications

404.20 Switch Marking

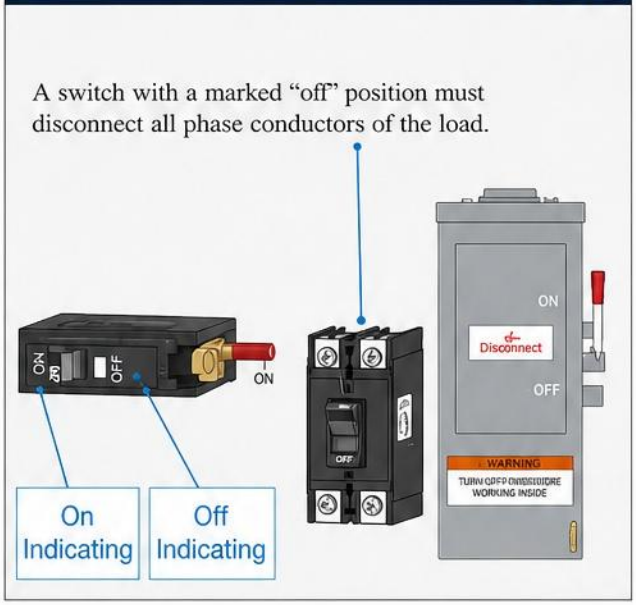
(A) Markings. Switches must be marked with the current, voltage, and, if horsepower rated, the maximum rating for which they are designed.

(B) Off Indication. If in the "off" position, a switching device with a marked "off" position must completely disconnect all phase conductors of the load it controls. ▶Figure 404–15

Figure 404–14 Switches, Bonding of Nonmetallic Enclosures 404.12

Nonmetallic enclosures for switches and circuit breakers must be installed with a wiring method that provides or includes an equipment grounding conductor.

Figure 404–15 Switch, Off Indication 404.20(B)



Article 340—Overcurrent Protection

Article 340 covers general requirements for overcurrent protection and includes specific rules for various types of equipment.

340.1 Scope

This article covers overcurrent protection of conductors and equipment.

340.2 General

340.2(A) Application

Each conductor shall have overcurrent protection in accordance with 240.4, 240.6, and 240.7.

340.2(B) Rating or Setting

Overcurrent devices shall have a rating or setting not higher than the ampacity of the conductors supplied, except as permitted in 240.4(B) and 240.4(D).

340.2(C) Short-Circuit Current Rating

Each overcurrent device shall have a short-circuit current rating not less than the available fault current.

340.2(D) Exposed Live Parts

Overcurrent devices shall be arranged so that their exposed live parts are inaccessible unless the overcurrent device can be removed without exposing the live parts.

340.3 Types of Overcurrent Devices

340.3(A) General

Overcurrent protection shall be by fuses or inverse time circuit breakers except as permitted in 240.7.

340.3(B) Meters

Overcurrent protection for conductors on the load side of watt-hour meters and their socket assemblies shall not be required.

340.3(C) Control Circuits

Overcurrent protection shall not be required for control circuits or for alarm systems and signaling circuits.

340.3(D) Motor Branch Circuits

Overcurrent protection for motor branch-circuit conductors shall be permitted to be omitted in accordance with 430.32.

340.3(E) Transformer Secondary Conductors

Overcurrent protection shall be permitted to be omitted from secondary conductors of a transformer in accordance with 450.3(B).

340.3(F) Other Systems

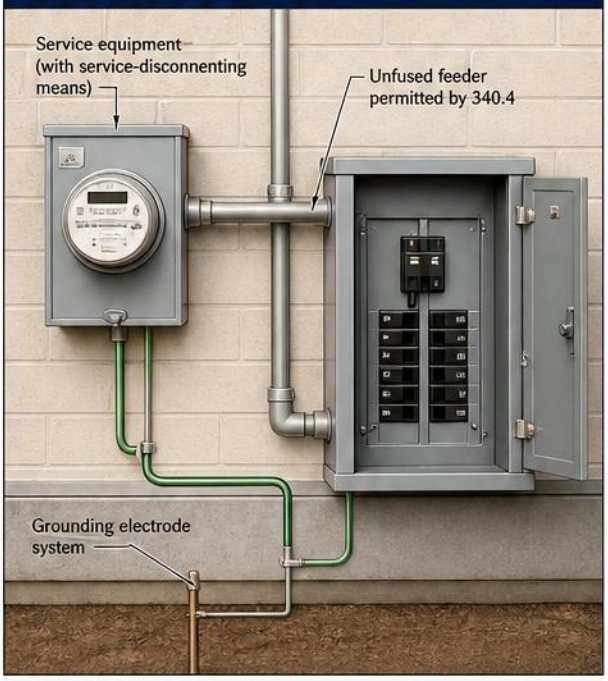
Overcurrent protection shall be permitted to be omitted from systems in accordance with 480.3.

340.4 Unfused Conductors

Conductors shall be permitted to be run from a system without overcurrent protection where such conductors are installed in accordance with Parts II and III of Article 300.

Conductors shall be permitted to be run from an obelectrical equipment without overcurrent protection where the conductors are installed within the equipment in accordance with Parts IV, V, VI, and VII of Article 300.

Figure 340–1 Unfused Feeder from Service-Disconnecting Means 340.4



A feeder can be run from service equipment without additional overcurrent protection when installed in accordance with Parts II and III of Article 300.

Notes

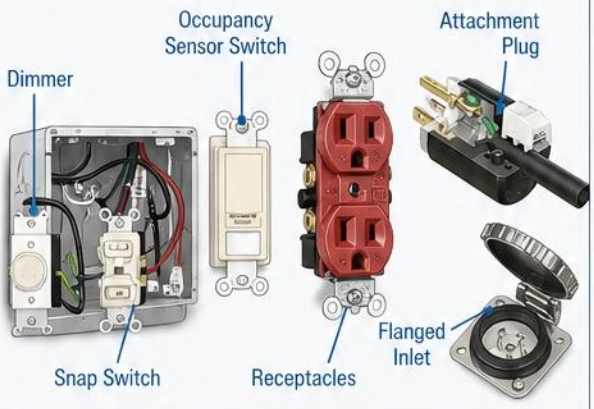
ARTICLE 406 Wiring Devices

Introduction to Article 406—Wiring Devices

This article sets forth the requirements for the rating, type, and installation of *wiring devices*. Typical wiring devices include attachment plugs, receptacles, general-use snap switches, pendant switches, surface switches, dimmers, electronic control switches, and lighting control switches.

Wiring Device. An electrical device with a yoke or used with flexible cord or cable that serves as either a connection point to facilitate the flow of current, or as a control device in general distribution and branch circuits.

Figure 406–1 **406.1 Scope**



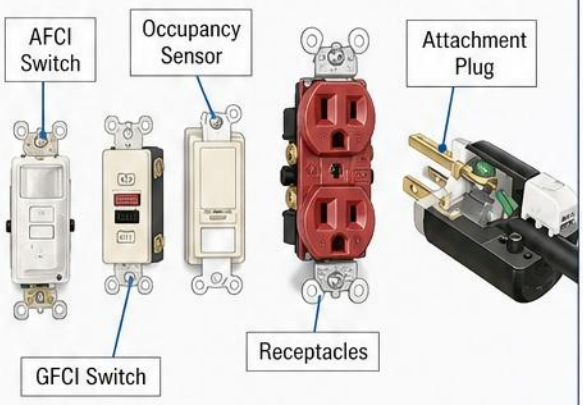
An electrical device with a yoke or used with flexible cord that serves as either a connection point to facilitate the flow of current or as a control device in general distribution and branch circuits.

Part I. General

406.1 Scope

This article sets forth the requirements for the rating, type, and installation of wiring devices.

Figure 406–2 **406.1 Scope**



This article sets forth the requirements for the rating, type, and installation of wiring devices.

406.2 Listing Requirements

Wiring devices must be listed.

406.9 Wiring Devices in Damp or Wet Locations

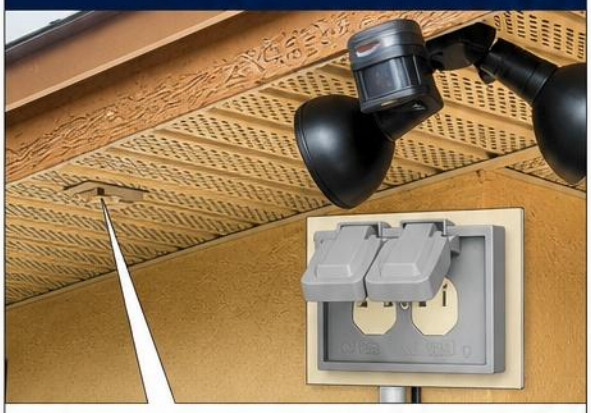
(A) Damp Locations.

(1) Receptacles.

(a) General. Installations suitable for wet locations are considered suitable for damp locations.

(b) Weatherproof Enclosure. Receptacles located outdoors and protected from exposure to the weather must be installed within an enclosure that is weatherproof when the cover is closed and with no attachment plug inserted.

Figure 406–3 | Wiring Devices, Damp Location Receptacles, Weatherproof Enclosure 406.9(A)(1)(b)



Enclosure and cover for outdoor receptacles that are shielded from the weather must be weatherproof when the cover is closed and with no attachment plug inserted.

Weatherproof. An assembly built or safeguarded so that exposure to the elements will not interfere with proper operation.

Author's Comment:

- According to Table 110.28, Note 1, any NEMA Type 3 enclosure is identified as rainproof, raintight, or watertight; therefore it's considered weatherproof and suitable for this purpose.

(c) Weather-Resistant Receptacle. Receptacles installed in a damp location must be the *weather-resistant* (WR) type.

Receptacle, Weather-Resistant Receptacle (WR). A receptacle constructed to be resistant to the adverse effects of damp, wet, or outdoor locations. ▸Figure 406–4 and ▸Figure 406–5

(d) Cover. After installation, hinged covers of outlet box hoods must be capable of opening at least 90 degrees or completely open (if the cover is not designed to open 90 degrees from the closed to open position).

(2) Switches. Switches installed in damp locations must comply with the following:

(1) Surface-mounted switches must be installed in weatherproof enclosures.

(2) Flush-mounted switches must have weatherproof covers.

Figure 406–4 | Weather-Resistant Receptacle Article 100 Definition

A receptacle constructed to be resistant to the adverse effects of damp, wet, or outdoor locations.

Figure 406–5 | Weather-Resistant Receptacle Article 100 Definition

A receptacle constructed to be resistant to the adverse effects of damp, wet, or outdoor locations.

(B) Wet Locations.

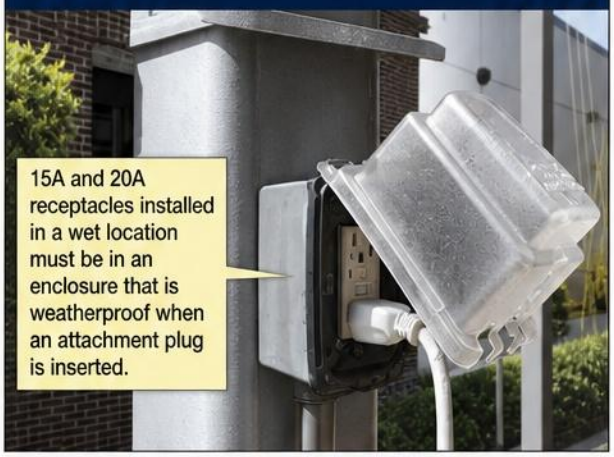
(1) 15A or 20A Receptacles.

(a) Weatherproof Enclosure. 15A or 20A receptacles installed in a wet location must be within an enclosure that is weatherproof when an attachment plug is inserted. ▸Figure 406–6

(b) Outlet Box Hood. An outlet box hood must be listed and identified as "extra duty." ▸Figure 406–7

(c) Covers. Hinged covers of outlet box hoods must be able to open at least 90 degrees or fully open (if the cover is not designed to open 90 degrees from the closed to open position) after installation. ▸Figure 406–8

Figure 406–6 406.9(B)(1)(a)

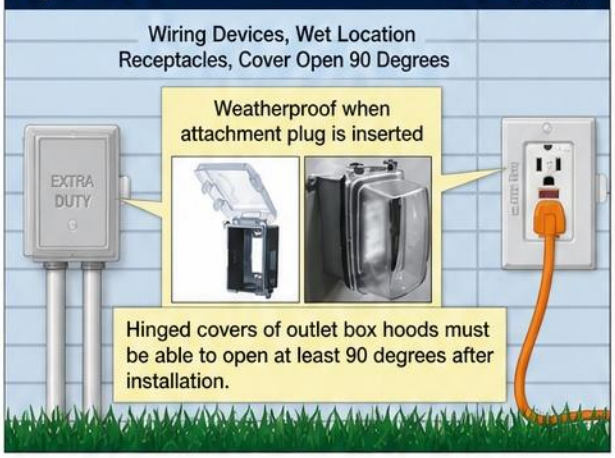


A weatherproof in-use cover protects the receptacle and the attachment plug when the plug is inserted.

Figure 406–7 406.9(B)(1)(b)

Use an outlet box hood marked for "extra duty" when protecting 15A or 20A receptacles in wet locations.

Figure 406–8 406.9(B)(1)(c)



Hinged outlet box hood covers must open at least 90 degrees after installation to ensure proper use.

AUTHOR'S COMMENT:

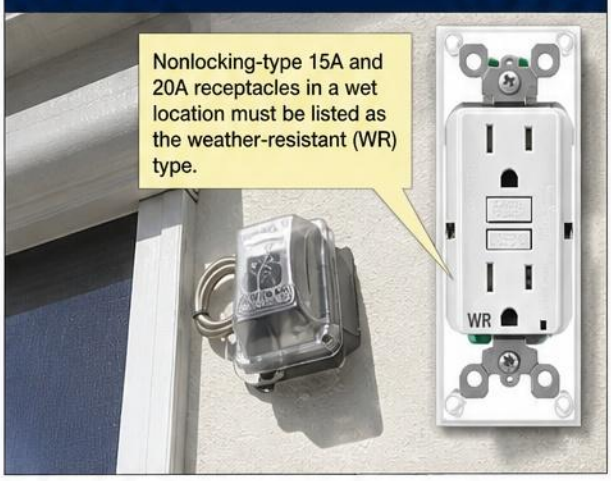
- The main difference between the cover for a 15A or 20A receptacle in a damp location [406.9(A)] or wet location [406.9(B)] is whether it is weather resistant when the attachment plug is inserted. ▶ Figure 406–9

Figure 406–9 406.9 Comment

The difference is whether the cover remains weatherproof once the attachment plug is inserted.

(d) Weather-Resistant Receptacle. Nonlocking-type 15A or 20A receptacles in a wet location must be listed as weather-resistant (WR) type. ▶ Figure 406–10

Figure 406–10 406.9(B)(1)(d)



Look for the WR marking to confirm the receptacle is weather-resistant for wet locations.

Author's Comment:

- Exposed plastic surface material of weather-resistant receptacles must have UV resistance to ensure that deterioration from sunlight does not take place or is minimal. In testing, receptacles are subjected to temperatures cycling from very cold to very warm conditions, and then subjected to additional dielectric testing. The rapid transition from the cold to warm temperatures changes the relative humidity and moisture content on the device, and the dielectric test ensures this will not create a breakdown of the insulation properties.

(3) Switches. Switches installed in wet locations must comply with the following:

(1) Surface-mounted general-use snap switches must be installed in weatherproof enclosures. ▸ Figure 406–11

Figure 406–11 Surface-Mounted Switch in Weatherproof Enclosure 406.9(B)(3)(1)

Surface-mounted general-use snap switches must be installed in weatherproof enclosures.

(2) Flush-mounted general-use snap switches must have weatherproof covers. ▸ Figure 406–12

Figure 406–12 Flush-Mounted Switch in Wet Location 406.9(B)(3)(2)

Flush-mounted general-use snap switches must have weatherproof covers.

(C) Wiring Devices in Bathtub and Shower Space.

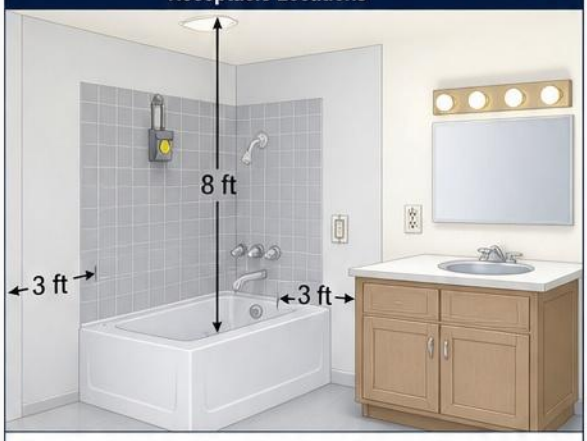
(1) Receptacles. Receptacles are not permitted inside a bathtub or shower or within the following zones:

(1) 3 ft horizontally from any outside edge of a bathtub or shower stall

(2) 8 ft vertically above the top of the bathtub rim or shower stall threshold

This bathtub and shower zone includes the outside space below and directly over the bathtub and shower space. ▸ Figure 406–13

Figure 406–13 Bathtub and Shower Zone Receptacle Locations 406.9(C)(1)



Receptacles are not permitted inside or within 3 ft horizontally from any outside edge of a bathtub or shower stall, including the space measured vertically from the floor to 8 ft vertically above the top of the bathtub rim or shower stall threshold.

Ex 1: Receptacles for hydromassage bathtubs installed in accordance with 680.73 are permitted to be installed in the prohibited receptacle zone. ▸ Figure 406–14

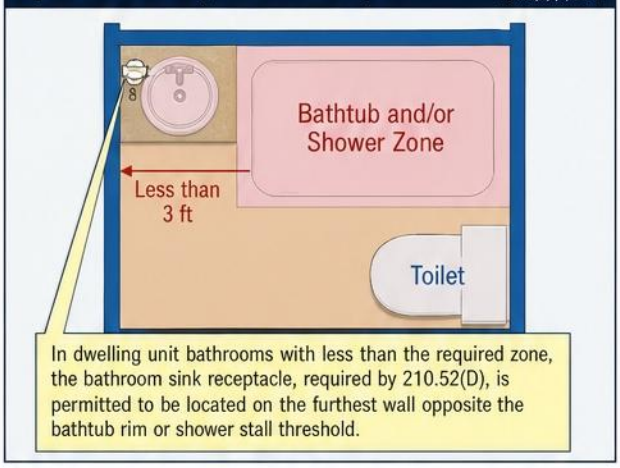
Ex 2: In dwelling unit bathrooms with less than the required zone, the bathroom sink receptacle, required by 210.52(D), is permitted to be located on the furthest wall opposite the bathtub rim or shower stall threshold. ▸ Figure 406–15

Ex 4: In dwelling unit bathrooms, a single receptacle for an electronic toilet or electronic bidet seat is permitted in the prohibited receptacle zone, if the receptacle is not in the space between the toilet and the bathtub or shower. ▸ Figure 406–16

Figure 406-14 Prohibited Hydromassage Bathtub Receptacle 406.9(C)(1) Ex 1

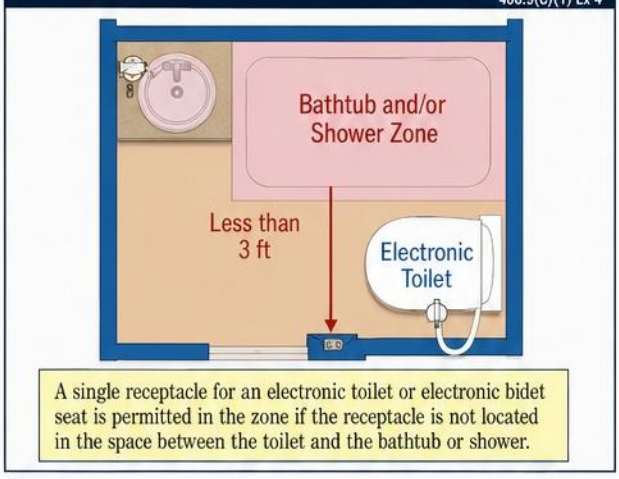
Receptacles for hydromassage bathtubs are not allowed in this restricted area.

Figure 406-15 Dwelling Unit Bathroom Receptacle 406.9(C)(1) Ex 2



When the room is smaller than the required zone, the sink receptacle (as required by 210.52(D)) may be placed on the farthest wall opposite the bathtub rim or shower threshold.

Figure 406-16 Dwelling Unit Electronic Toilet or Bidet Receptacle 406.9(C)(1) Ex 4



An electronic toilet or bidet seat receptacle is allowed in the zone provided it is not located between the toilet and the tub or shower.

(2) Switches. General-use snap switches cannot be installed within tub or shower spaces, unless it is part of a listed tub or shower assembly. Figure 406-17

Figure 406-17 Switches in Tub or Shower Spaces 406.9(C)(2)

A general-use snap switch is not permitted in the tub or shower area.

406.10 Wiring Device Terminations

Wiring device terminations must comply with all of the following:

(1) Devices Marked CO/ALR. Wiring devices with terminals marked CO/ALR can be used with aluminum, copper, and copper-clad aluminum conductors.

(2) Devices Not Marked CO/ALR. Wiring devices with terminals not marked CO/ALR must comply with both of the following:

a. Aluminum conductors are not permitted.

b. Copper and copper-clad aluminum conductors are permitted, but must be connected based on the AWG wire size and type of conductor identified by the manufacturer's instructions.

Author's Comment:

- According to *UL Category RTBT*, receptacle terminations are marked with the type of conductor material as follows:
  - Receptacle terminals marked "AL" are only suitable for aluminum wire.
  - Receptacle terminals marked "CU" are only suitable for copper wire. Figure 406-18
  - Receptacle terminals marked "CC-CU" are only suitable for copper and copper-clad aluminum wire.
  - Receptacle terminals marked "CO/ALR" are suitable for copper, copper-clad aluminum, and aluminum wire.

Figure 406–18 Wiring Device Termination Receptacle Marked CU 406.10 Comment

Per *UL* Category RTRT, receptacle terminations labeled "CU" are suitable only for copper conductors.

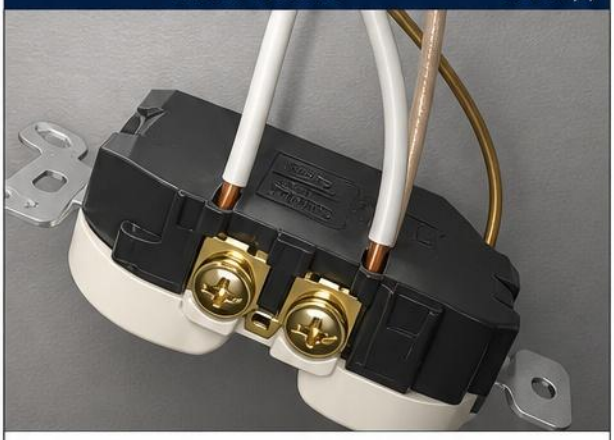
- Under *UL Category WAUR*, snap switch terminations on 15A or 20A devices not labeled "CO/ALR" are intended for use only with copper and copper-clad aluminum conductors. Snap switch terminations marked "CO/ALR" may be used with aluminum, copper, or copper-clad aluminum conductors.

(3) Push-In Terminals. Devices that use screwless push-in type terminals are approved only for 15A branch circuits connected with 14 AWG solid copper conductors. See Figure 406–19 and Figure 406–20.

Figure 406–19 Wiring Device Terminations Push-In Terminals 406.10(3)

Devices with screwless push-in terminals are approved only for 15A branch circuits connected with 14 AWG solid copper conductors.

Figure 406–20 Wiring Device Terminations Push-In Terminals 406.10(3)



Devices equipped with screwless push-in terminals are approved only for 15A branch circuits and must be used with 14 AWG solid copper conductors.

Part II. Receptacles, Cord Connectors, and Attachment Plugs (Caps)

Receptacle. A contact device installed at an outlet for the connection of an attachment plug. See Figure 406–21.

Figure 406–21 Receptacle Article 100 Definition

A contact device for the connection of an attachment plug.

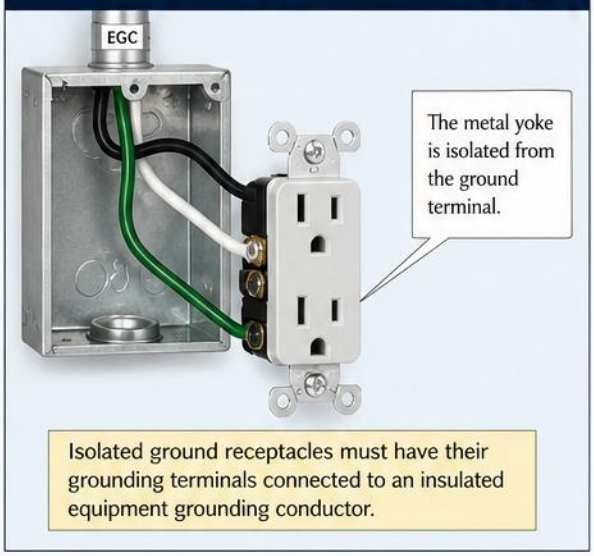
406.11 Receptacle Rating and Type

(C) Isolated Ground Receptacles. Isolated ground receptacles must be identified by an orange triangle on the face of the receptacle. See Figure 406–22.

Figure 406-22 Isolated Ground Receptacle (IG) Orange Triangle 406.11(C)

(1) Isolated Equipment Grounding Conductor. Isolated ground receptacles must have their grounding terminals connected to an insulated equipment grounding conductor in accordance with 250.146(D).

Figure 406-23 Isolated Ground Receptacle (IG) Connected to Insulated EGC 406.11(C)(1)



(D) Controlled Receptacle Marking. 15A or 20A, 125V nonlocking-type receptacles that are automatically controlled to remove power for energy management or building automation must be permanently marked with the word "controlled."

Figure 406-24 Automatically Controlled Receptacles Marking Symbol 406.11(D)

Author's Comment:

- *ICC Energy Code C405 and ASHRAE 90.1 require "Automatic Receptacle Control" to reduce electrical power demands on commercial buildings from cord-and-plug-connected loads (even in the off state) such as cell phone chargers, computer monitors, task lighting, and other equipment that consume energy.*

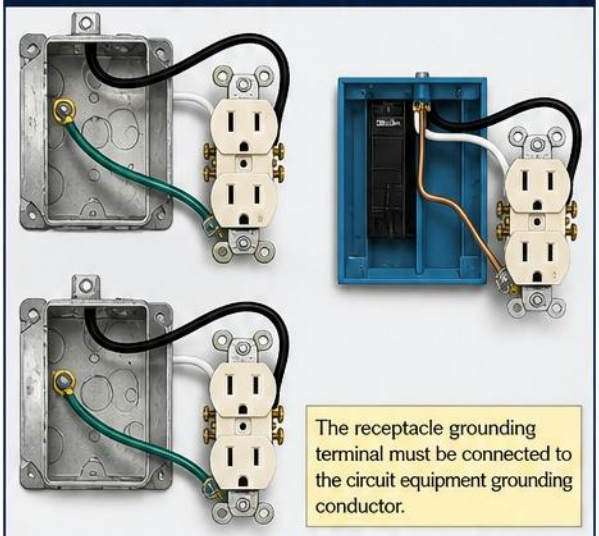
406.12 General Installation Requirements

(A) Grounding Type. Receptacles installed on 15A or 20A branch circuits must be of the grounding type, except as permitted for 2-wire receptacle replacements in 406.4(D)(2). ▶ Figure 406-25

Figure 406-25 Receptacles, Grounding-Type 15A and 20A Branch Circuits 406.12(A)

(C) Methods of Connection to Equipment Grounding Conductor. The receptacle grounding terminal must be connected to the circuit equipment grounding conductor in accordance with 250.146.

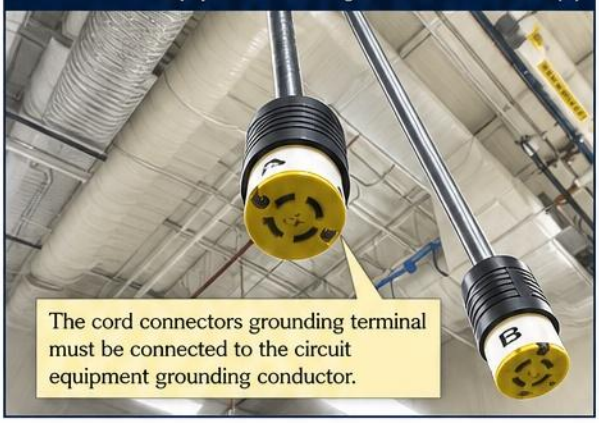
Figure 406–26 Receptacle, Connection to Equipment Grounding Conductor 406.12(C)



The receptacle grounding terminal must be connected to the circuit equipment grounding conductor.

The cord connectors grounding terminal must be connected to the circuit equipment grounding conductor.

Figure 406–27 Cord Connector, Connection to Equipment Grounding Conductor 406.12(C)



Cord Connector. A contact device terminated to a flexible cord that accepts an attachment plug or other insertion.

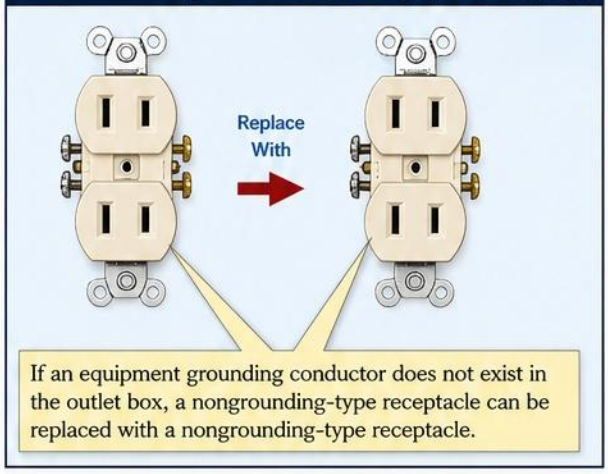
(D) Receptacle Replacements. Receptacles that are replaced must comply with the following:

(1) Equipment Grounding Conductor in Box. If an equipment grounding conductor exists in an outlet box, replacement receptacles must be of the grounding type and the receptacle's grounding terminal must be connected to the circuit equipment grounding conductor in accordance with 406.11.

(2) No Equipment Grounding Conductor in Box. If an equipment grounding conductor does not exist in the outlet box, replacement receptacles can be any of the following:

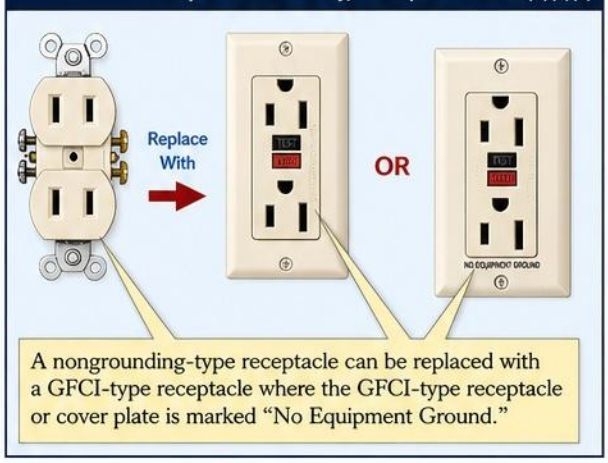
(a) Nongrounding-type Receptacle. Non-grounding-type receptacles can be replaced with a non-grounding-type receptacle.

Figure 406–28 Receptacles, Nongrounding-Type Replaced with Nongrounding-Type 406.12(D)(2)(a)



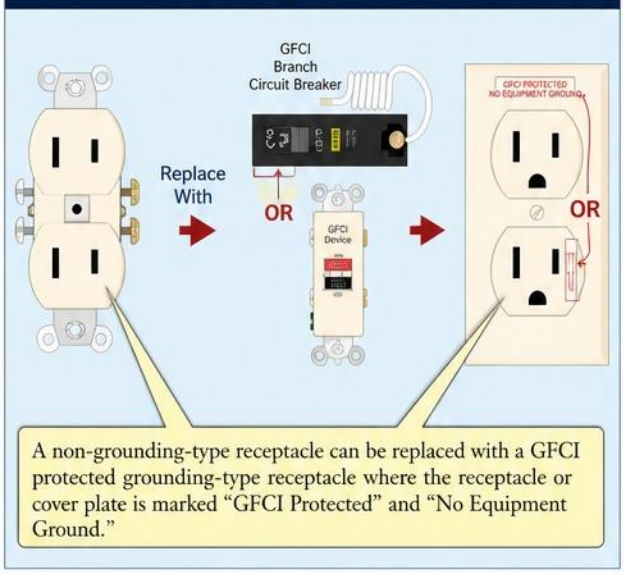
(b) GFCI-Type Receptacle. Non-grounding-type receptacles can be replaced with a GFCI-type receptacle where the GFCI-type receptacle or cover plate is marked "No Equipment Ground."

Figure 406–29 Receptacle, Nongrounding-Type Replaced with GFCI-Type Receptacle 406.12(D)(2)(b)



(c) GFCI Protected Grounding-Type Receptacle. Non-grounding-type receptacles can be replaced with a *GFCI* protected grounding-type receptacle where the receptacle or cover plate is marked "GFCI Protected" and "No Equipment Ground."

Figure 406–30 GFCI Protected Grounding-Type Receptacle Replacement 406.12(D)(2)(c)



Author's Comment:

- GFCI protection functions properly on a 2-wire circuit without an equipment grounding conductor because the circuit's equipment grounding conductor serves no role in the operation of a GFCI device.

(3) GFCI Protection Required. When receptacles are replaced in locations where GFCI protection is required, the replacement receptacles must be GFCI protected.

Author's Comment:

- List item (3) of the exception allows a 3-wire dryer and range receptacle with a neutral-to-ground bond as permitted by 250.140(B) for existing installations to be replaced with a 3-wire receptacle.

(4) AFCI Protection Required. When receptacles are replaced in locations where AFCI protection is required, the replacement receptacles must be AFCI protected by one of the following:

(1) Listed AFCI receptacle

(2) Protected by a listed AFCI receptacle

(3) Protected by an AFCI circuit breaker

(5) Tamper-Resistant Receptacles. When existing receptacles are replaced in locations where tamper resistance is required [406.12], the replacement receptacles must be listed tamper resistant, except as follows:

(1) Where a nongrounding receptacle is replaced with another nongrounding receptacle

(2) Where a receptacle connected to aluminum conductors is replaced with a CO/ALR receptacle

(6) Weather-Resistant Receptacles. When existing receptacles are replaced in locations where weather resistance is required, replacement receptacles must be weather resistant in accordance with 406.9(A) and (B).

(7) Controlled Receptacles. Automatically controlled receptacles must be replaced with an equivalently controlled receptacle. If automatic control of the receptacle is no longer required, the replacement receptacle must not be marked in accordance with 406.11(D).

(G) Protection of Floor Receptacles.

(1) Physical Protection. Physical protection of floor receptacles must allow floor-cleaning equipment to be operated without damaging the receptacles. [Figure 406–31]

Figure 406–31 Physical Protection of Floor Receptacles 406.12(G)(1)

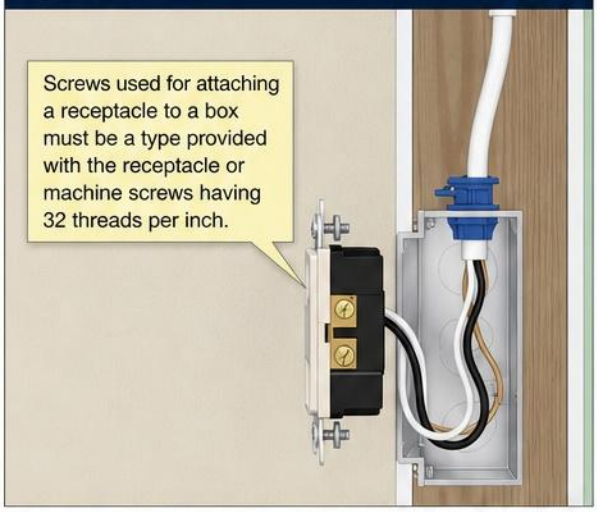
Physical protection of floor receptacles must allow floor-cleaning equipment to be operated without damaging the receptacles.

(2) GFCI Protected. All 125V, single-phase, 15A or 20A floor receptacles in food courts and passenger transportation facilities waiting spaces must be GFCI protected.

406.14 Receptacle Mounting

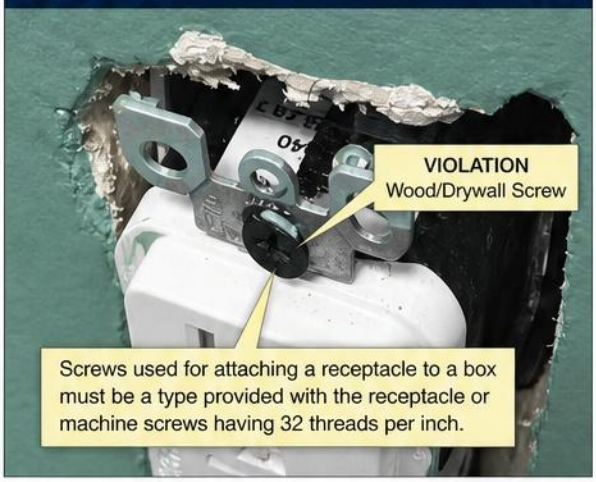
Screws used for attaching a receptacle to a box must be a type provided with the receptacle or machine screws having 32 threads per inch. ▶ **Figure 406–32** and ▶ **Figure 406–33**

Figure 406–32 406.14



The screws that secure a receptacle to a box must be either the type supplied with the device or machine screws with 32 threads per inch.

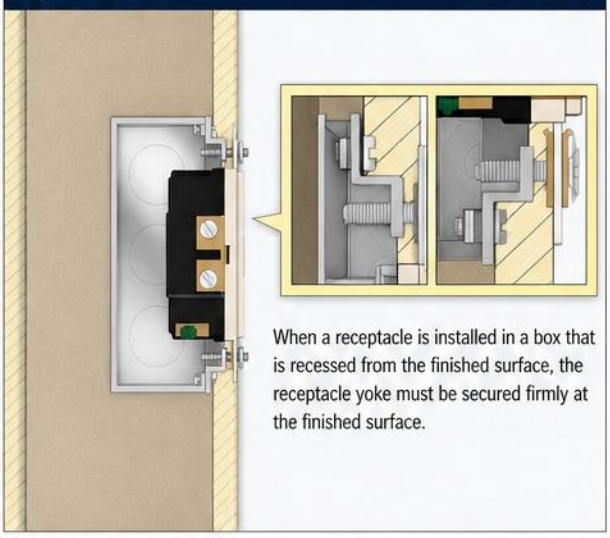
Figure 406–33 406.14



Using wood or drywall screws to fasten a receptacle to a box does not comply because the screws are not of the required type.

(A) Boxes Set Back. Receptacles mounted in boxes that are set back from the finished surface must be installed so the receptacle yoke is held rigidly at the finished surface. ▶ **Figure 406–34**

Figure 406–34 406.14(A)



Receptacles set back in boxes must be fastened so the yoke is tight against the finished surface.

Author's Comment:

In walls or ceilings of noncombustible material (such as drywall) outlet boxes are not permitted to be set back more than ¼ in. from the finished surface. In walls or ceilings of combustible material, outlet boxes must be flush with the finished surface [314.20]. There must not be any gaps of more than ⅛ in. at the edge of the outlet box [314.21].

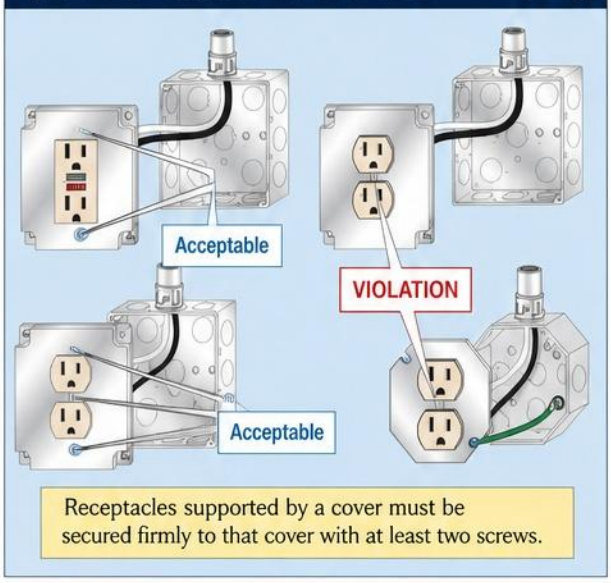
(B) Boxes Flush with Surface. Receptacles mounted in boxes that are flush with the finished surface must have the receptacle yoke held rigidly to the box or box cover. ▶ **Figure 406–35**

Figure 406–35 406.14(B)

When a receptacle is installed in a box that is flush with the finished surface, the yoke must be secured firmly to the box or box cover.

(C) Receptacles Mounted on Covers. Receptacles supported by a cover must be secured firmly to that cover with at least two screws. **Figure 406–36**

Figure 406–36 Receptacles Mounted on Covers 406.14(C)



(D) Position of Receptacle Faces. Receptacles must be flush with, or project from, the faceplates.

(E) Receptacles in Countertops. Receptacle assemblies installed in countertops must be listed for countertop applications. **Figure 406–37**

Figure 406–37 Receptacles in Countertops 406.14(E)

(F) Receptacles in Work Surfaces. Receptacle assemblies in work surfaces must be listed for work surfaces or countertop applications.

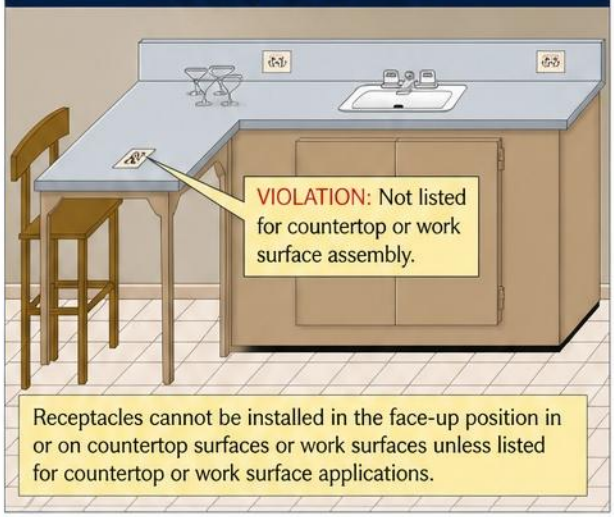
Author's Comment:

In accordance with *UL 498*, work surface pop-up receptacle assemblies are subjected to a spill test that is equivalent to an 8-oz cup of coffee or a soft drink. These receptacle assemblies cannot be used in countertops.

(G) Receptacle Orientation. Receptacles are not permitted to be installed in a face-up position in any of the following locations:

(1) Countertop and Work Surfaces. Where listed for countertop surface or work surface applications, receptacles are permitted to be installed in a face-up position on countertop surfaces or work surfaces. **Figure 406–38**

Figure 406–38 Receptacle Face-Up Position Countertop and Work Surfaces 406.14(G)(1)



(2) Under Sinks. Receptacles are not permitted to be installed in a face-up position in the area below a sink.

Author's Comment:

The position of the ground terminal of a receptacle is not specified in the *NEC* so it can be up, down, or to the side. Proposals to specify the mounting position of the ground terminal have been rejected throughout many *Code* revision cycles. **Figure 406–39**

(J) Voltage Between Adjacent Devices. Receptacles are not permitted to be in enclosures with other switches or receptacles if the voltage between the devices exceeds 300V, unless the devices are separated by barriers identified for the purpose. **Figure 406–40**

Figure 406–39 Receptacle Ground Terminal Position *406.14(G) Comment*

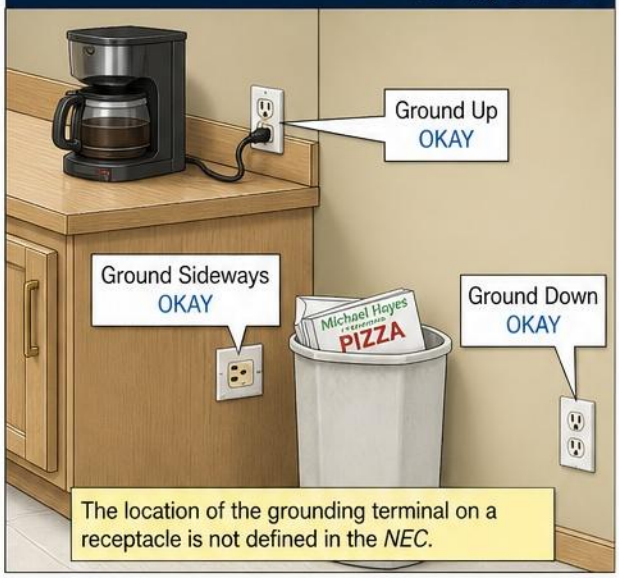


Figure 406–41 Receptacle Faceplate or Cover Plate Cover Opening *406.16*

Figure 406–40 Receptacles, Voltage Between Devices Maximum 300V *406.14(J)*

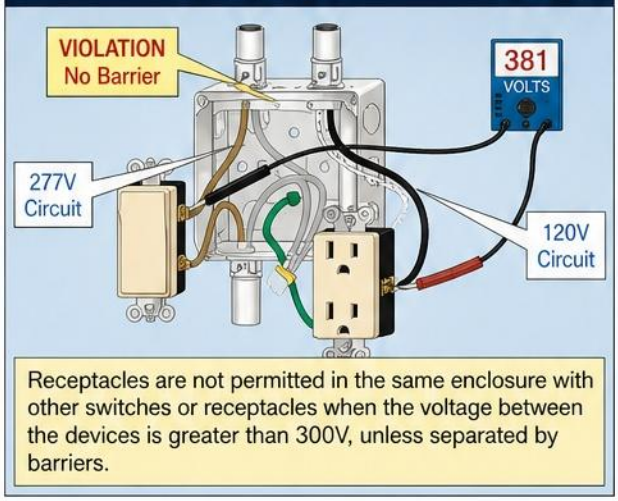
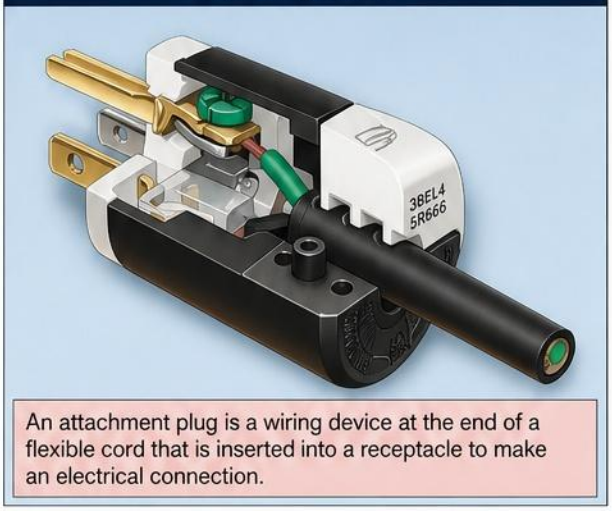


Figure 406–42 Attachment Plug *Article 100 Definition*



406.16 Receptacle Faceplates or Cover Plates

Receptacle faceplates or cover plates must completely enclose the outlet openings and be pressed tight against the mounting surface. ▸ Figure 406–41

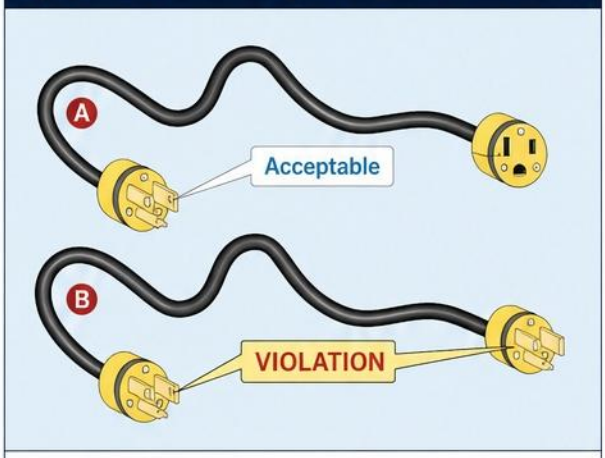
406.18 Attachment Plugs and Flanged Surface Inlets

Attachment Plug. An attachment plug is a wiring device at the end of a flexible cord that is inserted into a receptacle to make an electrical connection. ▸ Figure 406–42

(B) Attachment Plugs. Attachment plugs must be installed so their blades are not energized, unless inserted into an energized receptacle or cord connector. ▸ Figure 406–43

(D) Flanged Surface Inlet. A flanged surface inlet must be installed so the blades are not energized, unless an energized cord connector is inserted into the inlet. ▸ Figure 406–44

Figure 406–43 Attachment Plugs, No Energized Parts 406.18(B)



Attachment plugs must be installed so their blades are not energized unless inserted into an energized receptacle or cord connector.

Figure 406–44 Flanged Surface Inlets, No Energized Parts 406.18(D)

A flanged surface inlet must be installed so the blades are not energized unless an energized cord connector is inserted into the inlet.

406.26 Tamper-Resistant Receptacles

Nonlocking-type 15A or 20A, 125V and 250V receptacles in the following areas must be tamper-resistant:

Author's Comment:

- Inserting an object into one slot of a tamper-resistant receptacle does not open the internal shutter mechanism. Simultaneous pressure applied to the polarized slots is required to insert the plug.
  - **Figure 406–45**

Figure 406–45 Receptacles, Tamper-Resistant 406.26 Comment

Placing an object into only one slot does not open the internal tamper-resistant shutter. Simultaneous pressure applied to the polarized slots is required to insert the plug.

(1) Dwelling units, boathouses, mobile/manufactured homes including their attached or detached garages and accessory buildings, and common areas of multifamily dwellings **Figure 406–46**

Figure 406–46 Receptacles, Tamper-Resistant Dwellings and Common Areas 406.26(1)

Receptacles rated 15A and 20A in dwelling units, boathouses, mobile homes, and manufactured homes, including their attached or detached garages and accessory buildings, and common areas of multifamily dwellings must be tamper-resistant.

(2) Hotel/motel guest rooms or guest suites and their common areas

(3) *Childcare facilities*

Child Care Facility. A building or portions of a building used for educational, supervision, or personal care services for five or more children, seven years of age or less.

(4) Preschools and education facilities

AUTHOR'S COMMENT

- This applies to all educational facilities (such as high schools, colleges, vocational schools, universities, and so forth).

(5) Within clinics, medical/dental offices, outpatient facilities, and the following spaces:

a. Business offices accessible to the general public

b. Lobbies and waiting spaces

c. Spaces of nursing homes and limited care facilities used exclusively as patient sleeping rooms

(6) Places of awaiting transportation (such as gymnasiums, skating rinks, fitness centers, and auditoriums)

(7) Dormitories

(8) Residential care/assisted living facilities, social and substance abuse rehabilitation facilities, and group homes

(9) Foster care facilities, nursing homes, and psychiatric hospitals

(10) Areas and common areas of agricultural buildings accessible to the public

(11) Park and recreation areas ▶ Figure 406–47

Figure 406–47 Parks and Recreational Areas 406.26(11)

Receptacles rated 15A or 20A in park and recreation areas must be tamper-resistant.

Note 3: Areas of agricultural buildings frequently converted to hospitality areas include petting zoos, stables, and buildings used for recreation or educational purposes.

Note 4: Park and recreation areas can include garden areas, play areas, and similar areas.

Ex to (1) through (10): Receptacles in the following locations are not required to be tamper-resistant:

(1) Receptacles more than 5½ ft above the floor ▶ Figure 406–48

Figure 406–48 Receptacles More Than 5½ ft Above the Floor 406.26 Ex 1 to (1) through (10)

Receptacles located more than 5½ ft above the floor are not required to be tamper-resistant.

(2) *Receptacles that are part of a luminaire or appliance*

(3) Receptacles within a dedicated space for a cord-and-plug-connected appliance that in normal use is not easily moved

(4) *Nongrounding* receptacles installed as permitted in 406.12(D)(2)(a)

Part III. General-Use Snap Switches, Dimmers, and Electronic Control Switches

406.30 Switch Connections

Switch, General-Use Snap Switch. A switch constructed to be installed in a device box or box cover. ▶ Figure 406–49

(C) Switches Controlling Lighting Loads. Switches controlling line-to-neutral lighting loads must have a neutral conductor installed at all switches serving bathroom, hallways, stairways, *habitable rooms*, or occupiable spaces as defined in the building code. ▶ Figure 406–50

Habitable Room. A room for living, sleeping, eating, or cooking, but excluding bathrooms, toilet rooms, closets, hallways, storage/otility spaces, and similar areas. ▶ Figure 406–51

Figure 406–49 General-Use Snap Switch — Article 100 Definition

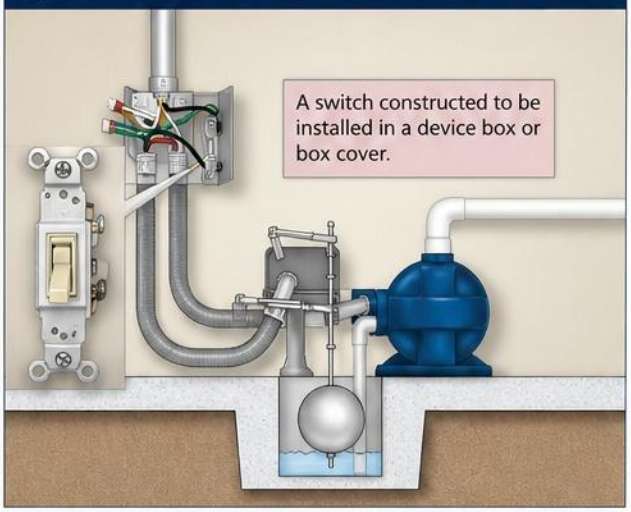


Figure 406–50 Switches Controlling Lighting, Neutral Required — 406.30(C)

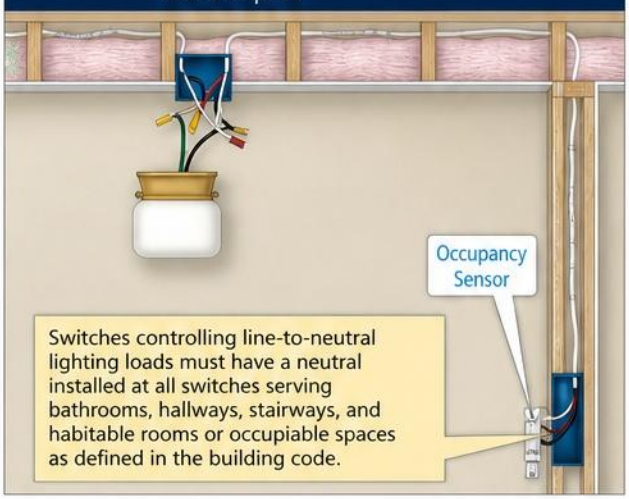
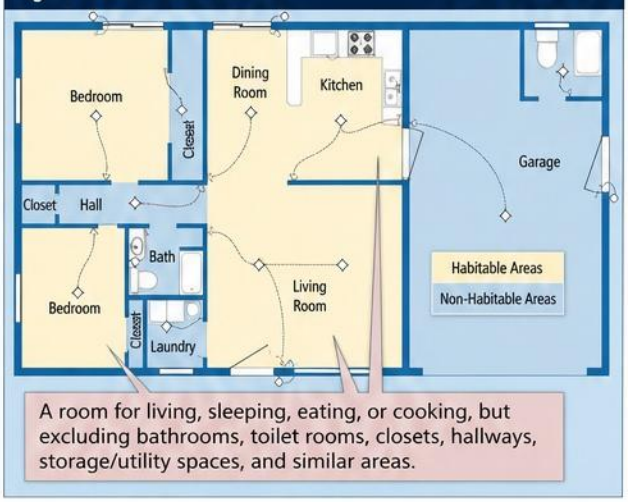


Figure 406–51 Habitable Room — Article 100 Definition

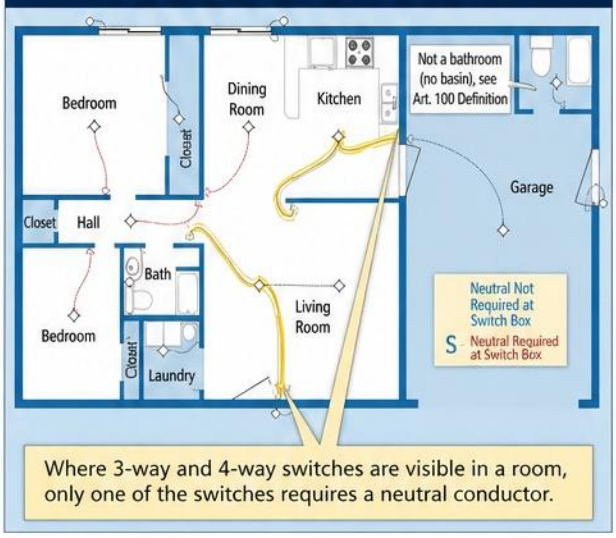


Author's Comment:

According to the building code, an occupiable space is a room or enclosed space designed for human occupancy in which individuals congregate for amusement, educational (or similar) purposes, or where occupants are engaged in labor. An occupiable space is equipped with means of egress, plus meeting the requirements of the building code for light and ventilation.

Where 3-way and 4-way switches are visible in a room, only one of the switches requires a neutral conductor. **Figure 406–52**

Figure 406–52 Switches Controlling Lighting 3-way and 4-way Switches, Neutral Required — 406.30(C)



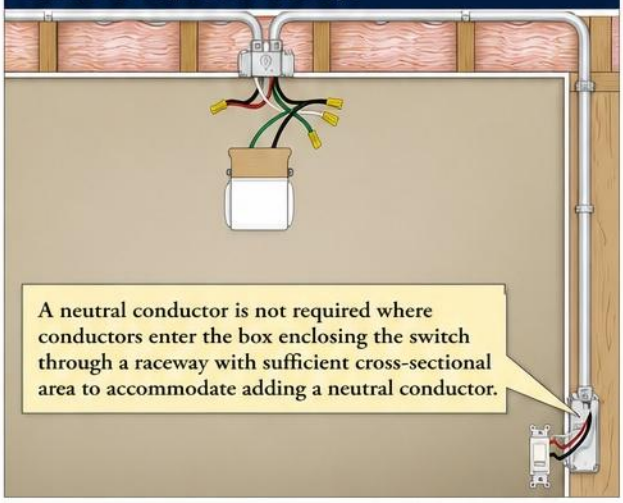
A neutral conductor is not required at lighting switch locations under any of the following conditions:

(1) Where conductors enter the box enclosing the switch through a raceway with enough cross-sectional area to accommodate a neutral conductor **Figure 406–53**

(4) Where switches control receptacles **Figure 406–54**

If not already present, a neutral conductor must be installed for any replacement switch that requires line-to-neutral voltage to operate the electronics of the switch in the standby mode in accordance with 406.50. **Figure 406–55**

Figure 406–53 **406.30(C)(1)**
Switches Controlling Lighting
Neutral Not Required in Raceways

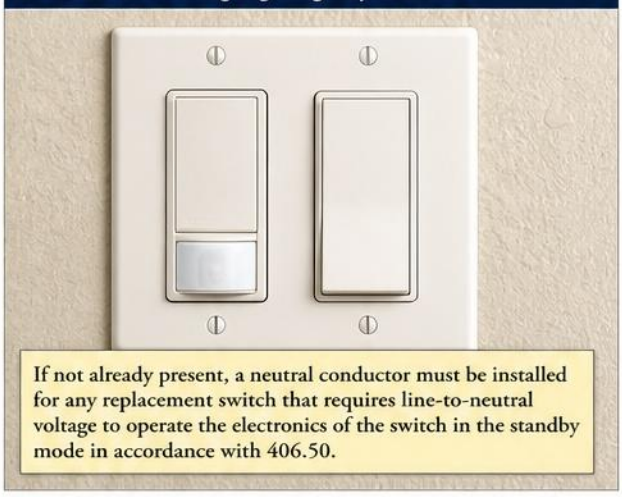


Example: A neutral conductor is not required for replacement switches installed in locations where the neutral conductor cannot be extended without removing finished materials.

Figure 406–54 **406.30(C)(4)**
Switches Controlling Receptacles
Neutral Not Required

Example: A neutral conductor is not required for a switch that controls a receptacle.

Figure 406–55 **406.30(C)**
Switches Controlling Lighting Replacement



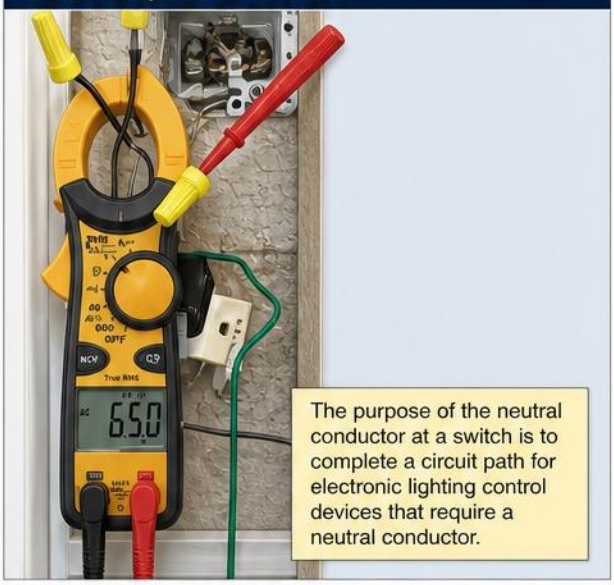
Example: If not already present, a neutral conductor must be installed for replacement switches that require line-to-neutral voltage in standby mode to power their electronics.

Example: A neutral conductor is not required for replacement switches installed in locations where the neutral conductor cannot be extended without removing finished materials. The number of electronic lighting control switches without a neutral conductor on a branch circuit is not permitted to exceed five, and the number of electronic lighting control switches connected to any feeder is not permitted to exceed 25.

Note: The purpose of the neutral conductor at a switch is to complete a circuit path for electronic lighting control devices that require a neutral conductor.

▶ Figure 406–56

Figure 406–56 ***406.30(C) Note***
Switches Controlling Lighting
Neutral Completes Circuit Path



Example: The neutral conductor at a switch is used to complete the circuit path for electronic lighting control devices that require a neutral conductor.

406.38 ACCESSIBILITY AND GROUPING

(A) Location. Switches must comply with both of the following:

(1) Readily Accessible. Switches must be capable of being operated from a readily accessible location.

(2) Maximum Height. The switch operating handle when in its highest position is not permitted to be more than 6 ft 7 in. above the floor, finish grade, or working platform.

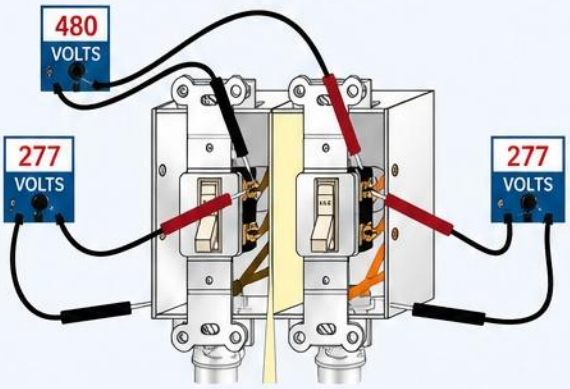
Example to (2): *The switch operating handle is permitted to be higher than 6 ft 7 in., if located next to motors, appliances, or equipment they supply.*

(B) Voltage Between Devices. The maximum voltage between snap switches and adjacent switches or receptacles is 300V, unless the devices are separated by a barrier identified for the purpose.

▶ Figure 406–57

Figure 406–57 406.38(B)

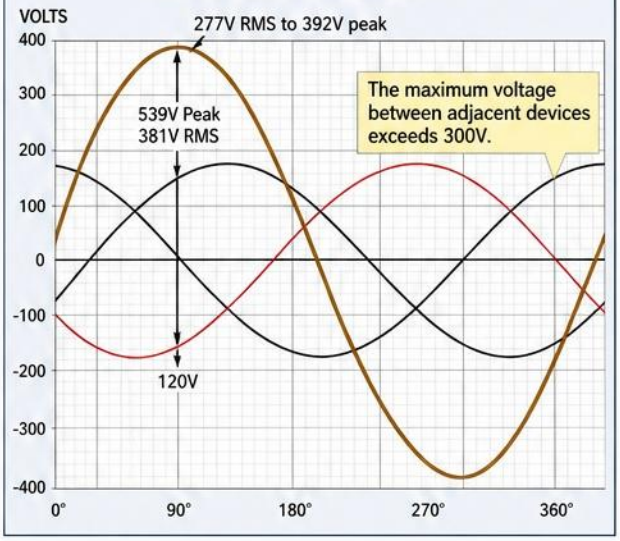
Switches, Voltage Between Devices
Maximum 300V



The maximum voltage between snap switches and other snap switches and receptacles is 300V, unless the devices are separated by a barrier identified for the purpose.

Figure 406–59 406.38(B) Comment

Switches, Voltage Between Devices
Different Nominal Voltage Systems



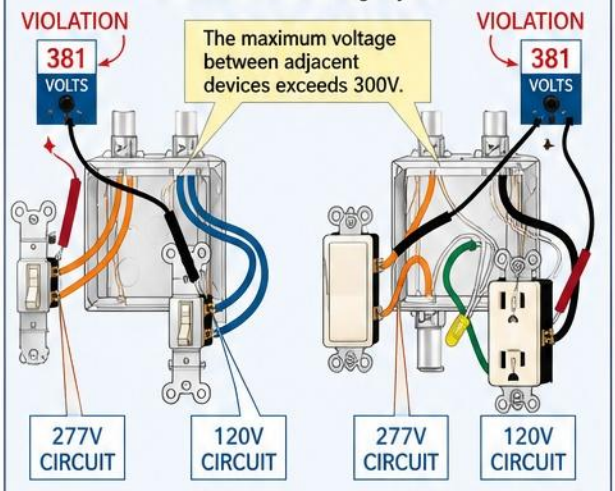
AUTHOR'S COMMENT

The voltage difference between devices is the difference in voltage between the conductors at any given moment. When adjacent devices are connected to different systems such as 208Y/120V and 480Y/277V, the voltage difference between the devices can be as much as 381V.

See **Figure 406–58** and **Figure 406–59**.

Figure 406–58 406.38(B) Comment

Switches, Voltage Between Devices
Different Nominal Voltage Systems



406.40 Switches, Dimmers, and Control Switches

(A) Faceplates. Faceplates for switches, dimmers, and control switches must completely close the outlet box opening. Where the device is flush mounted, the faceplate must rest against the wall surface.

See **Figure 406–60**.

Figure 406–60 406.40(A)

Switch Faceplates, Flush Mounted

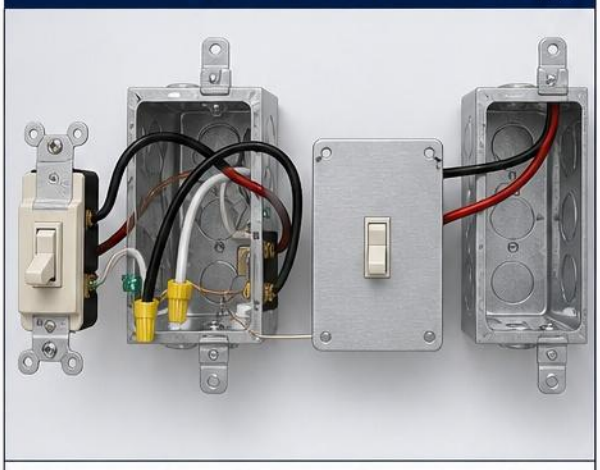
Faceplates for switches, dimmers, and control switches must completely cover the outlet box opening. Where flush mounted, the faceplate must seat against the wall surface.

(B) Equipment Grounding Conductor. Switches, dimmers, and control switches and metal cover plates must be connected to the circuit equipment grounding conductor as follows:

(1) Metal Boxes or Metal Covers. Switches mounted to metal boxes or metal covers are considered connected to the circuit equipment grounding conductor by the use of the metal mounting screws.

See **Figure 406–61**.

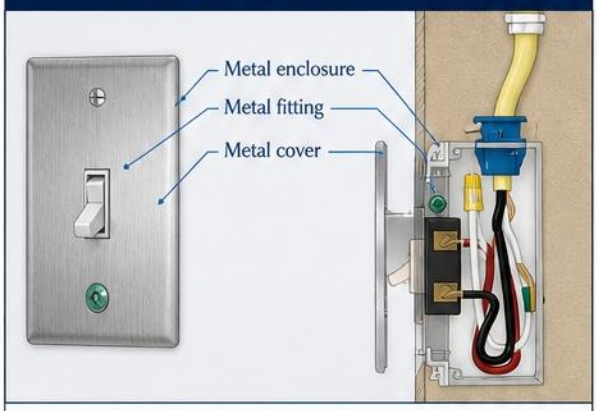
Figure 406–61 Switches, Equipment Grounding Conductor Metal Boxes or Metal Covers 406.40(B)(1)



Switches mounted to metal boxes or metal covers are considered connected to the circuit equipment grounding conductor by the use of the metal mounting screws.

Metal Faceplates or Cover Plates. Metal faceplates or cover plates are considered connected to the circuit equipment grounding conductor by the use of metal screws that secure the metal faceplate or cover plate to the switch. ▶ **Figure 406–62**

Figure 406–62 Switches, Equipment Grounding Conductor Metal Cover Plate 406.40(B)(1)



Metal cover plates are considered connected to the circuit equipment grounding conductor by the use of metal screws that secure the metal cover plate to the switch.

(2) Nonmetallic Boxes. Switches in nonmetallic boxes must have the grounding terminal of the switch connected to the circuit equipment grounding conductor. ▶ **Figure 406–63**

Author's Comment:

- A switch with a metal faceplate installed in a nonmetallic box poses a shock hazard if it becomes energized. An effective ground-fault current path is required by connecting the metal faceplate with metal screws to a switch that is connected to the circuit equipment grounding conductor [250.109].

Figure 406–63 Switches, Equipment Grounding Conductor Nonmetallic Boxes 406.40(B)(2)

Switches in nonmetallic boxes must have the grounding terminal of the switch connected to the circuit equipment grounding conductor.

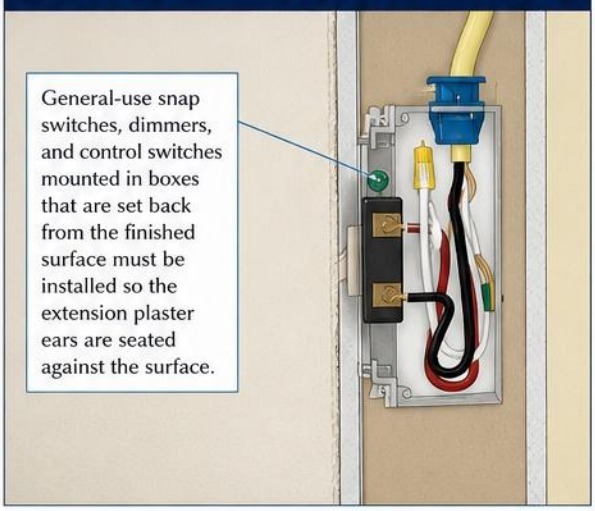
Ex 1: At an existing installation, where no equipment grounding conductor is present at the switch location, a switch without a connection to the equipment grounding conductor is permitted. A switch under this exception must have a cover plate that is nonmetallic with nonmetallic screws, or the replacement switch must be GFCI protected.

406.42 Snap Switches, Dimmers, and Control Switches Mounting

(B) Box Mounting.

Box Set Back. General-use snap switches, dimmers, and control switches mounted in boxes that are set back from the finished surface must be installed so the extension plaster ears are seated against the surface. ▶ **Figure 406–64**

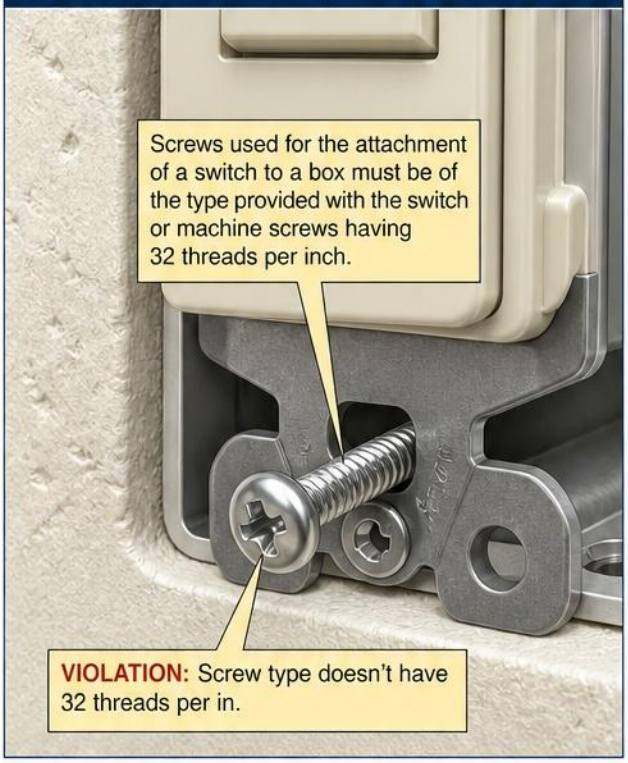
Figure 406–64 Switch Mounting Boxes set Back 406.42(B)



Boxes Flush with Surface. General-use snap switches, dimmers, and control switches installed in boxes so that they are flush with the finished surface must be secured with the switch yoke seated against the box.

When fastening a switch to a box, the screws provided with the switch or machine screws must be of the type that has 32 threads per inch. ▶ **Figure 406–65**

Figure 406–65 Switch Mounting Screw Type 406.42(B)



Screws used to fasten a switch to a box must have 32 threads per inch.

406.46 Snap Switch Rating and Use

General-use snap switches must be permanently marked with their ratings as stated.

(A) Alternating-Current General-Use Snap Switches. General-use snap switches may be used to control:

(4) Motor loads whose current does not exceed 80 percent of the ampere rating of the snap switch [430.109(C)(2)]

(5) Electronic ballasts, self-ballasted lamps, compact fluorescent lamps, and LED lamp loads together with their related drivers, provided the total does not exceed 20A and the ampere rating of the switch at the voltage applied.

ARTICLE 100 DEFINITIONS

Article 100 contains terms used throughout the *NEC* that have specific meanings. Using these defined terms ensures consistency and avoids confusion. Below are paraphrased examples of key definitions from this article.

BRANCH CIRCUIT

The circuit conductors between the final overcurrent device protecting the circuit and the outlets.

SHORT-CIRCUIT CURRENT RATING

The highest prospective short-circuit current that equipment, devices, or components are intended to withstand under specified conditions without sustaining damage.

SERVICE

The conductors and equipment for delivering electric energy from the utility system to the service disconnecting means, including the service drop, service lateral, and service-entrance conductors.

SERVICE DISCONNECTING MEANS

The means incorporated in or as a part of the service equipment that disconnects all ungrounded service conductors from all other conductors.

SEPARATELY DERIVED SYSTEM

A power system supplied by a source other than a utility where the system conductors are not directly connected to the conductors of another power system.

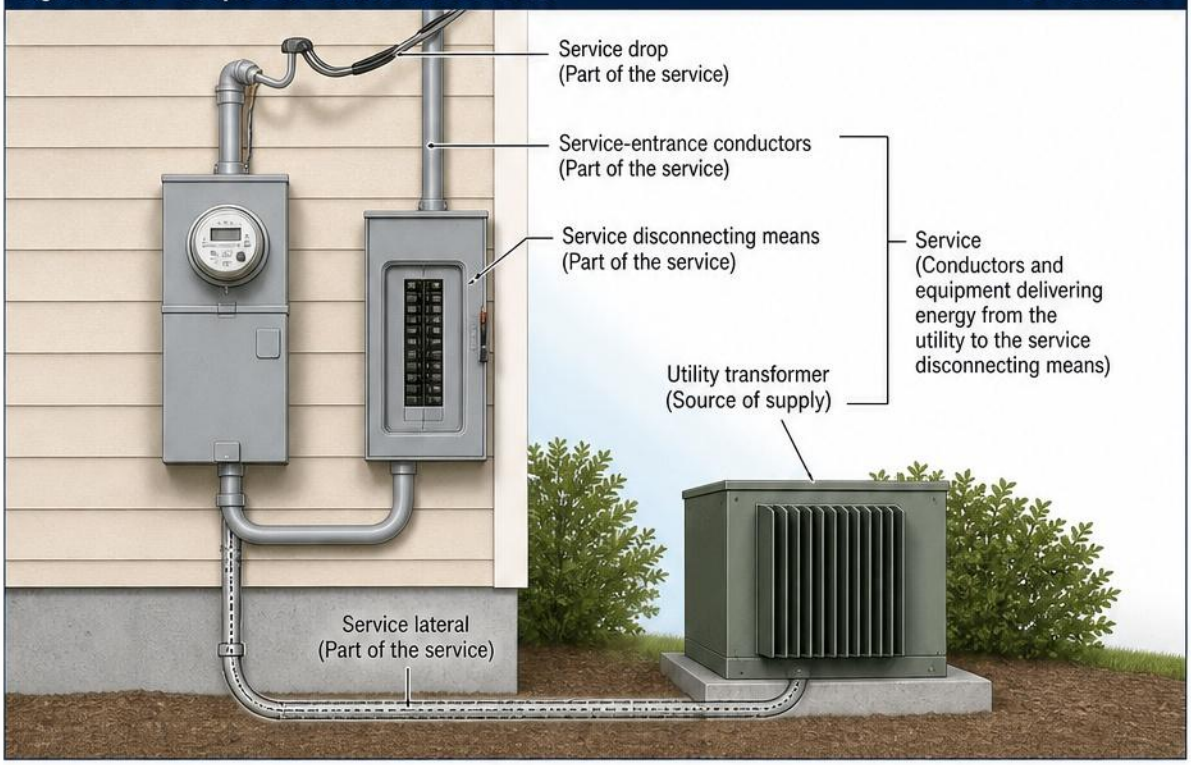
TRANSFORMER

A static device that transfers electrical energy from one circuit to one or more other circuits through electromagnetic induction.

VOLTS, NOMINAL

The stated value of voltage used to designate or identify an electrical system or circuit.

Figure 100–1 Components of an Electrical Service — **100 Definitions**



This illustration shows the main components of an electrical service. The service consists of the conductors and equipment that deliver electrical energy from the utility system to the service disconnecting means, including the service drop, service lateral, service-entrance conductors, and associated equipment.

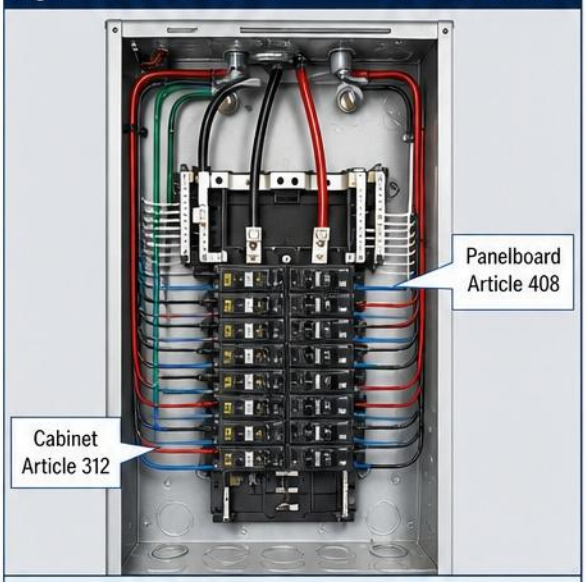
ARTICLE 408 Switchboards and Panelboards

Introduction to Article 408—Switchboards and Panelboards

Article 408 specifies the requirements for *panelboards* and *switchboards* that regulate power and lighting circuits (operating at 1000 Vac, 1500 Vdc, or less), unless specifically referenced. The slang term in the electrical field for a panelboard is "the guts."

Panelboard. An assembly with buses and overcurrent protective devices designed to be placed in a cabinet or enclosure.

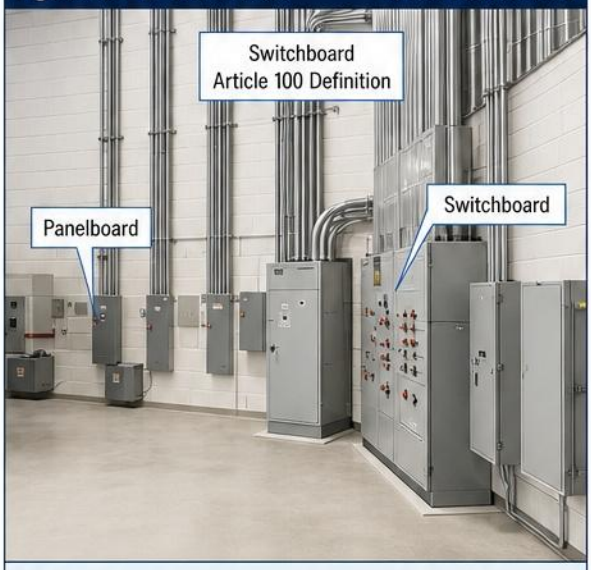
Figure 408–1 Panelboard — Article 100 Definition



An assembly with buses and overcurrent protective devices designed to be placed in a cabinet or enclosure.

Switchboard. Large single panel, frame, or assembly of panels which contain switches, overcurrent and other protective devices, buses, and instruments.

Figure 408–2 Switchboard — Article 100 Definition



A large single panel, frame, or assembly of panels on which contains switches, overcurrent and other protective devices, buses, and instruments.

Part I. General

408.1 Scope

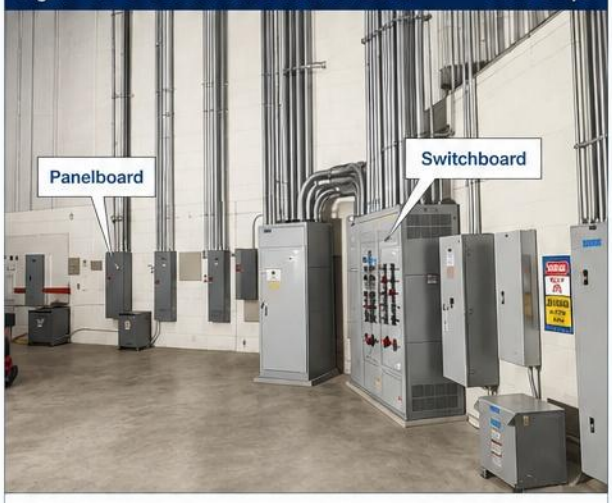
This article contains the requirements for switchboards and panelboards that control power and lighting circuits.

▶ Figure 408–3

408.4 Circuit Directory and Description

(A) Circuit Descriptions. Every circuit and circuit modification must be provided with a legible and permanent description that complies with all of the following conditions as applicable:

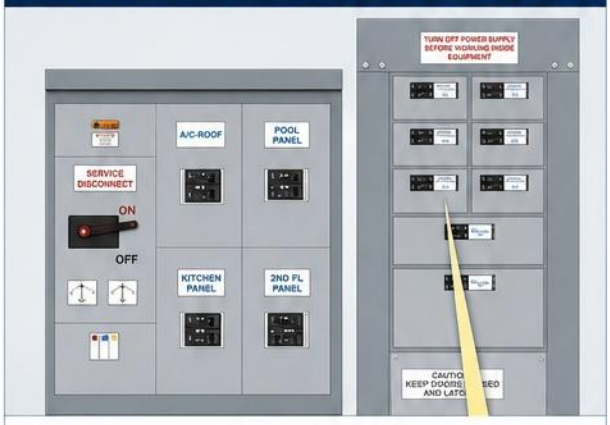
Figure 408–3 Switchboards and Panelboards **408.1 Scope**



Article 408 contains requirements for switchboards and panelboards that control power and lighting circuits.

(1) Switchboard. The circuit description must be located at each circuit breaker. **Figure 408–4**

Figure 408–4 Switchboards Circuit Description Directory **408.4(A)(1)**



The circuit description for switchboards must be located at each circuit breaker.

(2) Panelboard. The circuit description must be located on the face, inside, or in an approved location adjacent to the panel door. **Figure 408–5**

(3) Purpose of Circuit Description. The circuit description must be clear and specific to the purpose or use of each circuit as determined by the AHJ, including spare positions for unused overcurrent protective devices. **Figure 408–6**

(4) Circuit Description Details. The circuit description must have a degree of detail and clarity that is unlikely to result in confusion between circuits as determined by the AHJ.

Figure 408–5 Panelboards Circuit Description Directory **408.4(A)(2)**

The circuit description must be located on the face, inside, or in an approved location adjacent to the panel door.

Figure 408–5 Switchboards and Panelboards Purpose of Circuit Description **408.4(A)(3)**

The circuit description must be clear and specific to the purpose or use of each circuit, including spare positions for unused overcurrent protective devices.

(5) Transient Conditions. The circuit description must not be dependent on transient conditions of occupancy (such as "Dad's Office"). **Figure 408–7**

(6) Abbreviations and Symbols. The circuit description must be clear in explaining abbreviations and symbols when used. **Figure 408–8**

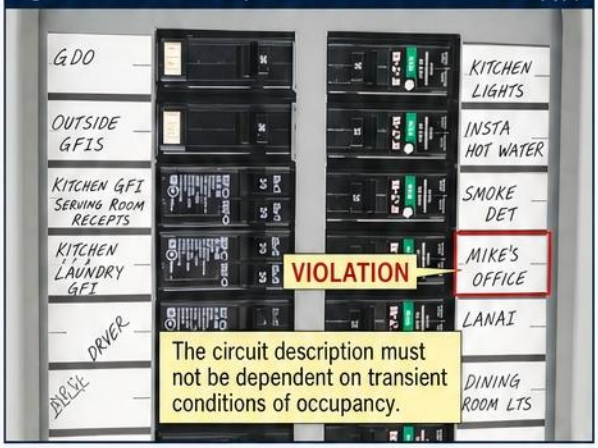
(B) Description of Source of Supply. In other than one-and-two-family dwelling units, switchboards and panelboards supplied by a feeder must be marked as follows:

(1) With the identification and physical location where the power supply originates. **Figure 408–9**

(2) With a permanent label that withstands the environment involved in accordance with 110.22(A)

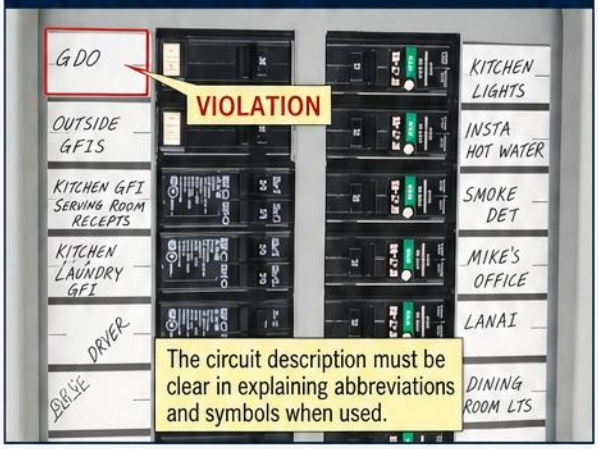
(3) No handwritten marking

Figure 408–7 Circuit Description, Transient Conditions 408.4(A)(5)



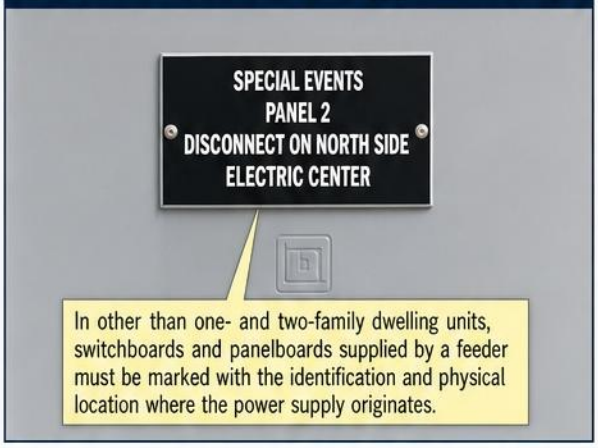
Circuit descriptions must not rely on temporary or changeable occupancy conditions.

Figure 408–8 Abbreviations and Symbols 408.4(A)(6)



Any abbreviations or symbols used in circuit descriptions must be explained so the meaning is clear.

Figure 408–9 Identification of Source of Supply 408.4(B)(1)



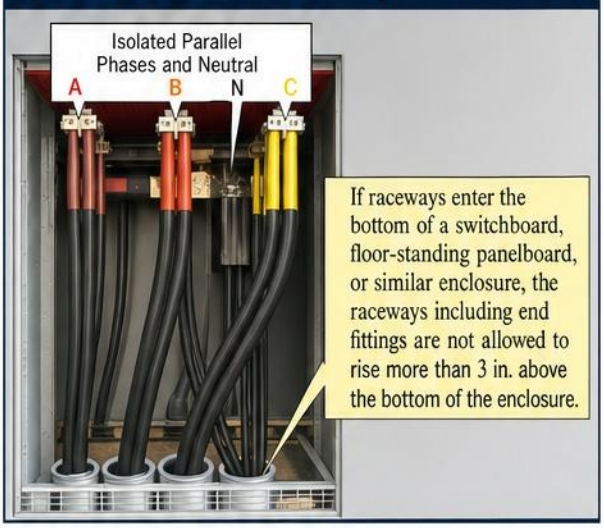
The source of supply must be identified and physically located for all installations except one- and two-family dwellings.

408.5 Clearance for Conductors Entering Bus Enclosures

Raceways including end fittings are not allowed to extend more than 3 in. above the bottom of the enclosure if raceways enter the bottom of a switchboard, floor-standing panelboard, or similar enclosure.

Figure 408–10

Figure 408–10 Conductor Clearance for Entering Enclosures 408.5



Raceways entering the bottom must not project more than 3 in. above the enclosure bottom.

408.6 Short-Circuit Current Rating

Switchboards and panelboards must have a short-circuit current rating not less than the available fault current on the line side of the equipment. In other than one- and two-family dwelling units, switchboards and panelboards must comply with the following:

(1) Available fault current and the date the calculation was performed must be field marked in a readily accessible location on the enclosure at the point of supply. Figure 408–11

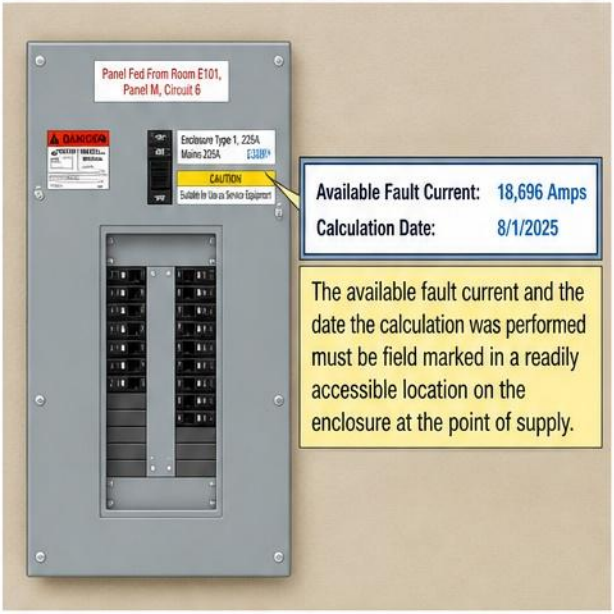
(2) Short-circuit current rating of switchboards and panelboards, at nominal circuit voltage (based on the overcurrent protective device), must be field marked in a readily accessible location on the enclosure.

(3) Marking required by 408.6(1) and (2) must comply with 110.21(B).

(4) Available fault current calculation must be documented and made available to those authorized to inspect, install, or maintain the installation.

(5) Where modifications occur that affect the available fault current at the line terminals of the equipment, the following applies:

Figure 408–11
Switchboards and Panelboards, Available Fault Current
Other than One- and Two-Family Dwelling Units **408.6(1)**



Field marking of the available fault current and calculation date provides essential information for verifying equipment ratings.

a. When necessary, the available fault current must be recalculated to confirm that the equipment's ratings are not less than the available fault current at the line terminals.

b. The field markings required by 408.6(1) must be revised to represent the updated value of available fault current.

When adding interrupting capacity by installing replacement devices or overcurrent protective devices, the interrupting rating must be equal to or greater than the available fault current marked on the equipment.

Note: For series combination systems, see 110.22.

Short-Circuit Current Rating. The fault current at the nominal voltage to which equipment is connected must be capable of being connected without damaging the equipment beyond defined acceptance limits.

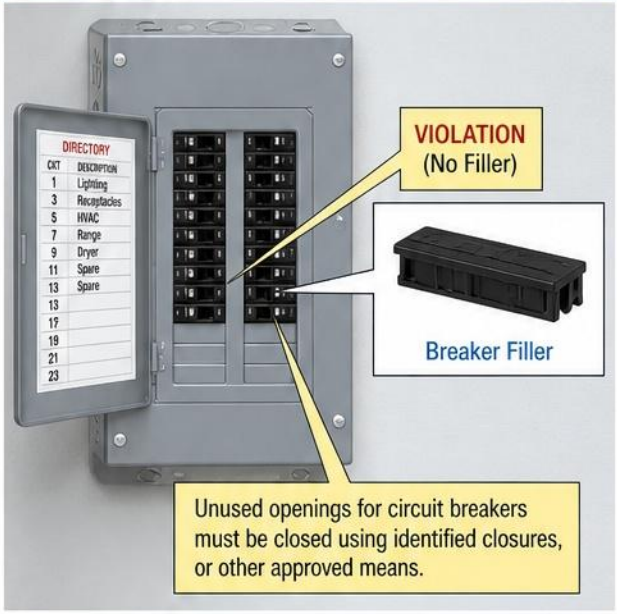
408.7 Unused Openings

Any unused openings for circuit breakers must be closed with identified closures or other approved means that offer protection substantially equivalent to the enclosure wall. **Figure 408–12**

408.9 Replacement Panelboards

Replacement panelboards are permitted to be installed in existing enclosures in accordance with 408.9(A) or (B).

Figure 408–12
Switchboards and Panelboards
Unused Openings **408.7**



All unused breaker openings must be properly closed to prevent accidental contact with live parts.

(A) Panelboards Listed for the Specific Enclosure. A replacement panelboard is listed for the specific enclosure identified by either catalog number or dimensional information is permitted.

(B) Panelboards Not Listed for the Specific Enclosure.

10,000A and Greater. If the available fault current is greater than 10,000A, the completed work for the replacement panelboard must be *field labeled.*

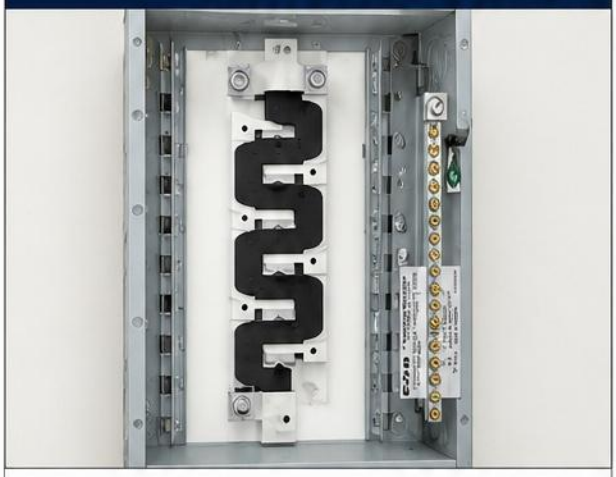
Field Labeled (as applied to evaluated products). Equipment or materials which have a label, symbol, or other identifying mark of a Field Evaluation Body (FEB). This indicates the equipment or materials were evaluated and found to comply with the requirements described in the accompanying field evaluation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

Not Over 10,000A. If the available fault current is not over 10,000A, the replacement panelboard must be identified for the application. Any previously listed marking on the cabinet that pertains to the panelboard must be removed. **Figure 408–13**

Author's Comment:

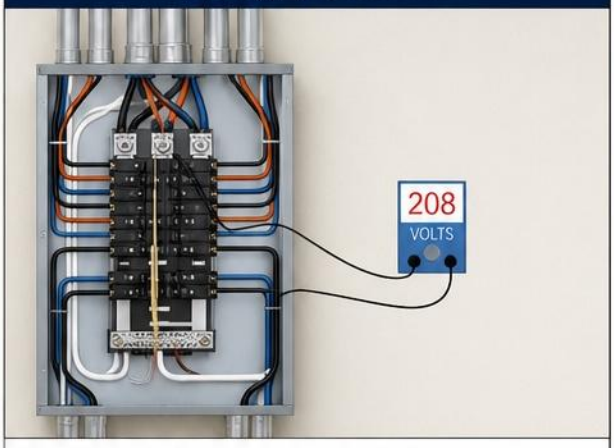
- In accordance with Article 100 definition of 'reconditioned,' replacing a panelboard is not considered reconditioning.

Figure 408-13 Panelboard Replacement Not Listed for the Specific Enclosure 408.9(B)



Replacement panelboards are permitted to be installed in existing enclosures not listed for the specific panelboard if the available fault current is not over 10,000A and the replacement panelboard is identified for the application.

Figure 408-15 Switchboards and Panelboards Bus/Phase Arrangement, High-Leg 408.10(E)(1) Note and 110.15



On a 4-wire, delta-connected, three-phase system, the conductor with the 208V-to-ground must be durably and permanently marked orange by an outer finish or other effective means that is orange at all splices and terminations where the neutral conductor is present.

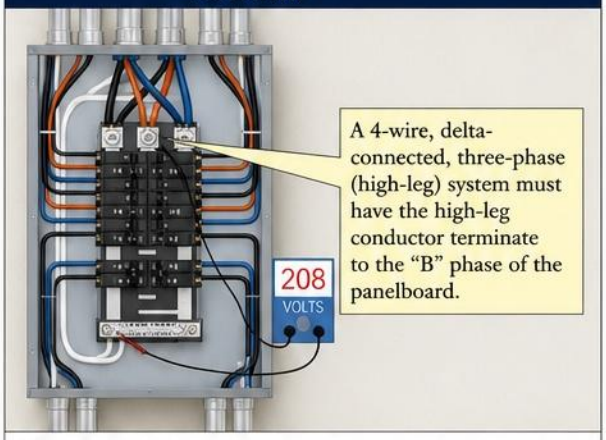
408.10 Busbars and Conductors Arrangement

(E) Bus Arrangement.

(1) Phase Arrangement. Panelboards supplied by a 4-wire, delta-connected, three-phase (high-leg) system must have the high-leg conductor (which operates at 208V to ground) terminate to the B phase of the panelboard. Figure 408-14

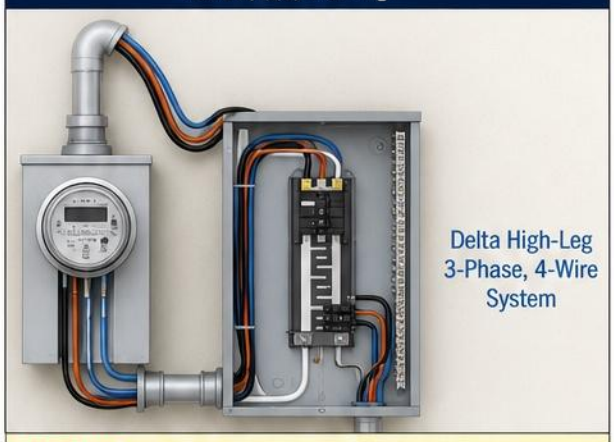
WARNING: In accordance with *ANSI C12.1*, the standard for meter equipment requires the high-leg conductor (208V to neutral) to terminate on the C phase (right) of the meter socket enclosure. This is because the demand meter needs 120V, which it gets from the B phase. Figure 408-16

Figure 408-14 Switchboards and Panelboards Bus/Phase Arrangement, High-Leg 408.10(E)(1)



Note: On a 4-wire, delta-connected, three-phase system, the conductor with the 208V-to-ground must be durably and permanently marked orange by an outer finish or other effective means that is orange at all splices and terminations where the neutral conductor is present [110.15]. Figure 408-15

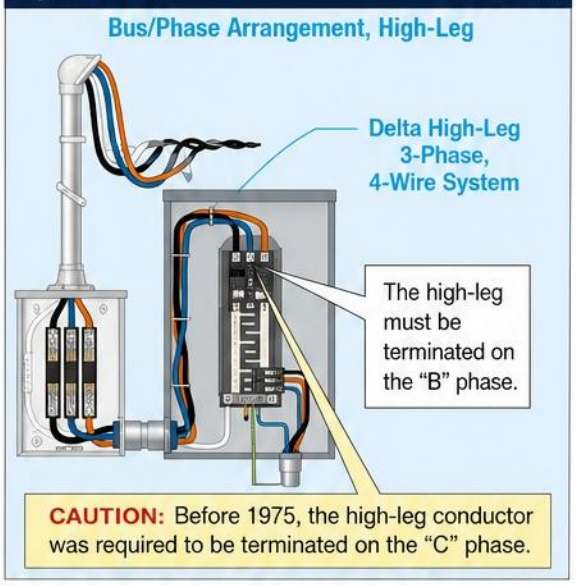
Figure 408-16 Switchboards and Panelboards Bus/Phase Arrangement, High-Leg 408.10(E)(1) Warning



WARNING: ANSI C12.1 standard for meter equipment requires the high-leg conductor (208V to neutral) to terminate on the "C" (right) phase of the meter socket enclosure.

WARNING: When substituting equipment in existing installations that includes a high-leg conductor, take care to ensure the high-leg conductor occupies the same phase position as the original. Before 1975, the high-leg conductor was required to be connected to the C phase on panelboards and switchboards. If the high-leg is not reconnected in accordance with the existing installation, 120V circuits could become inadvertently tied to the 208V high-leg, creating a serious hazard.

Figure 408–17 408.10(E)(1)



High-leg conductor termination requirements for delta high-leg systems.

(F) Switchboard and Panelboard Identification.

(1) High-Leg Identification. A switchboard or panelboard that uses a 4-wire, delta-connected system (with the midpoint of one phase winding grounded) must be identified on the front of the enclosure as follows: "CAUTION _____ PHASE HAS _____ VOLTS TO GROUND."

408.14 Panelboard and Switchboard Ampere Rating

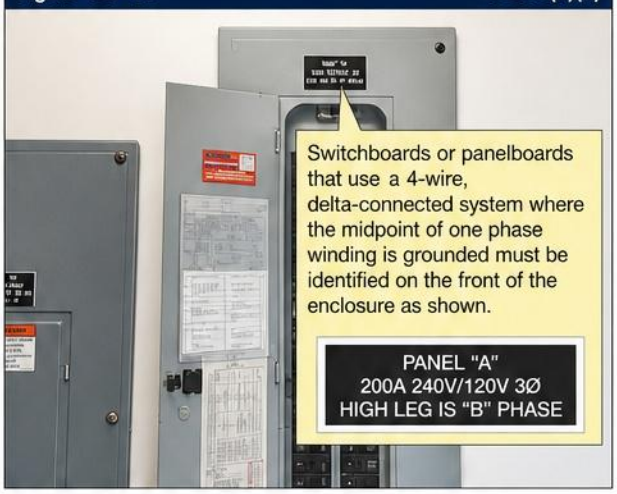
The ampere rating of a switchboard or panelboard must not be less than the calculated load in accordance with Article 120.

Part III. Panelboards

408.36 Overcurrent Protection

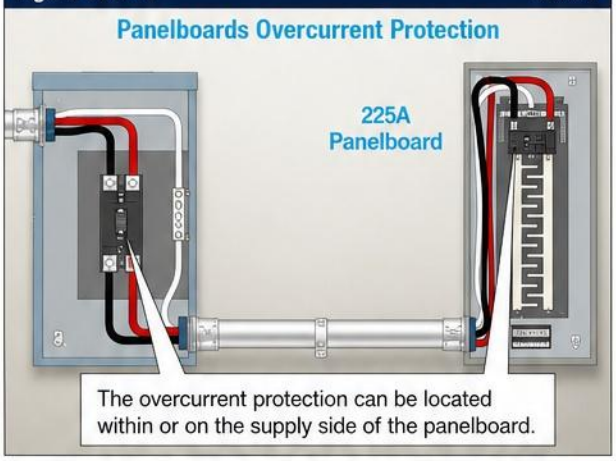
Panelboards must be provided with overcurrent protection at any point on the supply side of the panelboard with a rating not greater than the panelboard.

Figure 408–18 408.10(F)(1)



Identify the enclosure with the required wording on the front.

Figure 408–19 408.36



Overcurrent protection may be installed inside the panelboard or on its supply side.

(B) Panelboards Supplied by a Transformer.

When a panelboard is fed by a transformer, the overcurrent protection for the panelboard must be located either on the secondary side of the transformer, ahead of it, or within the panelboard.

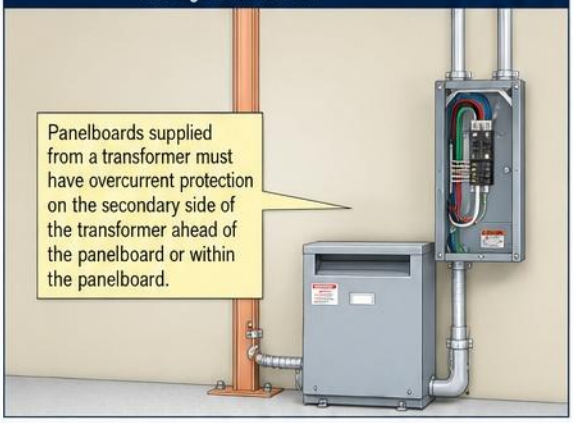
(D) Back-Fed Devices.

Plug-in circuit breakers that are back-fed must be securely fastened in place with a retaining device that requires more than a simple pull to remove the breaker from the panelboard.

Author's Comment:

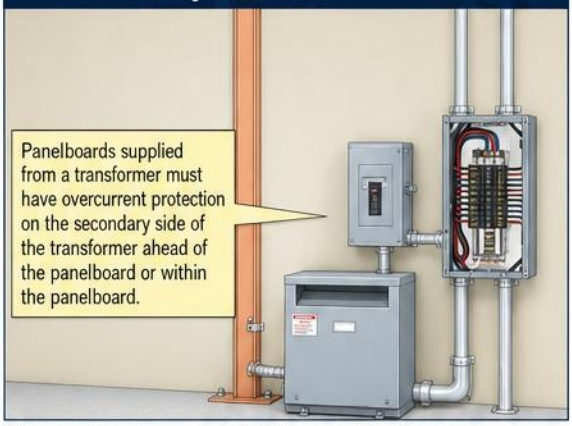
- The purpose of the breaker fastener is to prevent the circuit breaker from being accidentally removed from the panelboard while energized, thereby exposing someone to dangerous voltage.

Figure 408-20 Overcurrent Protection Supplied Through a Transformer 408.36(B)



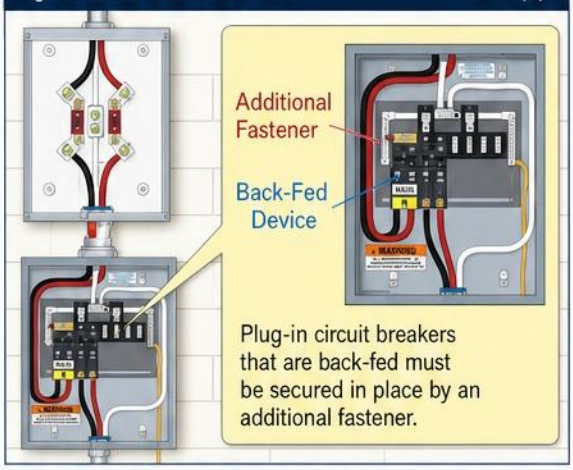
When panelboards are supplied through a transformer, overcurrent protection must be installed on the transformer's secondary, either before the panelboard or within the panelboard.

Figure 408-21 Overcurrent Protection Supplied Through a Transformer 408.36(B)



When panelboards are supplied through a transformer, overcurrent protection must be installed on the transformer's secondary, either before the panelboard or within the panelboard.

Figure 408-22 Back-Fed Devices 408.36(D)

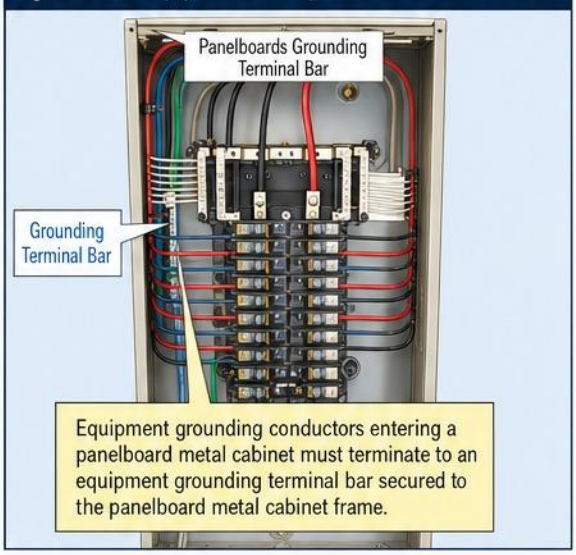


Plug-in circuit breakers that are supplied from the load side (back-fed) must be locked in position using an extra fastener.

408.40 Equipment Grounding Conductor

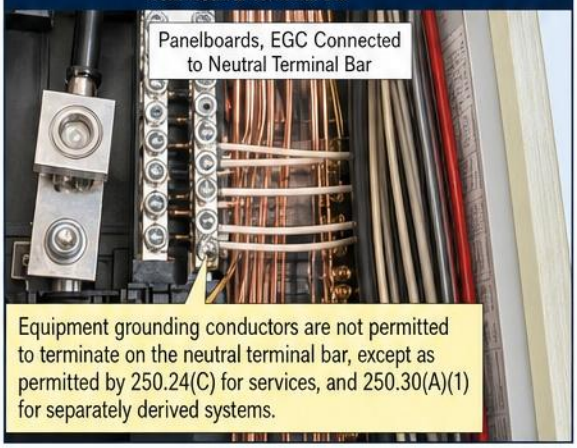
Equipment grounding conductors entering a panelboard metal cabinet must terminate to an equipment grounding terminal bar secured to the panelboard metal cabinet frame. ▶ Figure 408-23

Figure 408-23 Equipment Grounding Conductor Termination 408.40



Equipment grounding conductors are not permitted to terminate on the neutral terminal bar, except as permitted by 250.24(C) for services, and 250.30(A)(1) for separately derived systems. ▶ Figure 408-24

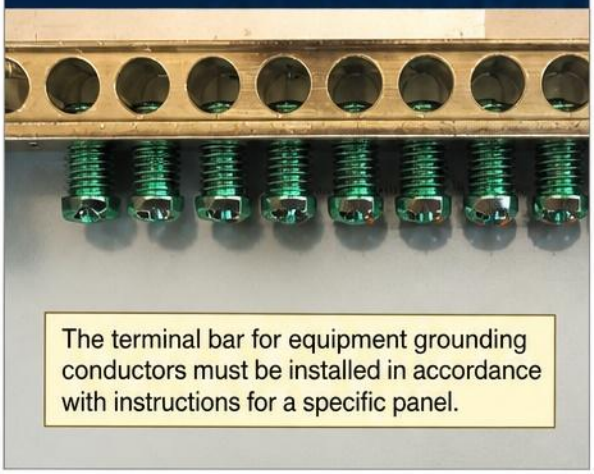
Figure 408-24 Equipment Grounding Conductors Prohibited from Neutral Terminal Bar 408.40



Author's Comment

- The terminal bar for equipment grounding conductors must be installed in accordance with the manufacturer's instructions for a specific panel. ▶ Figure 408-25

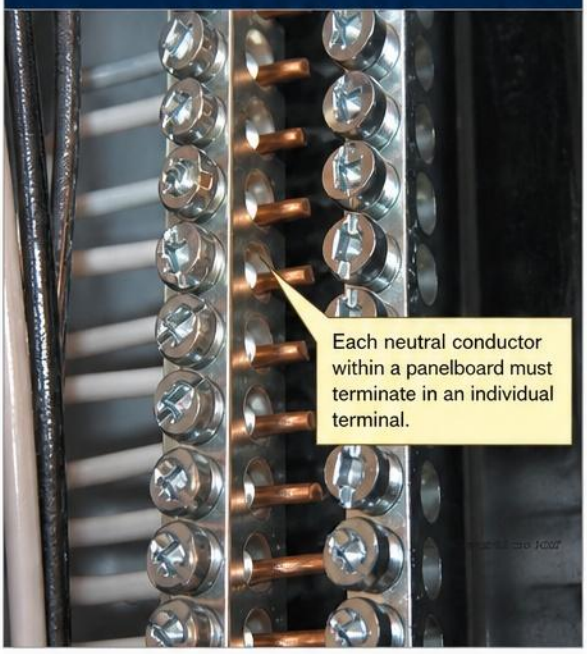
Figure 408–25 | Panelboards, EGC Terminal Manufacturer Instructions 408.40 Comment



408.41 Neutral Conductor Terminations

Each neutral conductor within a panelboard must terminate in an individual terminal. ▸Figure 408–26

Figure 408–26 | Panelboards, Neutral Conductor Terminations 408.41

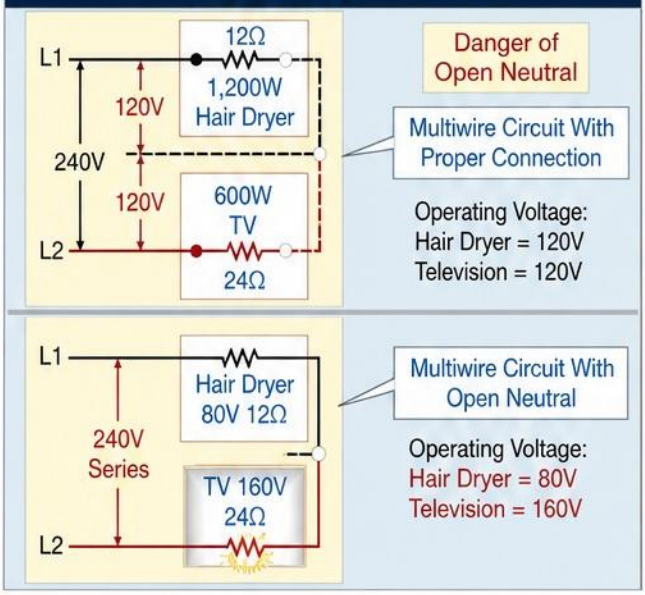


Ex: Neutral conductors run in parallel are permitted to terminate to a single terminal, if the terminal is identified for more than one conductor [110.14(A)].

Author's Comment:

- If two neutral conductors are connected to the same terminal, and someone removes one of them, the other neutral conductor might unintentionally be removed as well. If that happens to the neutral conductor of a multiwire circuit, it can result in excessive line-to-neutral voltage for one of the circuits, as well as undervoltage for the other. See 300.15(B) for details. ▸Figure 408–27

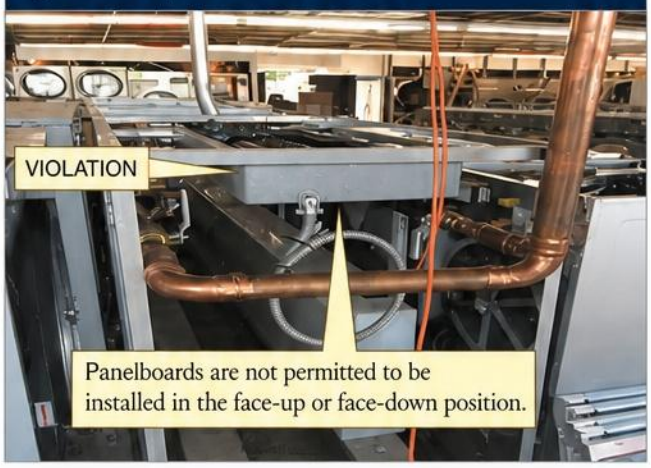
Figure 408–27 | Panelboards, Neutral Conductor Termination *408.41 Comment*



408.43 Panelboard Orientation

Panelboards are not permitted to be installed in the face-up or face-down position. ▸Figure 408–28

Figure 408–28 | Panelboard Orientation 408.43



ARTICLE 410 Luminaires

Introduction to Article 410—Luminaires

This article sets out the requirements for *luminaires*, lighting accessories (intended for temporary, seasonal, or holiday use), portable flexible lighting products, and the associated wiring and equipment. Because luminaires vary in type and intended use, manufacturers' instructions are essential for correct installation. Refer to the *UL Luminaire Marking Guide*, which offers guidance for installing common incandescent, fluorescent, and high-intensity discharge (HID) luminaires.

Luminaire. Equipment intended to illuminate a space or object(s) to support visual tasks, activities, aesthetics, or security.

Figure 410–1 Luminaire — **NEC 100**
Article 100 Definition

Equipment intended to illuminate a space or object(s) to support visual tasks, activities, aesthetics, or security.

Part I. General

410.1 Scope — NEC 410.1

This article sets out the requirements for luminaires and their associated wiring and equipment.

See Figure 410–2.

Figure 410–2 Luminaires — **NEC 410.1**
410.1 Scope

Article 410 establishes the requirements for luminaires and the wiring and equipment that serve them.

410.2 Listing Required — NEC 410.2

Luminaires, lampholders, lighting systems, and retrofit kits must be listed.

See Figure 410–3.

Lampholder. A contact device that provides an electrical connection to a lamp.

See Figure 410–4.

Figure 410–3 Luminaires, Listing Required 410.2

Luminaires, lampholders, lighting systems, and retrofit kits must be listed.

Figure 410–5 Luminaires in Damp Locations 410.10(A)

Luminaires in a damp location must be marked "Suitable for Damp Locations," or "Suitable for Wet Locations."

Figure 410–4 Lampholder *Article 100 Definition*

A contact device that makes an electrical connection to a lamp.

Figure 410–6 Luminaires in Wet Locations 410.10(A)

Luminaires in a wet location must be marked "Suitable for Wet Locations."

Part II. Luminaire Locations

410.10 Luminaires in Specific Locations

(A) Wet or Damp Locations.

Damp Location. Luminaires installed in damp locations must be marked "suitable for wet locations" or "suitable for damp locations" or "suitable for wet locations." **Figure 410–5**

Wet Location. Luminaires installed in wet locations must be marked "suitable for wet locations." **Figure 410–6**

(B) Corrosive Locations. Luminaires installed in corrosive locations must be suitable for the location.

(D) Bathtub and Shower Areas. A luminaire in a bathtub or shower area must meet all the following requirements:

(1) No part of chain or cord-suspended luminaires, track lighting, pendants, or luminaire light kit on ceiling paddle fan can be within 3 ft horizontally and 8 ft vertically of the top of the bathtub rim or shower stall threshold; this zone is all-encompassing and includes spaces over tubs or showers **Figure 410–7**

(2) Luminaires within 8 ft vertically of the top of the bathtub or shower stall (not subject to shower spray) must be marked "suitable for damp locations"; luminaires subject to shower spray must be marked "suitable for wet locations" **Figure 410–8**

Figure 410–7 Luminaires in Bathtub and Shower Zone Where Not Permitted 410.10(D)(1)

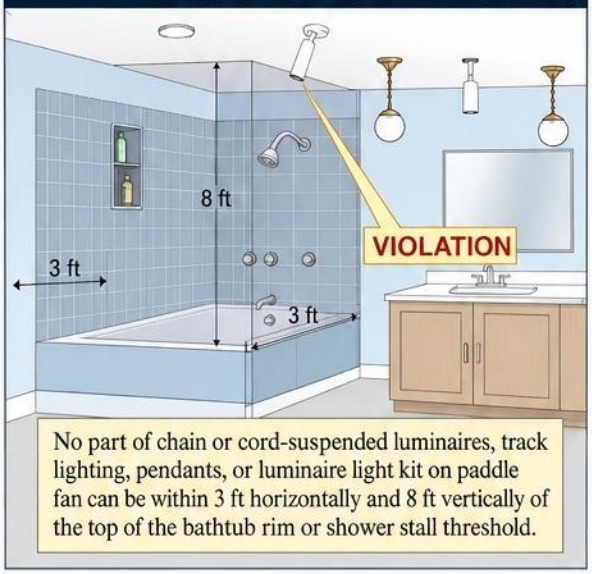
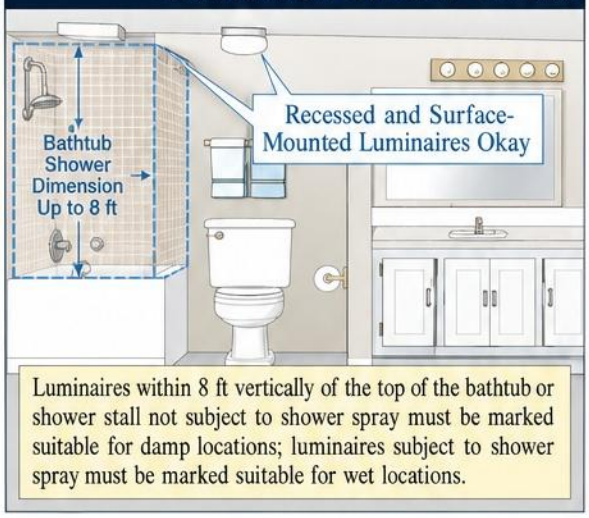


Figure 410–8 Luminaires in Bathtub and Shower Zone Suitable for Damp or Wet Location 410.10(D)(2)

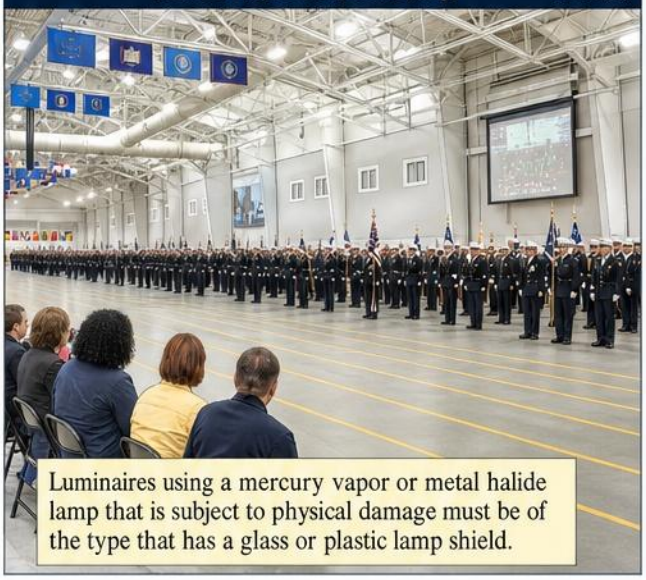


(E) Luminaires in Indoor Sports, Mixed-Use, and All-Purpose Facilities. Luminaires using a mercury vapor or metal halide lamp subject to physical damage and installed in seating areas of indoor sports, mixed-use, or all-purpose facilities must have a glass or plastic lamp shield. Such luminaires can have an additional guard.

(F) Luminaires Installed Under Roof Decking. Luminaires installed under roof decking where subject to physical damage as determined by the AHJ must be installed at least 1½ in. from the lowest surface of the roof decking measured from the bottom of the decking to the top of the luminaire.

Ex: The 1½ in. spacing is not required where metal-corrugated sheet roof decking is covered with a minimum 2 in. thick concrete slab (measured from the top of the corrugated roofing).

Figure 410–9 Luminaires in Sports and Mixed-Use Facilities Subject to Physical Damage 410.10(E)



410.16 Luminaires in Clothes Closets

(A) Clothes Closet Storage Space Definition. The clothes closet storage space is the volume bounded by the sides and back closet walls and planes extending from the closet floor vertically to a height of 6 ft, or to the highest clothes-hanging rod, and parallel to the walls at a horizontal distance of 24 in. from the sides and back of the closet walls, respectively.

The volume extends vertically to the closet ceiling parallel to the walls at a horizontal distance of 12 in. or the width of the shelf (whichever is greater).

For a closet that permits access to both sides of a hanging rod, the *clothes closet storage space* includes the volume below the highest rod extending 12 in. on either side of the rod on a plane horizontal to the floor extending the entire length of the rod. Figure 410–10

> ***Clothes Closet Storage Space.*** The area within a clothes closet in which combustible materials can be kept. Figure 410–11

(B) Luminaire Types Permitted. Only the following types of luminaires are permitted in the clothes closet:

(1) Incandescent or LED luminaires with an enclosed light source

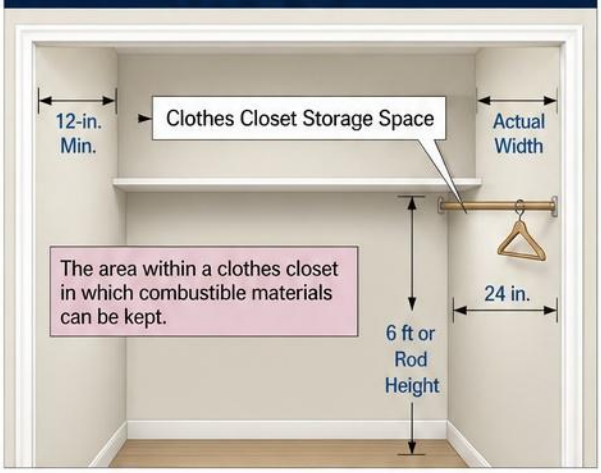
(2) Surface or recessed fluorescent luminaires

(3) Surface fluorescent or surface LED luminaires identified for use within the clothes closet storage space

Figure 410–10 Luminaries, Definition of Clothes Closet Storage Space 410.16(A)

This illustration defines the clothes closet storage space for 410.16(A).

Figure 410–11 Clothes Closet Storage Space Article 100 Definition



This illustration provides the Article 100 definition of clothes closet storage space.

(C) Luminaire Types Not Permitted. Luminaires with open or partially enclosed lamps and pendant luminaires cannot be installed in the clothes closet storage space, unless permitted in 410.16(B). Figure 410–12

(D) Location of Luminaires. Luminaires must maintain a minimum clearance from the clothes closet storage space as follows:

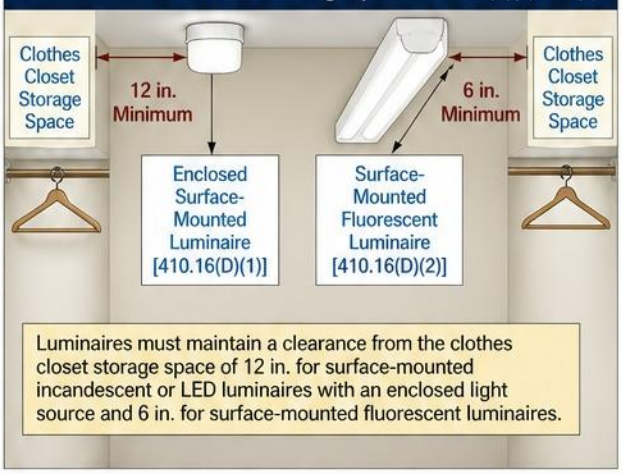
(1) 12 in. for surface incandescent or surface LED luminaires with an enclosed light source

(2) 6 in. for surface fluorescent luminaires Figure 410–13

Figure 410–12 Luminaires, Not Permitted Clothes Closet 410.16(C)

This example shows a pendant luminaire with an open lamp, which is not allowed in a clothes closet unless permitted by 410.16(B).

Figure 410–13 Luminaires, Surface-Mounted Clothes Closet Storage Space 410.16(D)(1) and (2)



Required clearances for surface-mounted luminaires in the clothes closet storage space.

(3) 6 in. for recessed incandescent or recessed LED luminaires with an enclosed light source

(4) 6 in. for recessed fluorescent luminaires ▶ Figure 410–14

Example: Surface fluorescent or surface LED luminaires are permitted within the clothes closet storage space if identified for this use. Figure 410–15

Author's Comment:

▶ In accordance with UL 1598, surface fluorescent or surface LED luminaires used within the clothes closet storage space must be marked "Luminaire is suitable for installation within clothes closet storage space" in the manufacturer's instructions.

Figure 410–14 Luminaires, Recessed Clothes Closets Storage Space 410.16(D)(3) and (4)

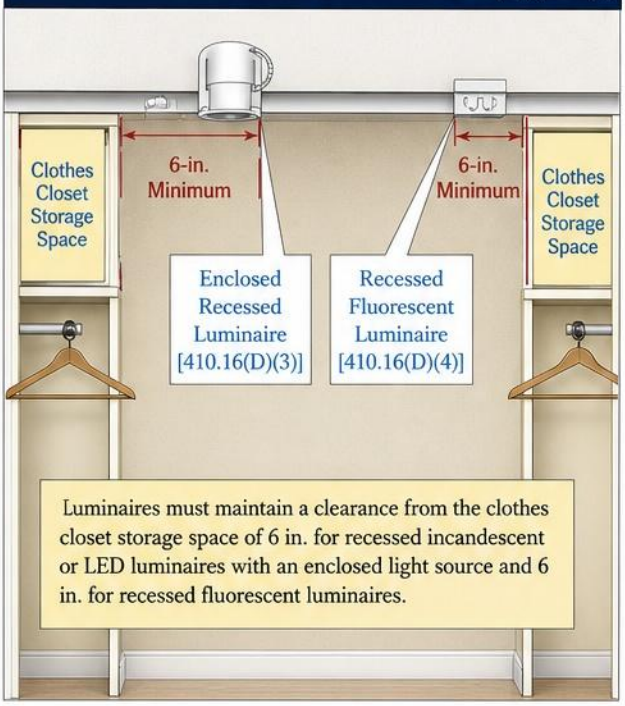
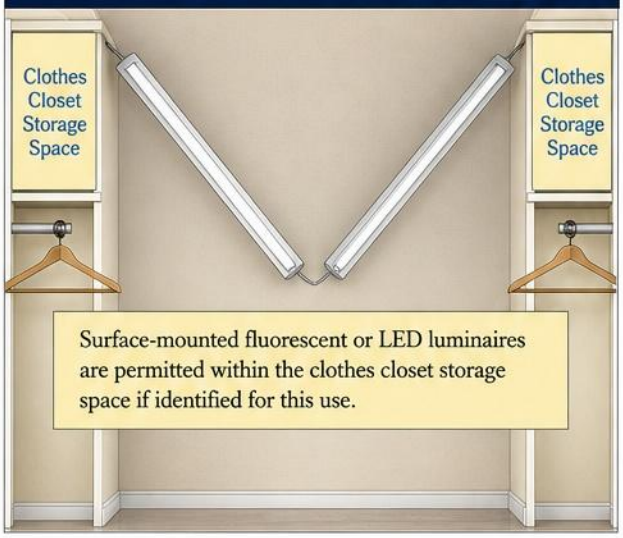


Figure 410–15 Luminaires, Surface-Mounted Identified for Clothes Closet Storage Space 410.16(D) Ex



Part III. Luminaire Outlet Boxes and Covers

410.22 Outlet Boxes to be Covered

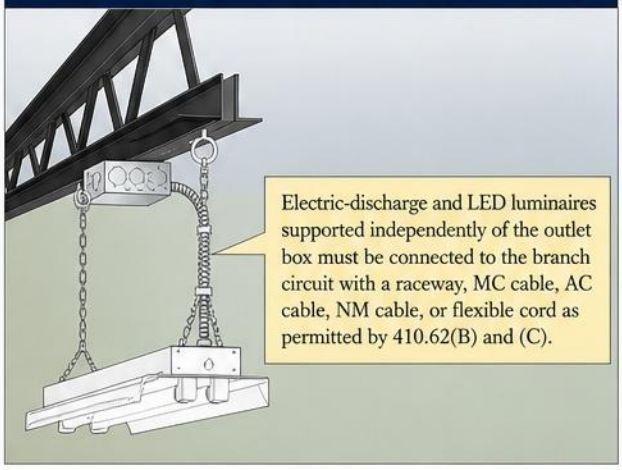
Outlet boxes for luminaires must be covered with a luminaire canopy or provided with a faceplate, or similar device. Figure 410–16

Figure 410–16 Luminaire Outlet Boxes to be Covered 410.22

410.24 Electric-Discharge and LED Luminaire Connection

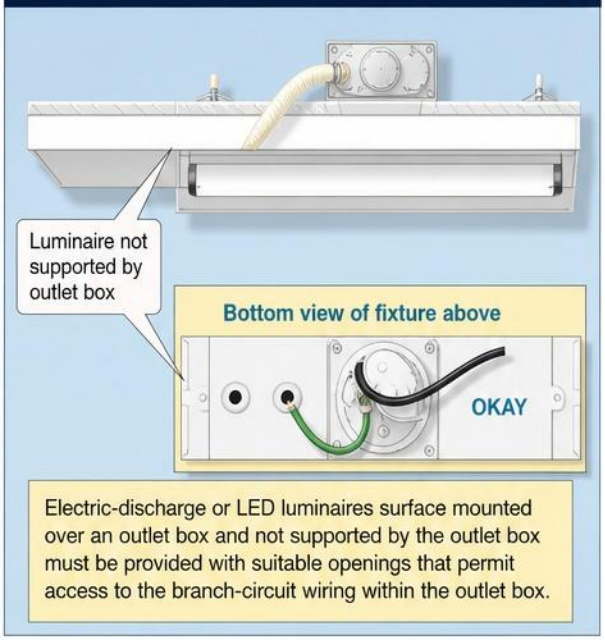
(A) Luminaires Supported Independently of the Outlet Box. Electric-discharge and LED luminaires supported independently of the outlet box must be connected to the branch circuit with a raceway, MC cable, AC cable, NM cable, or flexible cord in accordance with 410.62(B) or (C). Figure 410–17

Figure 410–17 Electric-Discharge and LED Luminaires Supported Independently of Outlet Box 410.24(A)



(B) Access to Outlet Box. Electric-discharge and LED luminaires surface mounted over an outlet box and not supported by the outlet box, must be provided with suitable openings that permit access to the branch-circuit wiring within the outlet box. Figure 410–18

Figure 410–18 Electric-Discharge and LED Luminaires Access to Outlet Box 410.24(B)



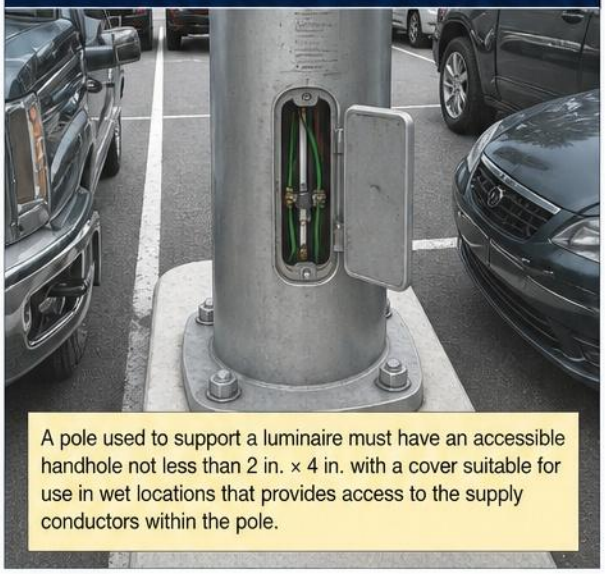
Part IV. Luminaire Supports

410.30 Luminaire Supports

(B) Poles Supporting Luminaires. Poles used to support luminaires can be used as a raceway to enclose supply conductors where the following conditions are met:

(1) Pole used to support a luminaire must have an accessible handhole not less than 2 in. × 4 in. with a cover suitable for use in wet locations that provides access to the supply conductors within the pole. ▸ **Figure 410–19**

Figure 410–19 Luminaire Support Pole Used as Raceway — Accessible Handhole 410.30(B)(1)



Ex 1: A handhole is not required for a pole that supports a luminaire 8 ft or less in height if the supply conductors are accessible by removing the luminaire. ▸ **Figure 410–20**

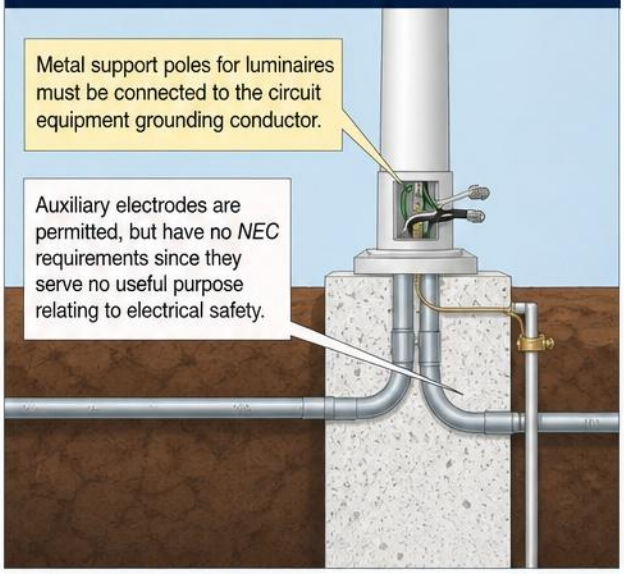
Figure 410–20 Luminaire on Support Pole Used as Raceway — Handhole Not Required 410.30(B)(1) Ex 1

(3) Metal pole must have an equipment grounding terminal accessible from the handhole.

Ex: A grounding terminal is not required for a pole that supports a luminaire 8 ft or less in height above grade if the splices are accessible by removing the luminaire.

(5) Metal poles for luminaires must be connected to the circuit equipment grounding conductor. ▸ **Figure 410–21**

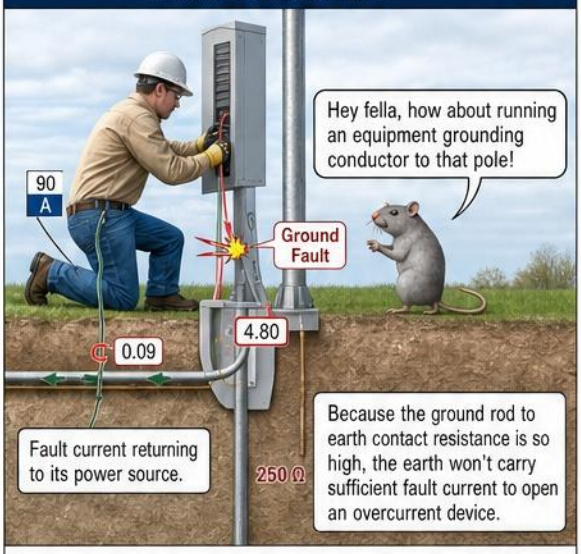
Figure 410–21 Luminaire Support Pole Used as Raceway — Connected to EGC 410.30(B)(5)



DANGER: Because the contact resistance of a ground rod to the earth is so high, little fault current returns to the power supply if it is the only fault current return path. As a result, the circuit overcurrent protective device will not open and clear the ground fault, and the metal pole will become and remain energized by the circuit voltage.

NEC 410.22

Figure 410-22 Ground Rod Not an Effective Fault Current Return Path *NEC 410.22*



A ground rod alone provides too much resistance, so very little fault current returns to the source.

410.36 MEANS OF SUPPORT

(A) Luminaires Supported by Outlet Boxes. Luminaires are permitted to be supported by outlet boxes installed in accordance with 314.23 and must comply with: *NEC 410.23*

Figure 410-23 Luminaires Supported by Outlet Boxes *NEC 410.36(A)*

Luminaires are permitted to be supported by outlet boxes installed in accordance with 314.23.

(1) Outlet boxes must comply with 314.27(A)

(B) Suspended-Ceiling Framing Members. Luminaires can be supported by suspended-ceiling framing members if attached with screws, bolts, rivets, or clips that are listed and identified for such use.

NEC 410.24

Figure 410-24 Luminaires Supported by Suspended-Ceiling Framing Members *NEC 410.24(B)*

Luminaires can be supported by suspended-ceiling framing members if attached with screws, bolts, rivets, or clips that are listed and identified for such use.

AUTHOR'S COMMENT:

- The *NEC* does not require independent support wires for suspended-ceiling luminaires installed in a suspended ceiling. *NEC 410.25*

Figure 410-25 Luminaires in Suspended-Ceiling Independent Support Wires *NEC 410.36(B) Comment*

The *NEC* doesn't require independent support wires for suspended-ceiling luminaires.

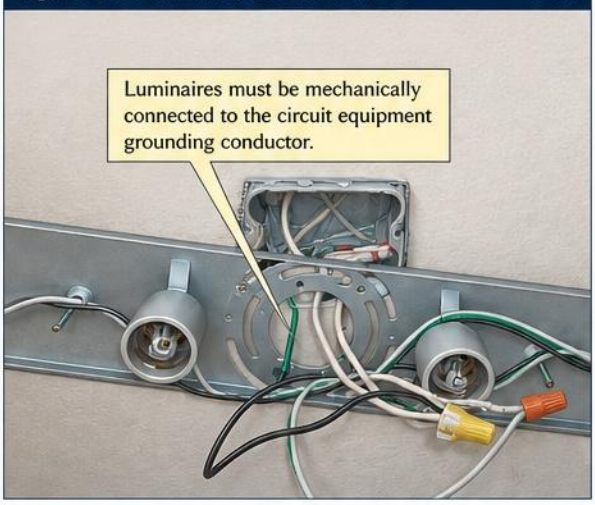
- To verify that you can support suspended ceiling luminaires to ceiling framing members with bolts, screws, or rivets for ceiling grid types light duty, medium duty, and heavy duty, see *ASTM C635* and *C636*.

Part V. Grounding (Bonding)

410.44 Connection to the Equipment Grounding Conductor

Luminaires must be mechanically connected to the circuit equipment grounding conductor. ▸Figure 410–26

Figure 410–26 Luminaires, Connected to an EGC 410.44



The green grounding conductor is bonded to the luminaire housing with a grounding screw, ensuring a mechanical connection to the circuit equipment grounding conductor (EGC).

Ex 2: Where no equipment grounding conductor exists at the outlet, replacement luminaires that are GFCI protected, or do not have exposed conductive parts, are not required to be connected to an equipment grounding conductor.

Part X. Special Provisions for Flush and Recessed Luminaires

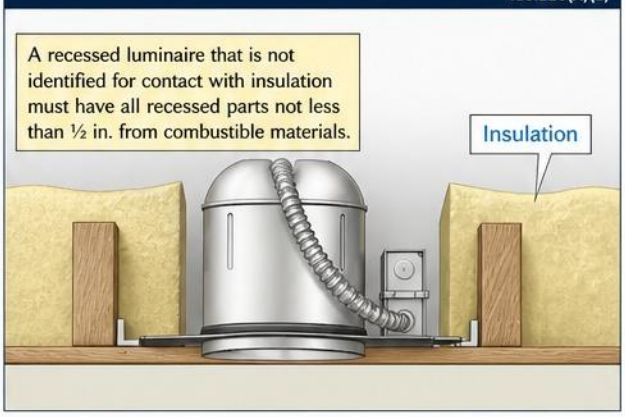
410.116 Clearance and Installation

(A) Clearances from Combustible Materials.

(1) No Contact with Insulation or Combustible Materials. A recessed luminaire not identified for contact with insulation is not permitted to be in direct contact with insulation. It must have all recessed parts except the points of supports not less than ½ in. from combustible materials. ▸Figure 410–27

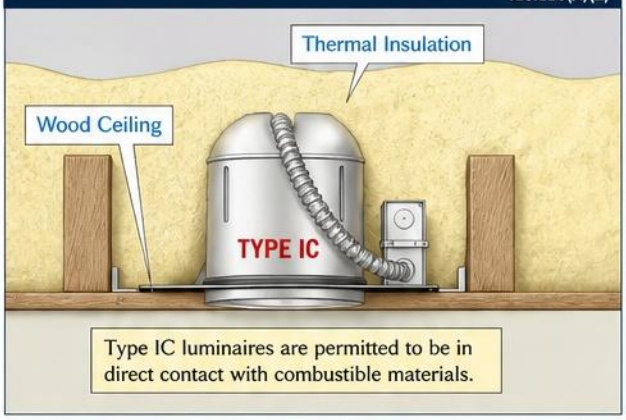
(2) Contact with Insulation or Combustible Materials. A recessed luminaire identified for contact with insulation (IC) is permitted to be in direct contact with insulation and combustible materials. ▸Figure 410–28

Figure 410–27 Recessed Luminaires, Clearance from Combustible Materials, Non-Type IC Luminaires 410.116(A)(1)



This non–Type IC luminaire maintains the required ½-in. clearance between all recessed parts and combustible materials.

Figure 410–28 Recessed Luminaires, Clearance from Combustible Materials, Type IC Luminaires 410.116(A)(2)



Because this luminaire is identified as Type IC, it may be installed in direct contact with thermal insulation and other combustible materials.

Author's Comment:

- A Type IC luminaire has internal thermal protection.

(B) Clearances from Thermal Insulation. Unless the luminaire is identified as Type IC for insulation contact, thermal insulation must not be installed above a recessed luminaire or within 3 in. of the luminaire's enclosure, wiring compartment, ballast, transformer, LED driver, or power supply.

(C) Installation in Fire-Resistant Construction. Where a luminaire is recessed in fire-resistant material in a fire-resistant building construction, the recessed luminaire must satisfy one of the following:

(1) Listed for use in fire-resistance-rated construction
(2) Installed in (or used with) a luminaire enclosure that is listed for use in fire-resistance-rated construction
(3) Listed and installed in accordance with a tested fire-resistance-rated assembly

When a tested fire-resistance-rated assembly permits installation of a recessed fluorescent luminaire, a recessed LED luminaire of comparable construction is allowed.

PART XIII. TRACK LIGHTING

410.150 INSTALLATION

(A) Track Lighting. Track lighting must be permanently installed and permanently connected to the branch-circuit wiring.

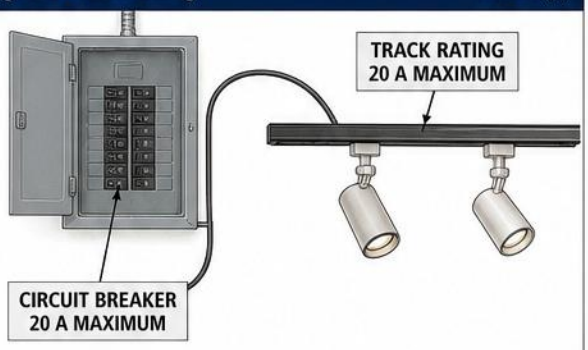
> ***Lighting, Track Lighting.*** A manufactured assembly to support and energize luminaires on a track. Its length can be altered by the addition or subtraction of track section.

(B) Circuit Rating. The connected load is not permitted to exceed the rating of the track and must not be supplied by a circuit whose rating exceeds that of the track.

Figure 1 Permanent Installation 410.150(A)

Track lighting must be permanently installed and permanently connected to the branch-circuit wiring.

Figure 2 Circuit Rating 410.150(B)



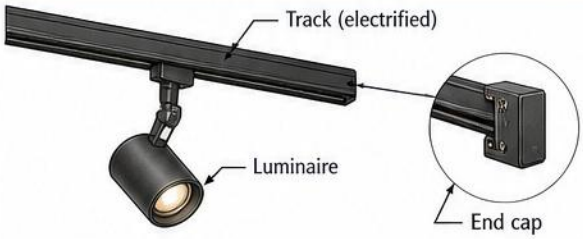
The connected load may not exceed the rating of the track and must not be supplied by a circuit with a higher rating than the track.

(C) Locations Not Permitted.

(1) Subjected to physical damage
(2) Wet or damp locations
(3) Subject to corrosive vapors
(4) Storage battery rooms
(5) Any hazardous location
(6) Concealed
(7) Extended through walls, partitions, or floors
(8) Less than 5 ft above the finished floor, except where protected from physical damage
(9) Within 3 ft horizontally and 8 ft vertically of the top of a bathtub rim or shower space [410.10(D)(1)]

Figure 3 Locations Not Permitted 410.150(C)

Figure 4 Definition—Lighting, Track Lighting 410.150(A) Informational Note



A manufactured assembly to support and energize luminaires on a track. Its length can be altered by the addition or subtraction of track section.

Notes

Overview

The *National Electrical Code* (NEC) establishes requirements that ensure electrical systems are installed in a safe, reliable, and effective manner. These requirements cover a wide range of topics, including wiring methods, equipment installation, grounding, overcurrent protection, and special occupancies.

NEC® requirements are organized by articles, each addressing a specific subject area. Understanding how these articles relate and interact is essential for accurate installations and inspections.

Article 100 – General

Article 100 contains definitions, general requirements, and rules of construction that apply throughout the Code. Key topics include:

- Definitions of terms used throughout the NEC
- General installation requirements
- Approval of equipment and materials
- Electrical connections and fastening
- Working space requirements
- Identification and warning
- Voltage limitations
- Equipment accessibility

These foundational rules support safe installations across all types of electrical systems.

Article 250 – Grounding and Bonding

Article 250 establishes requirements for grounding and bonding electrical systems and equipment to ensure the safety of persons and the proper operation of electrical systems.

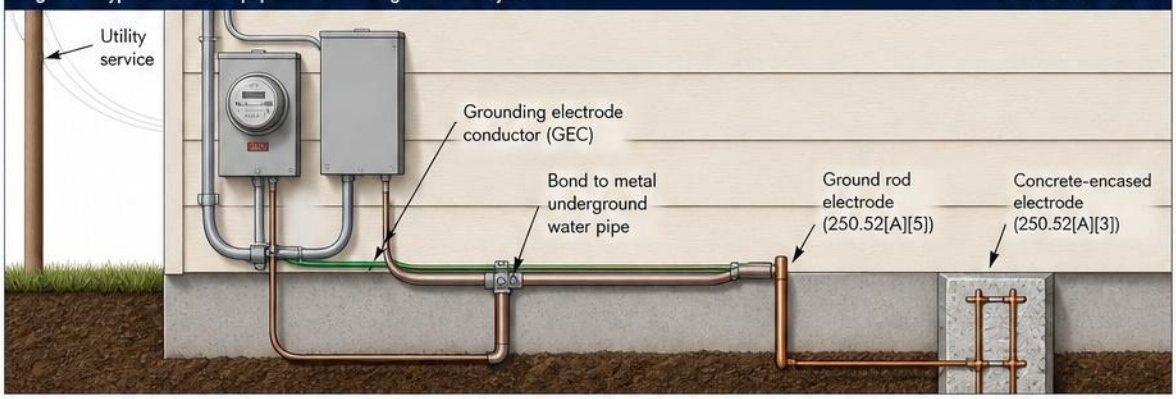
Key requirements include:

- Grounding electrode system (250.50 through 250.70)
- Equipment grounding conductors (250.118)
- Bonding of equipment (250.4)
- Bonding of enclosures and raceways (250.92)
- Service neutral bonding (250.24)
- Separately derived systems (250.30)

Bonding connects metal parts likely to become energized so they remain at the same electrical potential. Grounding connects the system to earth to stabilize voltage and clear faults.

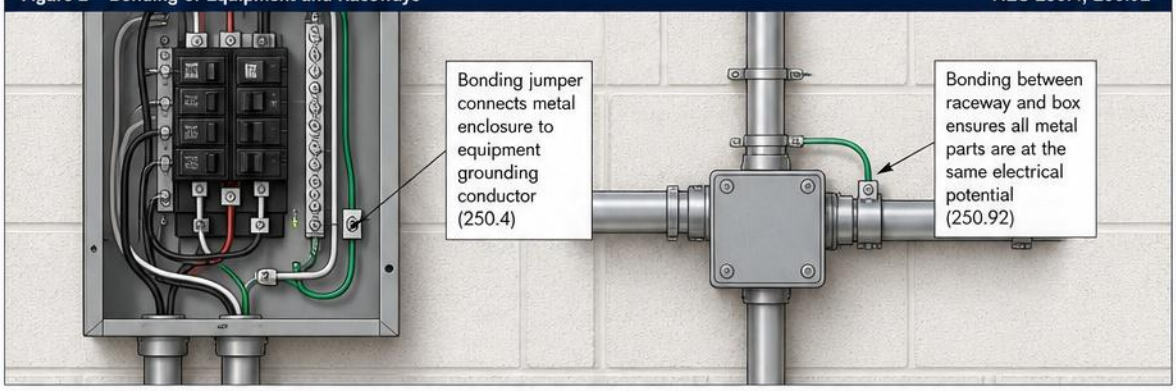
Figure 1 illustrates a typical service equipment grounding electrode system. Figure 2 shows bonding of equipment and raceways within a building.

Figure 1 Typical Service Equipment Grounding Electrode System NEC 250.50–250.70



The grounding electrode system connects the electrical system to earth using one or more electrodes in accordance with NEC 250.50 through 250.70.

Figure 2 Bonding of Equipment and Raceways NEC 250.4, 250.92



Bonding ensures metal parts likely to become energized remain at the same electrical potential, reducing shock hazard and supporting the effective operation of protective devices.

ARTICLE 411 Low-Voltage Lighting

Introduction to Article 411—Low-Voltage Lighting

Article 411 addresses low-voltage lighting systems and related components. These systems are commonly used for landscape lighting, under kitchen cabinets, or for display lighting in commercial buildings, art galleries, and museums. Keep in mind that the smaller size of this article might lead to the mistaken belief that low-voltage lighting doesn't matter. In reality, these systems are limited in voltage, but the permitted current can be up to 25A, which presents a possible fire hazard.

411.1 Scope

The requirements for low-voltage lighting systems and their associated components are covered in this article.

Figure 411–1

Figure 411–1 Scope 411.1

Article 411 covers the requirements for low-voltage lighting systems and their associated components.

411.2 Listing Requirements

(A) Listed System. A low-voltage lighting system may include a listed low-voltage lighting system, which comprises a power supply and luminaires.

Figure 411–2

Figure 411–2 Listed Low-Voltage Lighting System 411.2(A)

A listed low-voltage lighting system includes the power supply and luminaires.

(B) Assembly of Listed Parts. A low-voltage lighting system can be assembled using the following listed and identified parts:

(1) Low-voltage luminaires

(2) Power supply

(3) Low-voltage luminaire fitting

(4) Approved cables or any Chapter 3 wiring method

411.4 Low-Voltage Lighting Systems

Low-voltage lighting systems consist of an isolating power supply, luminaires, and associated equipment.

(A) Power Supply Limitations. The output rating of each low-voltage lighting circuit is not permitted to exceed 25A.

Figure 411–3 Low-Voltage Lighting Systems Power Supply Limitations 411.4(A)

The output rating of each low-voltage lighting circuit is not permitted to exceed 25A.

(B) Voltage Limitations. Low-voltage lighting systems are limited to 30 Vac or 60 Vdc in dry locations; and 15 Vac or 30 Vdc in wet locations.

Figure 411–4 Low-Voltage Lighting Systems Voltage Limitations 411.4(B)

Low-voltage lighting systems are limited to 30 Vac or 60 Vdc in dry locations and 15 Vac or 30 Vdc in wet locations.

411.6 Specific Location Requirements

(A) Concealed Wiring. Conductors concealed or installed through a wall, floor, or ceiling must comply with one of the following:

(1) Use a Chapter 3 wiring method

(2) Supplied by a listed Class 2 power-limited power supply, Class 2 power-limited cables installed in accordance with 725.130

(B) Pools, Hot Tubs, Fountains, and Similar Locations. Low-voltage lighting systems must not be located less than 10 ft horizontally from the nearest edge of the water, unless permitted by 680.22(B)(6).

Figure 411–5 Low-Voltage Lighting Systems Pools, Spas, and Fountains 411.6(B)

Low-voltage lighting systems must not be located less than 10 ft horizontally from the nearest edge of the water, unless permitted by 680.22(B)(6).

Author's Comment:

- Low-voltage lighting supplied by a transformer that is listed, labeled, and identified for swimming pools can be installed within 5 ft of the water [680.22(B)(6)].

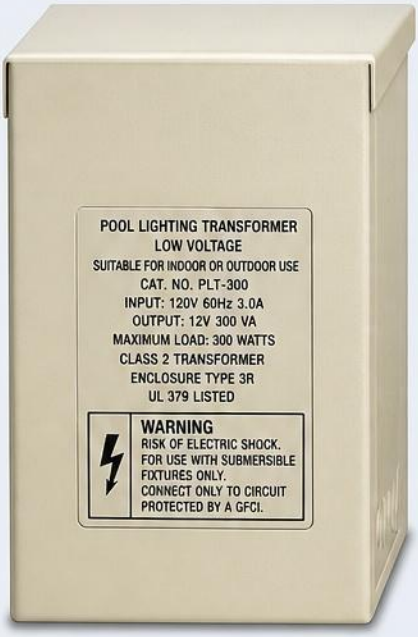
Figure 411–6

411.8 Branch Circuit

(A) Lighting Systems Supplied by Class 2 Power Sources. Conductors and equipment supplying Class 2 power sources must comply with 725.127.

(B) Lighting Systems Supplied by Other than Class 2 Power Sources. The branch circuit that supplies other than Class 2 power sources for low-voltage lighting covered by this article is not to exceed 20A.

Figure 411-6 Low-Voltage Lighting Systems Pools, Spas, and Fountains **411.6(B)(6)**



Low-voltage lighting for swimming pools is provided by a transformer that is listed, identified, and intended for that application and that is installed within 5 feet of the water [680.22(B)(6)].

Notes

Article 100
Scope

This Code covers the installation and inspection of electrical equipment, wiring, and materials that supply alternating current at 50 to 1000 volts or direct current at 120 to 1500 volts.

It also applies to related equipment such as conductors, controls, fittings, devices, appliances, and raceways installed for light, heat, power, communication, signaling, and fire alarm systems.

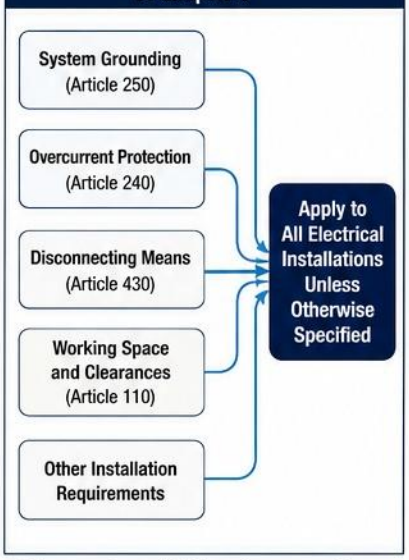
The purpose of this Code is the practical safeguarding of persons and property from hazards arising from the use of electricity.

Article 90
Introduction

Chapter 9 contains requirements that apply generally to electrical installations in all occupancies unless a more specific requirement is provided in another article.

These rules cover system grounding (Article 250), overcurrent protection (Article 240), disconnecting means (Article 430), working space and clearances (Article 110), and other fundamental installation practices essential for safe and reliable operation.

Figure 90.1 General Scope of Chapter 9



Chapter 9 establishes the general rules that apply to electrical installations across all occupancies unless a more specific requirement is provided elsewhere in the Code.

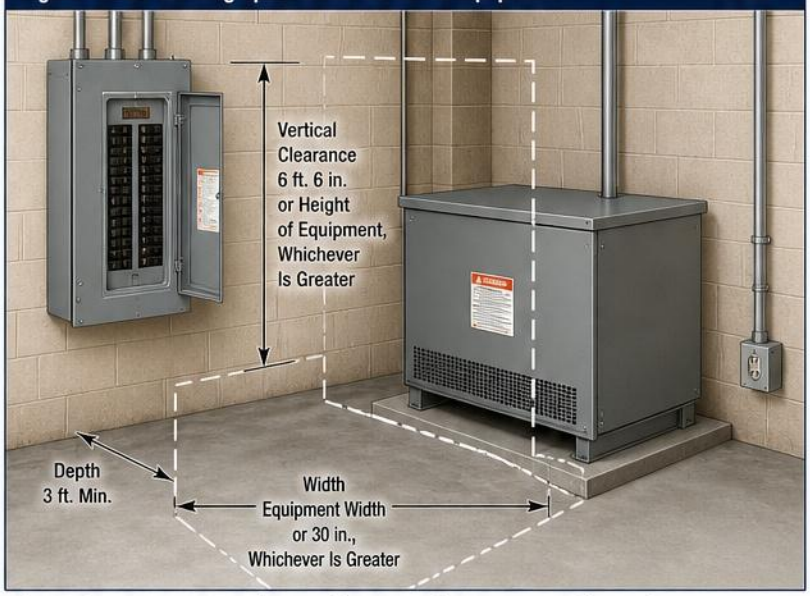
Article 110
General Requirements for Electrical Installations

Electrical installations must be planned, installed, and used so that they are safe for people and property and are suitable for their intended purpose.

Equipment must be installed in a neat and workmanlike manner. It must be accessible for operation, inspection, testing, and maintenance without requiring removal of building parts or damage to the structure.

Electrical installations must also provide ample working space and safe access to equipment.

Figure 110.26 Working Space About Electrical Equipment 110.26

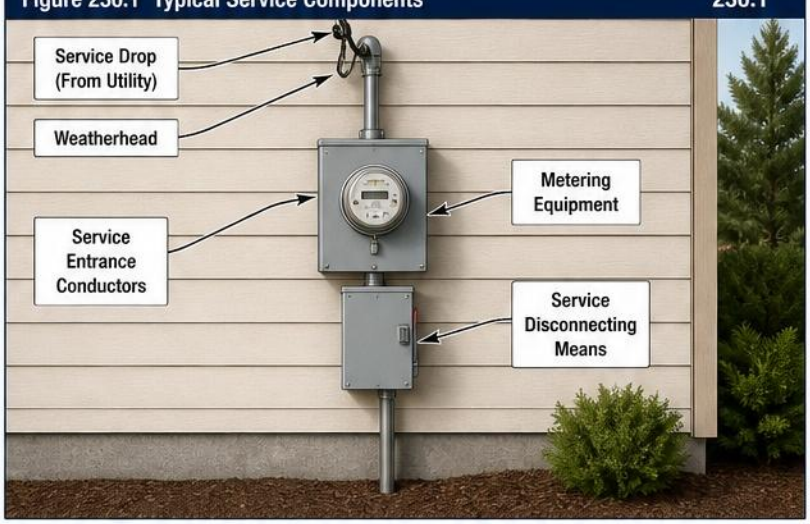


Electrical equipment must have sufficient working space to allow safe access for operation, inspection, testing, and maintenance.

Article 230
Services

A service is the conductors and equipment that deliver electrical power from the serving utility to the service disconnecting means. Services include service conductors, service-entrance conductors, metering equipment, and related fittings.

Figure 230.1 Typical Service Components 230.1



A service includes all conductors and equipment that supply power from the serving utility to the service disconnecting means.

ARTICLE 422 Appliances

INTRODUCTION TO ARTICLE 422—APPLIANCES

This article specifies the requirements for electrical appliances that are installed in any location and are intended to remain in place, or that are connected by a flexible cord and plug. Examples include ranges, ovens, cooktops, refrigerators, drinking water coolers, and beverage dispensers.

Part I. General

422.1 Scope

This article sets forth the rules for electrical appliances in any location.

Figure 422–1 Appliances 422.1 Scope NEC 422.1

Examples of appliances covered by Article 422 in any location.

422.2 Listing Required

Appliances must be included in a list published by a recognized testing laboratory.

422.5 GFCI Protection

(A) Appliances. Appliances with a rating of 60A or less and that are not connected to systems exceeding 150V to ground (120V, 208V, 240V, 120/240V, 208Y/120V) must be provided with GFCI protection.

(1) Automotive vacuum machines

Figure 422–2 Automotive Vacuum Machines NEC 422.5(A)(1)

(2) Drinking water coolers and bottle fill stations

(3) Cord-and-plug-connected high-pressure spray washing machines

(4) Tire inflation machines

(5) Vending machines

(6) Sump pumps

Figure 422–3 Drinking Water Coolers, and Bottle Fill Stations NEC 422.5(A)(2)

Drinking water coolers, and bottle fill stations rated 60A or less and not over 150V to ground must be GFCI protected.

Figure 422–4 Tire Inflation Machines NEC 422.5(A)(4)

Tire inflation machines rated 60A or less and not over 150V to ground must be GFCI protected.

Figure 422–5 Vending Machines NEC 422.5(A)(5)

Vending machines rated 60A or less and not over 150V to ground must be GFCI protected.

Figure 422–6 Sump Pumps NEC 422.5(A)(6)

Sump pumps rated 60A or less and not over 150V to ground must be GFCI protected.

Figure 422–7 Dishwashers NEC 422.5(A)(7)

Dishwashers rated 60A or less and not over 150V to ground must be GFCI protected.

Note: See 210.8 which specifies requirements for GFCI protection for branch-circuit outlets where the location warrants such protection.

(B) Type and Location. The GFCI must be *readily accessible*, *listed*, and be *within* a:

(1) GFCI circuit breaker

(2) GFCI faceless device or receptacle

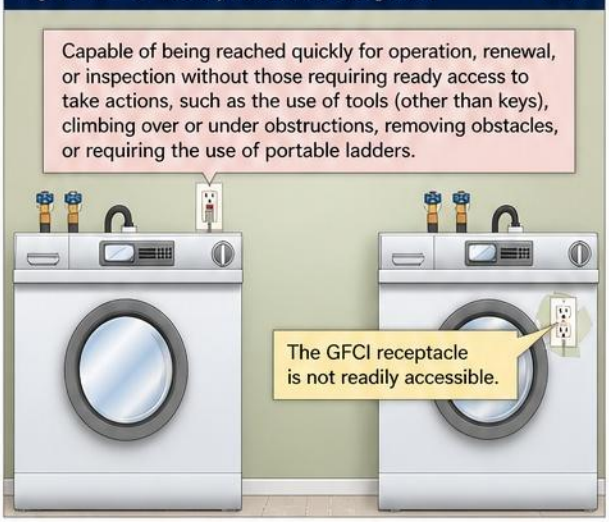
(3) GFCI integral with the attachment plug

(4) GFCI within the supply cord not more than 12 in. from the attachment plug

(5) Factory installed GFCI within the appliance

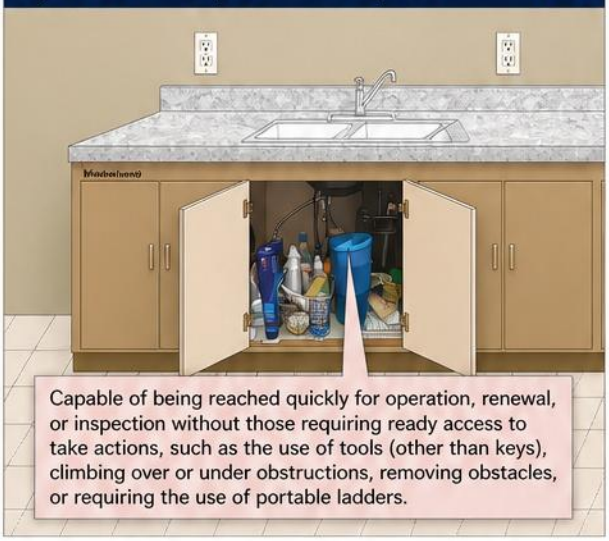
Accessible, Readily Accessible. Capable of being reached quickly for operation, renewal, or inspection without those requiring ready access to take actions, such as the use of tools (other than keys), climbing over or under obstructions, removing obstacles, or requiring the use of portable ladders. ▶ 422–8 and ▶ 422–9

Figure 422–8 Readily Accessible Receptacles 422.8



The GFCI receptacle is not readily accessible.

Figure 422–9 Readily Accessible Receptacles 422.9



The receptacles above the countertop are readily accessible.

Author's Comment:

- GFCIs are required to be tested monthly in accordance with the manufacturer's instructions. Because GFCIs can only be properly tested by pressing the GFCI test button, they must be in a readily accessible location.

PART II. BRANCH-CIRCUIT REQUIREMENTS

422.10 BRANCH CIRCUITS

(A) Individual Branch Circuit.

(1) Branch-circuit conductors must have an ampacity not less than the marked rating of the appliance in accordance with the manufacturer's instructions. ▶ 422.10

Figure 422–10 Individual Branch-Circuit Conductor Ampacity 422.10(A)(1)

Tankless Water Heater

Name	ECO55B2	ECO65BA	ECO90B2	ECO140B	ECO180B
Wattage	5.5kW	6.5kW	9kW	6.5kW	18kW
Voltage	240V	240V	240V	240V	240V
Max. Amperage	23A	27A	37.5A	58A	75A
Required Breaker	1x30AMP Double Pole	1x30AMP Double Pole	1x40AMP Double Pole	1x60AMP Double Pole	2x40AMP Double Pole
Wire Gauge	1x 10 AWG/2 with Grounding	1x 10 AWG/2 with Grounding	1x 8 AWG/2 with Grounding	1x 6 AWG/2 with Grounding	2x 8 AWG/2 with Grounding
Dimensions	11.2"x15.25"x4.9"	10.2"x15.74"x2.05"	11.2"x16"x3.3"	11.4"x15.87"x3.46"	12.2"x17.2"x5.4"

Branch-circuit conductors must have an ampacity not less than the marked rating of the appliance in accordance with manufacturer instructions.

(B) Branch Circuits Supplying Two or More Loads. The ampere rating of a branch circuit supplying appliances and other loads is determined in accordance with 210.23.

422.11 OVERCURRENT PROTECTION

(A) Branch-Circuit Overcurrent Protection. The branch-circuit overcurrent protection device rating is not permitted to exceed the protective device rating marked on the appliance.

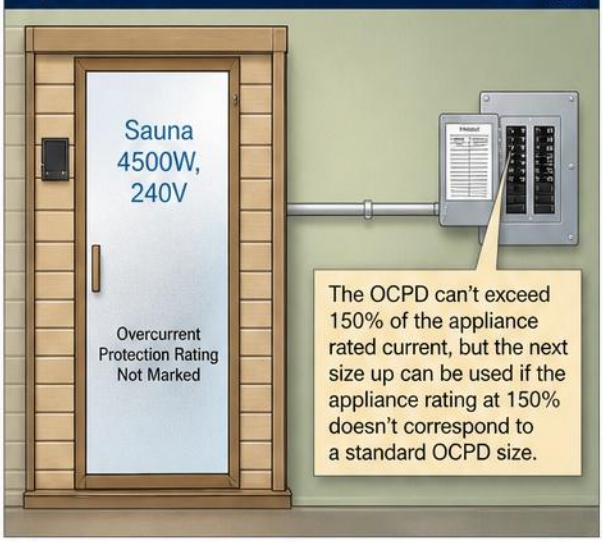
(E) Nonmotor Appliances. The appliance overcurrent protection must not:

(1) Exceed the overcurrent protection rating marked on the appliance

(2) Exceed 20A if the overcurrent protection rating is not marked, and the appliance is rated 13.30A or less

(3) Exceed 150 percent of the appliance rated current if the overcurrent protective device rating is not marked and the appliance is rated over 13.30A; where 150 percent of the appliance rating does not correspond to a standard overcurrent protective device ampere rating listed in 240.6(A), the next higher standard rating is permitted ▶ 422.11

Figure 422–11 422.11(E)(3)



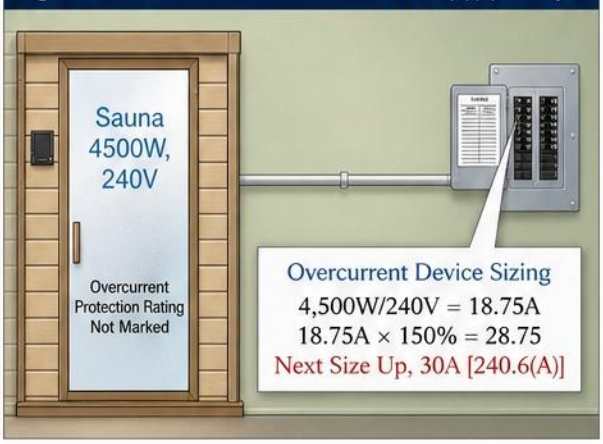
A sauna appliance with an OCPD whose rating is not marked. The OCPD cannot exceed 150 percent of the appliance current rating, but the next higher standard size is permitted if 150 percent does not match a standard OCPD size.

▶ Appliance Overcurrent Protection Sizing [422.11(E)(3)] Example

Question: *What is the maximum size overcurrent protective device required for a 4,500W, 240V sauna?* ▶Figure 422–12

(a) 20A (b) 30A (c) 40A (d) 50A

Figure 422–12 422.11(E)(3) Example



Solution:

Step 1: *Determine the circuit current rating.*

$I = P/E$

Circuit Current = 4,500W/240V

Circuit Current = 18.75A

Step 2: *Determine the overcurrent protection rating [422.11(E)(3)].*

OCPD Rating = 18.75A × 150%

OCPD Rating = 28.75A, next size up 30A

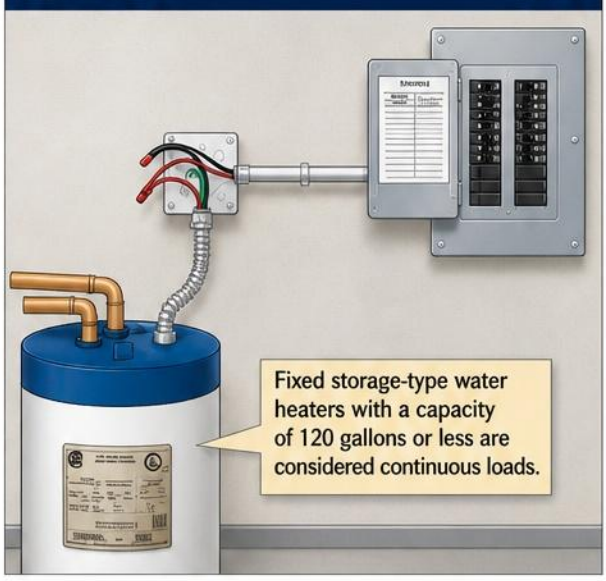
OCPD = 30A [240.6(A)]

Answer: (b) 30A

422.13 Storage Water Heaters

Fixed storage-type water heaters with a capacity of 120 gallons or less are considered continuous loads. ▶Figure 422–13

Figure 422–13 422.13



A fixed storage-type water heater with a capacity of 120 gallons or less is treated as a continuous load.

Author's Comment:

▶ The branch circuit for storage water heaters must be sized at 125 percent of the current rating of the nameplate in accordance with 210.19(A)(1).

➤ Storage Water Heater Conductor Size [422.13 and 210.19(A)(1)] Example

Question: What size conductor is needed for a 4,500W, 240V water heater? **Figure 422-14**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

Figure 422-14 Storage-Type Water Heater Branch-Circuit Sizing [422.13 and 210.19(A)(1)] Example **422.13, 210.19(A)(1)**

*Terminals Rated 60°C [110.14(C)(1)(*a*)(2)]

Solution:

Step 1: Find the branch-circuit rating for a continuous load [210.19(A)(1) and 422.13].

Circuit Current = 4,500W/240V
Circuit Current = 18.75A
Circuit Rating = 18.75A × 125%
Circuit Rating = 23.44A

Step 2: Select the conductor size using [110.14(C)(1)(a)(2) and Table 310.16].

Circuit Conductor = 10 AWG rated 30A at 60°C [110.14(C)(1)(a)(2) and Table 310.16]

Answer: (b) 10 AWG

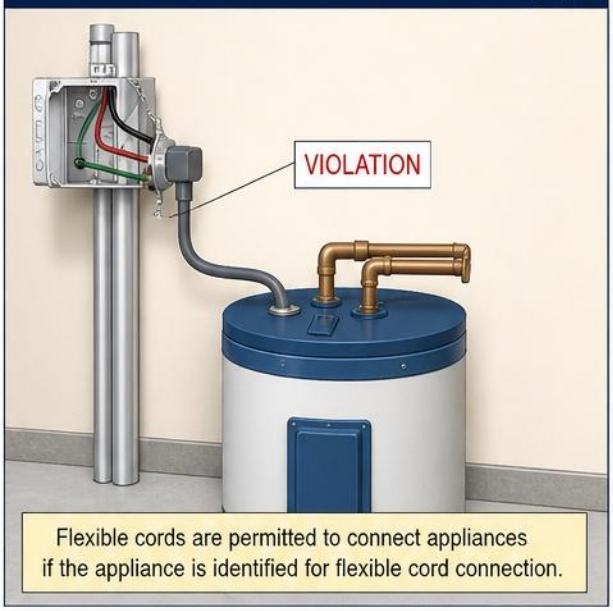
422.16 Flexible Cords

(A) General. Flexible cords are permitted to be used to:

(1) Connect appliances to facilitate their frequent interchange or to prevent the transmission of noise or vibration [400.10(A)(6) and (A)(7)]

(2) Make it easier to remove or disconnect appliances when the appliance is identified for flexible cord connection [400.10(A)(8)] **Figure 422-15**

Figure 422-15 Appliances Flexible Cord Connection **422.16(A)(2)**



(B) Specific Appliances.

(1) In-Sink Waste Disposal. A power-supply cord is permitted for an in-sink waste disposal if:

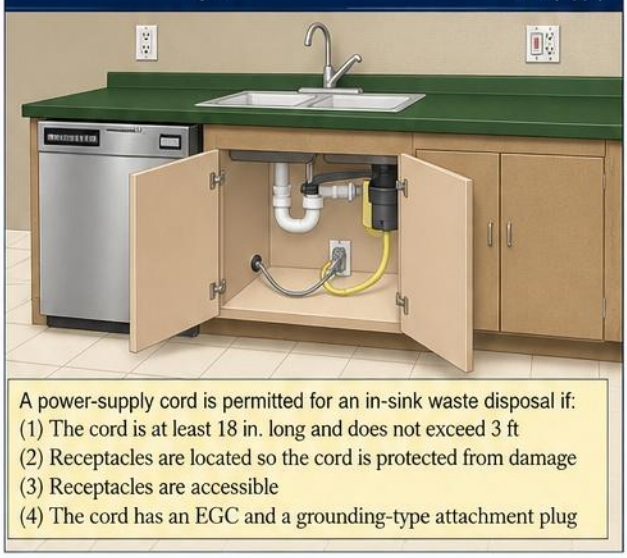
(1) The power-supply cord is at least 18 in. long and does not exceed 3 ft

(2) Receptacles are located so that the power-supply cord is protected from damage

(3) Receptacles are accessible

(4) Power-supply cord has an equipment grounding conductor and is terminated with a grounding-type attachment plug **Figure 422-16**

Figure 422-16 Appliances, Cord Connected Disposal **422.16(B)(1)**

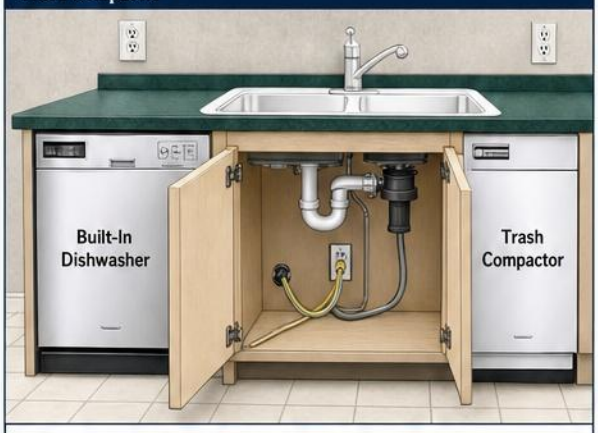


Ex: A listed appliance distinctly marked to identify it as protected by a system of double insulation is not required to be terminated with a grounding-type attachment plug.

(2) Built-In Dishwashers and Trash Compactors. A power-supply cord is permitted for a dishwasher or trash compactor if:

(1) For a trash compactor, the power-supply cord cannot be less than 3 ft or exceed 4 ft measured from the face of the attachment plug to the rear plane of the appliance ▶ Figure 422–17

Figure 422–17
Appliances, Cord Connected Trash Compactor 422.16(B)(2)(1)



The power supply cord cannot be less than 3 ft or exceed 4 ft in length, measured from the face of the attachment plug to the rear plane of the appliance.

(2) For a dishwasher, the power-supply cord cannot be less than 3 ft or exceed 6½ ft measured from the face of the attachment plug to the rear plane of the appliance ▶ Figure 422–18

Figure 422–18
Appliances, Cord Connected Dishwasher 422.16(B)(2)(2)

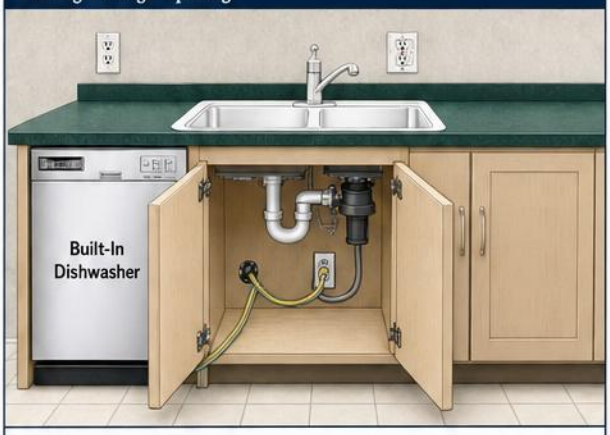
The power supply cord cannot be less than 3 ft or exceed 6½ ft in length, measured from the face of the attachment plug to the rear plane of the appliance.

(3) Receptacles are located so that the power-supply cord is protected from damage

(4) Receptacle for a trash compactor must be in the space occupied by the trash compactor or be in the space adjacent to the trash compactor; if a power-supply cord passes through an opening, it must be protected against damage by a bushing, grommet, smoothed edged, or other approved means

(5) Receptacle for the dishwasher is in the space adjacent to the dishwasher; if the power-supply cord passes through an opening, it must be protected against damage by a bushing, grommet, smoothed edged, or other approved means ▶ Figure 422–19

Figure 422–19
Appliances, Cord Connected Dishwasher Passing Through Opening 422.16(B)(2)(5)



If the power supply cord passes through an opening, it must be protected against damage by a bushing, grommet, smoothed edged, or other approved means.

(6) Receptacle is accessible

(7) Power-supply cord has an equipment grounding conductor and is terminated with a grounding-type attachment plug

Ex: A listed appliance distinctly marked to identify it as protected by a system of double insulation is not required to be terminated with a grounding-type attachment plug.

Author's Comment:

▶ The GFCI-type receptacle for the dishwasher is not permitted because it is not in a readily accessible location as required by 210.8.

(3) Wall-Mounted Ovens and Counter-Mounted Cooking Units. Wall-mounted ovens and counter-mounted cooking units can be cord-and-plug-connected with a flexible cord identified as suitable for the purpose in the appliance manufacturer's instructions. ▶ Figure 422–20

Figure 422–20 Wall-Mounted Ovens and Counter-Mounted Cooking Units Cord-and-Plug Connected 422.16(B)(3)

(4) Range Hoods and Microwave Oven/Range Hood Combinations. Range hoods and over-the-range microwave ovens with integral range hoods are permitted to be cord-and-plug-connected with a power-supply cord. The power-supply cord must be identified as suitable for use on range hoods in the appliance manufacturer's instructions where all the following conditions are met: ▶ Figure 422–21

Figure 422–21 Range, Microwave, and Oven Hoods Cord-and-Plug-Connected 422.16(B)(4)

(1) Power-supply cord is not less than 18 in. and does not exceed 4 ft long.

(2) Receptacles are located to protect against physical damage to the power-supply cord.

(3) Receptacles are supplied by an individual branch circuit.

(4) Receptacles are accessible.

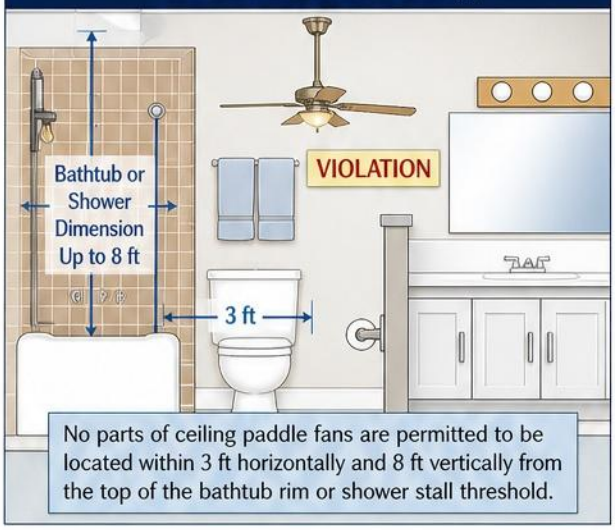
(5) Power-supply cords have an equipment grounding conductor and are terminated with a grounding-type attachment plug.

Ex: A listed appliance distinctly marked to identify it as protected by a system of double insulation is not required to be terminated with a grounding-type attachment plug.

422.18 Ceiling Paddle Fans

(B) Location. No parts of ceiling paddle fans are permitted to be located within 3 ft horizontally and 8 ft vertically from the top of the bathtub rim or shower stall threshold. ▶ Figure 422–22

Figure 422–22 Appliances, Ceiling Paddle Fans in Bathtub or Shower Zone 422.18(B)



422.20 Outlet Boxes to be Covered

Fan outlet boxes must have a cover, unless covered by a ceiling paddle fan canopy. ▶ Figure 422–23

Figure 422–23 Appliances, Ceiling Paddle Fan Outlet Boxes to be Covered 422.20

Part III. Disconnecting Means

422.30 Disconnect—General

Each appliance is required to be provided with a disconnecting means.

422.31 Permanently Connected Appliance Disconnects

(A) Appliances of Any VA Rating. A disconnecting means for a hard-wired appliance is required to be located within sight and not more than 50 ft from the appliance in accordance with 110.29, or the disconnect must be lockable open in accordance with 110.25.

See Figure 422–24 and Figure 422–25.

Figure 422–24 422.31(A)

Appliances, Disconnecting Means Within Sight

The disconnect for a hardwired appliance is required to be within sight from the appliance in accordance with 110.29.

Figure 422–25 422.31(A)

Appliances, Disconnecting Means Not Within Sight

If the disconnect for a hardwired appliance is not within sight, the disconnect must be lockable open in accordance with 110.25.

(B) Motor-Operated Appliances Rated Over ⅛ Horsepower. Motor-operated hard-wired appliances rated over ⅛ horsepower must have a disconnect within sight and not more than 50 ft from the appliance in accordance with 110.29, or the disconnect must be lockable open in accordance with 110.25.

422.33 Cord-and-Plug-Connected Appliances

(A) Attachment Plug. For cord-and-plug-connected appliances, the attachment plug and receptacle can serve as the appliance disconnect.

See Figure 422–26.

Figure 422–26 422.33(A)

Appliances, Disconnecting Means Attachment Plug

The attachment plug and receptacle can serve as the appliance disconnect.

ARTICLE 424 Fixed Electric Space-Heating Equipment

Introduction to Article 424—Fixed Electric Space-Heating Equipment

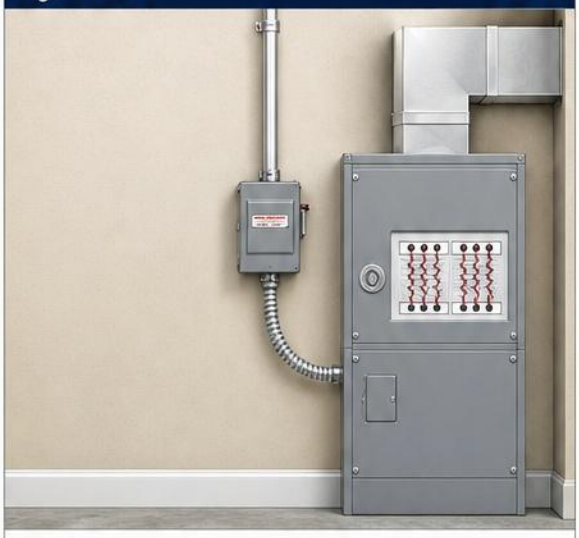
Article 424 specifies requirements for fixed electrical equipment used for space heating. This includes heating cables, unit heaters, boilers (such as those used for radiant heating), central heating systems, or other fixed electric space-heating equipment.

Part I. General

424.1 Scope

This article specifies requirements for fixed electrical space-heating equipment. ▶ Figure 424–1

Figure 424–1 424.1



Article 424 specifies requirements for fixed electrical space-heating equipment.

424.2 Listing Requirements

The following equipment must be listed:

(1) Electric baseboard heaters

(2) Heating cables

(3) Duct heaters

(4) Radiant heating systems

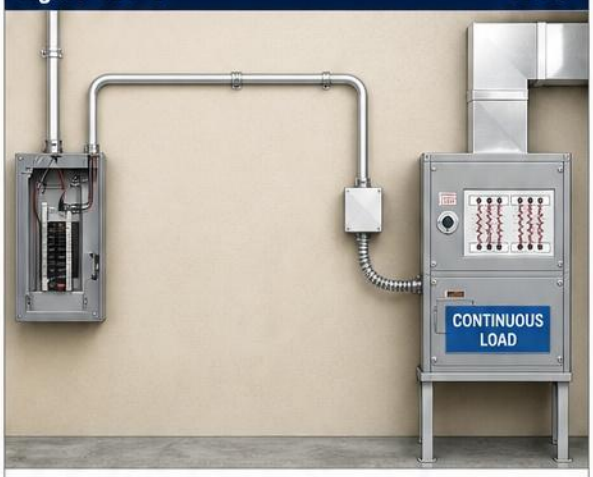
(5) Low-voltage fixed electric space-heating equipment

Note: For low-voltage fixed electric space-heating equipment requirements, see Article 424, Part X.

424.5 Continuous Load

Fixed electrical space-heating equipment and its associated motor loads are considered continuous loads. ▶ Figure 424–2

Figure 424–2 424.5



Fixed electrical space-heating equipment and its associated motor loads are considered continuous loads.

Author's Comment

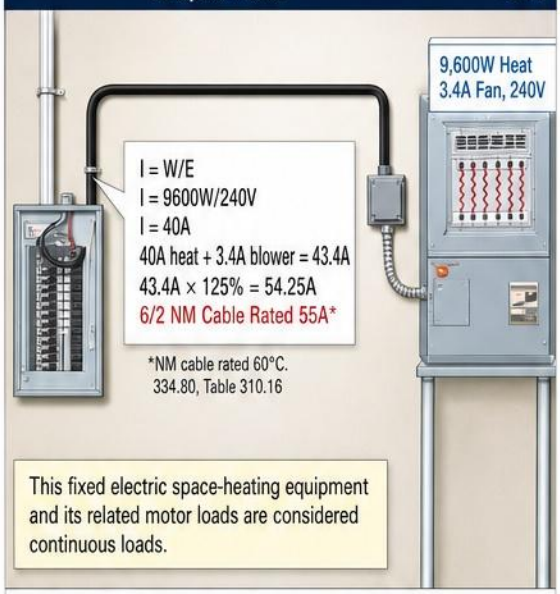
▶ The branch circuit for fixed electric space-heating equipment must be sized at 125 percent of the current rating of the nameplate in accordance with 210.19(A)(1).

▶ Conductor Ampacity—Space Heater [210.19(A)(1) and 424.5] Example

Question: *What size NM cable is needed for a 9,600W, 240V fixed electric space heater with a 3.4A, 240V blower motor?*
▶ Figure 424–3

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

Figure 424–3 Continuous Load Calculation for Space Heater 210.19(A)(1) 424.5



Use the total load and apply the 125 percent rule to determine conductor size.

Solution:

Step 1: *Determine the total load.*

I = Watts/Volts
I = 9,600W/240V
I = 40A

Total amperes = 40A (heat) + 3.4A (blower)
Total amperes = 43.4A

Step 2: *Select conductors at 125 percent of the total current load [110.14(C)(1)(a)(2), 210.19(A)(1), 424.5(B), and Table 310.16].*

Conductor = 43.4A × 125%
Conductor = 54.25A
Conductor = 6 AWG rated 55A at 60°C

Note: *Size the overcurrent protective device at 125 percent of the total current load [210.20(A), 240.4(B), and 240.6(A)].*

Overcurrent protection = 43.4A × 125%
Overcurrent protection = 54.25A, use the next size up: 60A [240.6(A)]

Answer: *(c) 6 AWG*

Part III. Fixed Electric Space-Heating Equipment

424.19 Disconnecting Means

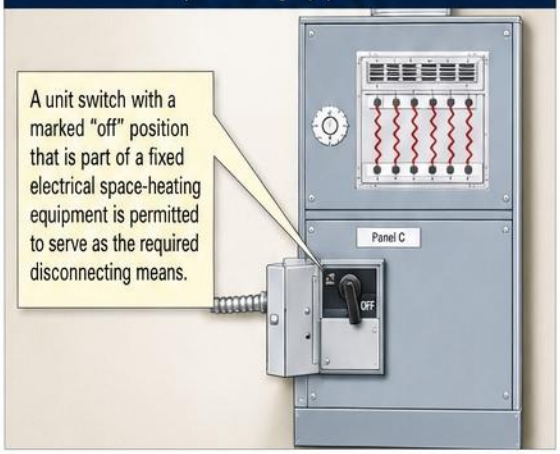
(B) Heating Equipment Without Supplementary Overcurrent Protection. The disconnect for fixed electrical space-heating equipment must be within sight and not more than 50 ft from the heating equipment in accordance with 110.29, or the disconnect must be lockable open in accordance with 110.25.
▶ Figure 424–4

Figure 424–4 Disconnecting Means for Space-Heating Equipment Without Overcurrent Protection 424.19(B)

The disconnect for fixed electrical space-heating equipment must be within sight and not more than 50 ft from the heating equipment in accordance with 110.29, or the disconnect must be lockable open in accordance with 110.25.

(C) Unit Switch(es) as Disconnecting Means. A unit switch(es) with a marked "off" position that is part of a fixed electrical space-heating equipment that opens all phase conductors is permitted to serve as the required disconnecting means. ▶ Figure 424–5

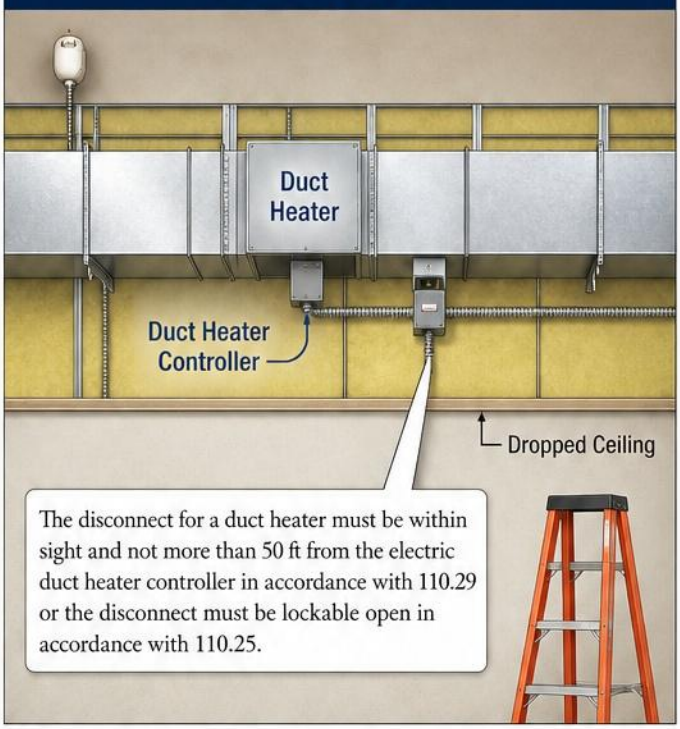
Figure 424–5 Unit Switch as Disconnecting Means for Space-Heating Equipment 424.19(C)



424.65 Location of Disconnecting Means for Electric Duct Heater

The disconnect for a duct heater must be within sight and not more than 50 ft from the electric duct heater controller in accordance with 110.29 or the disconnect must be lockable open in accordance with 110.25.

Figure 424–6 Duct Heater Controller Disconnect, Location | **424.65**



The disconnecting means for a duct heater must comply with proximity and locking requirements as specified.

Article 100 Definitions

The NEC® begins with Article 100, which contains important definitions used throughout the Code. Understanding these terms is essential for interpreting and applying Code requirements correctly.

Article 110 General Requirements

Article 110 sets forth general installation requirements that apply to all electrical systems unless modified elsewhere in the Code.

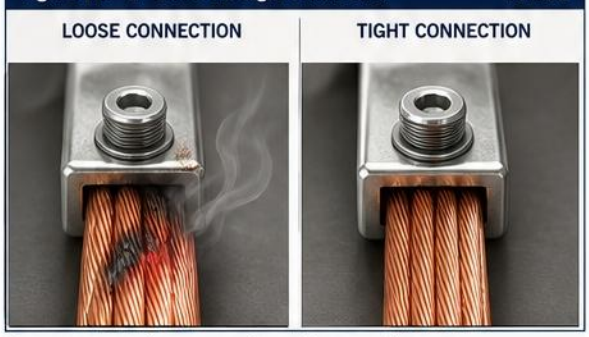
110.3 Approval

Electrical equipment must be approved. Approval ensures the equipment has been tested and evaluated for safety and performance.

110.12 Electrical Connections

Electrical connections must be tight and secure. Loose connections can cause overheating, arcing, and potential failure.

Figure 110–1 Loose vs. Tight Connection 110.12

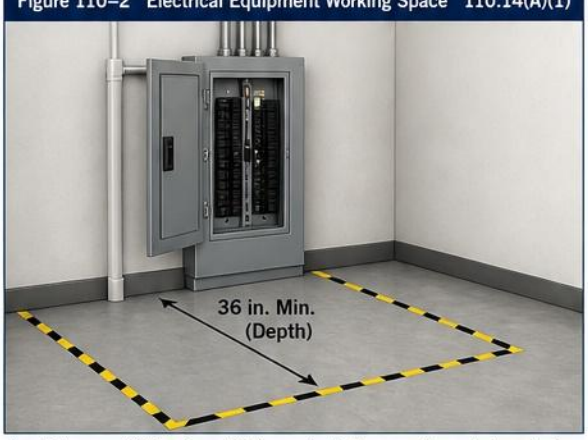


Loose connections create heat that can damage equipment and pose a fire hazard. Connections must be tightened to the manufacturer's torque specifications.

110.14 Electrical Equipment Working Space

Sufficient working space must be provided and maintained in front of electrical equipment to allow safe operation and maintenance.

Figure 110–2 Electrical Equipment Working Space 110.14(A)(1)

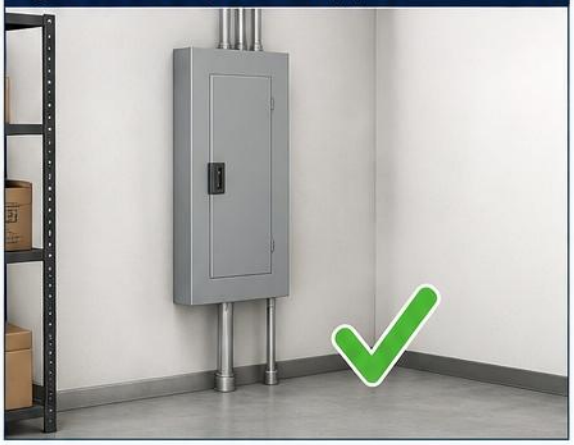


A minimum 36 inches (914 mm) of clear and unobstructed depth must be provided in front of electrical equipment.

110.15 Electrical Equipment Access and Readily Operable

Electrical equipment must be readily accessible and operable. Equipment must not be located in areas where access is likely to be obstructed.

Figure 110–3 Readily Accessible Equipment 110.15



110.16 Guarding of Live Parts

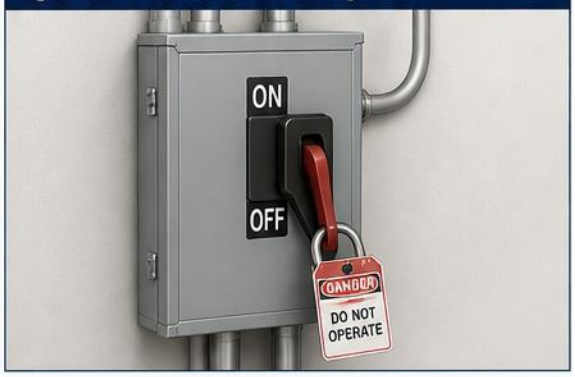
Live parts operating at 50 volts or more to ground must be guarded to prevent accidental contact.

Figure 110–4 Guarding Live Parts 110.16

110.26 Disconnecting Means

Each branch circuit and feeder must be provided with a disconnecting means that is capable of being locked in the open position.

Figure 110–5 Lockable Disconnecting Means 110.26



ARTICLE

430 Motor Circuits, Controllers, and Adjustable-Speed Drives

INTRODUCTION TO ARTICLE 430—MOTOR CIRCUITS, CONTROLLERS, AND ADJUSTABLE-SPEED DRIVES

Article 430 sets forth the specific requirements for installing motors, motor circuits, and motor controllers. It covers conductor sizing, short-circuit and ground-fault protection, motor overload protection, controller requirements, and disconnecting means. These rules apply to individual motors and to motor branch circuits, as well as to motor feeder and control systems, including adjustable-speed drives.

Part I. General

430.1 Scope

This article establishes the requirements for motor branch-circuit and feeder conductors sizing, including short-circuit and ground-fault protection, motor overload protection, motor control circuits, motor controllers, and adjustable-speed drives. ▶ Figure 430–1

Figure 430–1 Motor Circuits, Controllers, and Adjustable-Speed Drives 430.1 Scope

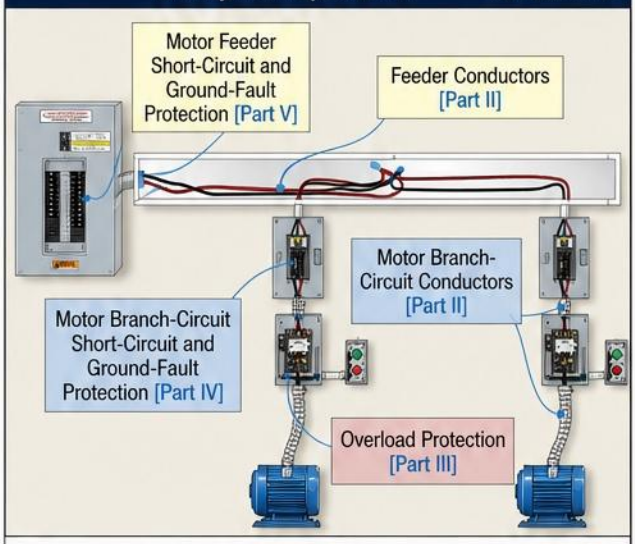
Article 430 sets forth the requirements for conductor sizing, short-circuit and ground-fault protection, overload protection, control circuits, controllers, and adjustable-speed drives for motors.

Author's Comment:

- This article is divided into fourteen parts, the most important being: ▶ Figure 430–2

- Part I—General
- Part II—Conductor Sizing
- Part III—Overload Protection
- Part IV—Branch-Circuit Short-Circuit and Ground-Fault Protection
- Part V—Feeder Short-Circuit and Ground-Fault Protection
- Part VI—Motor Control Circuits
- Part VII—Motor Controllers
- Part VIII—Motor Control Centers
- Part IX—Disconnecting Means
- Part X—Adjustable-Speed Drives
- Part XIV—Full-Load Current Tables

Figure 430–2 Motor Circuits, Controllers, and Adjustable-Speed Drives 430.1 Comment



This illustration shows the relationship of feeder and branch-circuit conductors, short-circuit and ground-fault protection, and overload protection in motor circuits.

Note 1: For the arrangement of this article, see Note Figure 430.1 in the *NEC*.

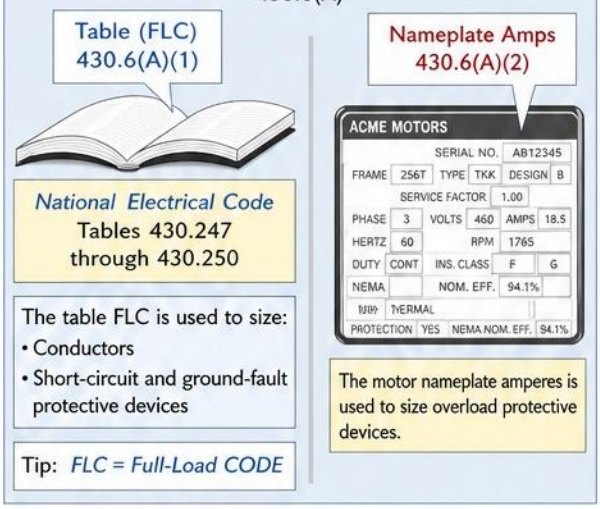
Note 3: The requirements related to air-conditioning and refrigerating equipment with hermetic refrigerant motor-compressors are contained in Article 440—not Article 430.

430.6 Motor Table Full-Load Current versus Motor Nameplate Current Rating

(A) General Requirements. Motor current ratings used for the application of this article are determined by 430.6(A)(1) and (A)(2).

Figure 430–3 **430.6(A)**

Motor Table FLC versus Motor Nameplate Amperes 430.6(A)



Motor table full-load current (FLC) and motor nameplate current values are used for different sizing purposes.

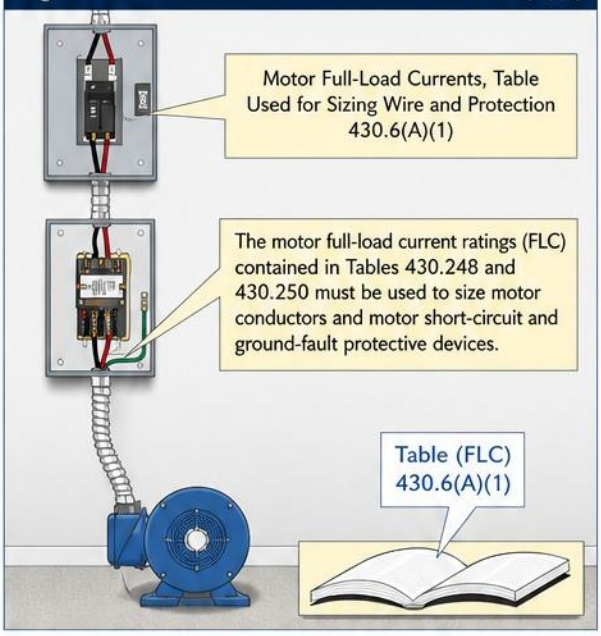
(1) Table Full-Load Current (FLC). The motor full-load current ratings contained in Tables 430.248 and 430.250 must be used, instead of the actual current rating marked on the motor nameplates, to determine the following:

(1) Ampacity of conductors [430.22 and 430.24]

(2) Current rating for disconnect (switches) [430.110]

(3) Current rating of the short-circuit and ground-fault protective device [430.52 and 430.62]

Figure 430–4 **430.6(A)(1)**



The motor full-load current ratings in Tables 430.248 and 430.250 are used for conductor and protective device sizing.

Author's Comment:

- The motor full-load amperes (FLA) identified on the motor nameplate [430.6(A)(2)] is not permitted to be used to determine the conductor ampacity or motor short-circuit and ground-fault overcurrent protective device—except for other than continuous-duty motor applications as covered in 430.22(E).

(2) Motor Nameplate Current Rating (FLA). The motor nameplate full-load amperes (FLA) must be used to determine the following:

(1) Overload protective devices [430.31]

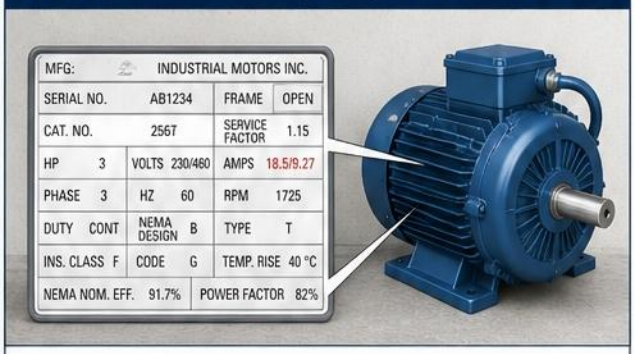
(2) Ampacity of conductors for other than continuous-duty motors [430.22(E)]

Author's Comment:

- The motor nameplate current rating is identified as full-load amperes (FLA). The FLA rating is the current in amperes the motor draws while producing its rated horsepower load at its rated voltage, based on its rated efficiency and power factor.

▶ Figure 430–5

Figure 430–5 Motor Nameplate Amperes (FLA) 430.6(A)(2)



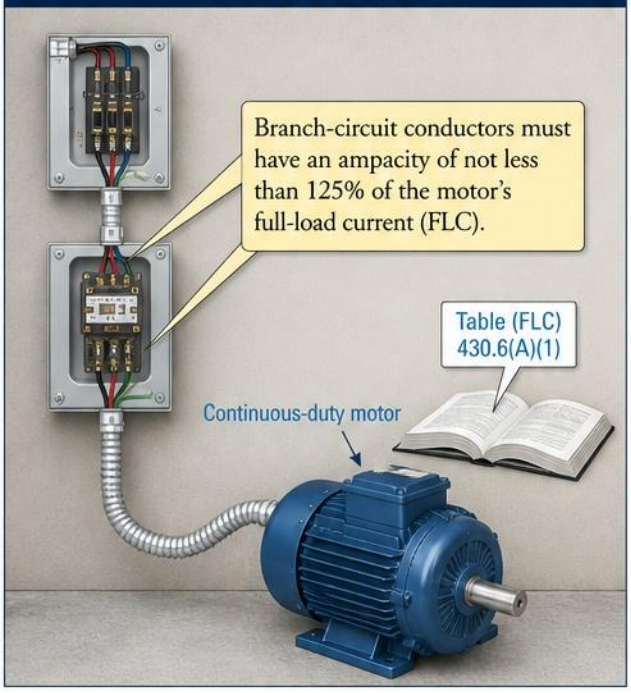
The current rating shown on the motor nameplate (in amperes) represents the current drawn by the motor at its rated horsepower, voltage, efficiency, and power factor.

Part II. Conductor Ampacity

430.22 Motor Conductor Ampacity

For continuous-duty motor installations, branch-circuit conductors must have an ampacity of not less than 125 percent of the motor's full-load current (FLC) as specified in Tables 430.248 and 430.250 [430.6(A)(1)]. **Figure 430–6.**

Figure 430–6 Motor Conductor Ampacity — Continuous-Duty Application 430.22

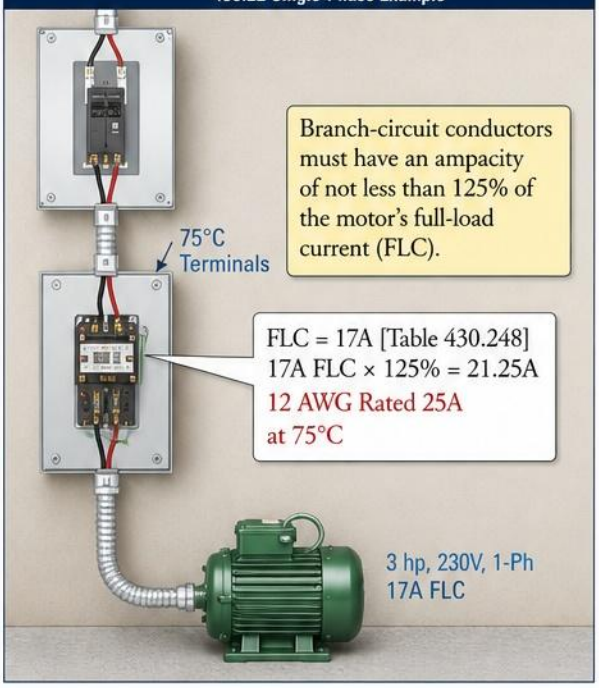


▶ Single-Phase Motor Conductor Ampacity [430.22] Example

Question: Where the equipment is rated for 75°C conductor, what size branch-circuit conductor is required for a 3 hp, 230V, *single-phase* motor in a continuous-duty application? **Figure 430–7.**

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG

Figure 430-7 Motor Conductor Sizing — Continuous-Duty Application 430.22 Single-Phase Example



Solution:

Step 1: *Determine the branch-circuit conductor size based on 125 percent of the motor's FLC.*

3 hp, 230V Motor FLC = 17A [Table 430.248]

Step 2: *Determine the conductor ampacity.*

Conductor Ampacity = 17A × 125%
Conductor Ampacity = 21.25A

Step 3: *Determine the conductor size.*

Conductor size is 12 AWG rated 25A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]

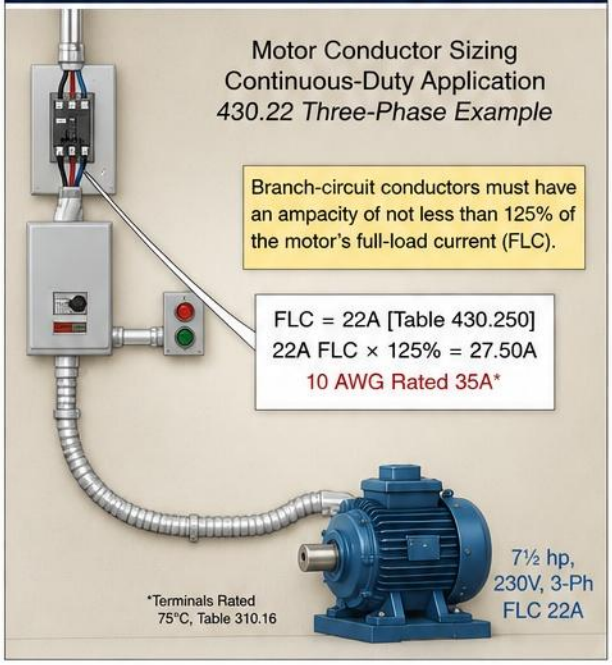
Answer: *(b) 12 AWG*

▶ Three-Phase Motor Conductor Ampacity Example [430.22]

Question: Where the equipment is rated for 75°C conductor, what size branch-circuit conductor is required for a 7½ hp, 230V, three-phase motor? ▶ **Figure 430–8**

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG

Figure 430–8 **430.22 Three-Phase Example**



Solution:

Step 1: *Determine the branch-circuit conductor size based on the motor's FLC [430.6(A)(1), 430.22, and Table 310.16].*

Motor FLC = 22A [Table 430.250]

Step 2: *Determine the conductor ampacity.*

Conductor Ampacity = 22A × 125%
Conductor Ampacity = 27.50A

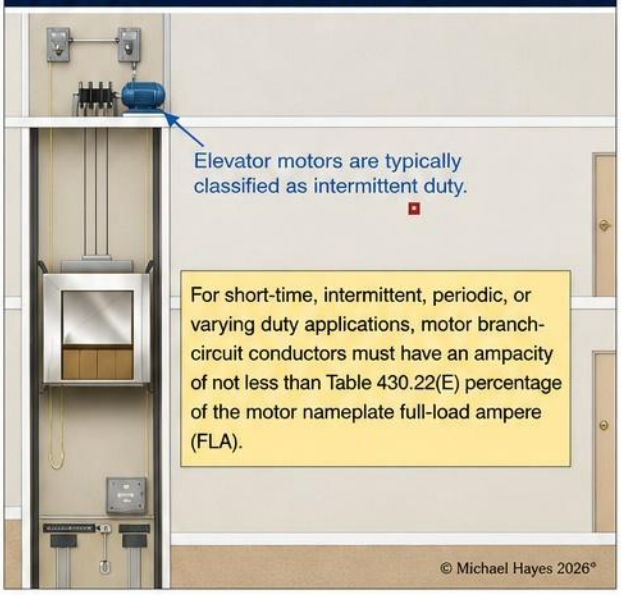
Step 3: *Determine the conductor size.*

Conductor size is 10 AWG rated 35A at 75°C [110.14(C)(1)(a)(2) and Table 310.16]

Answer: *(c) 10 AWG*

(E) Other Than Continuous Duty. For short-time, intermittent, periodic, or varying duty applications, motor branch-circuit conductors must have an ampacity of not less than the percentage of the motor nameplate full-load ampere (FLA) rating shown in Table 430.22(E). ▶ **Figure 430–9**

Figure 430–9 **430.22(E) Other Than Continuous Duty**



Author's Comment:

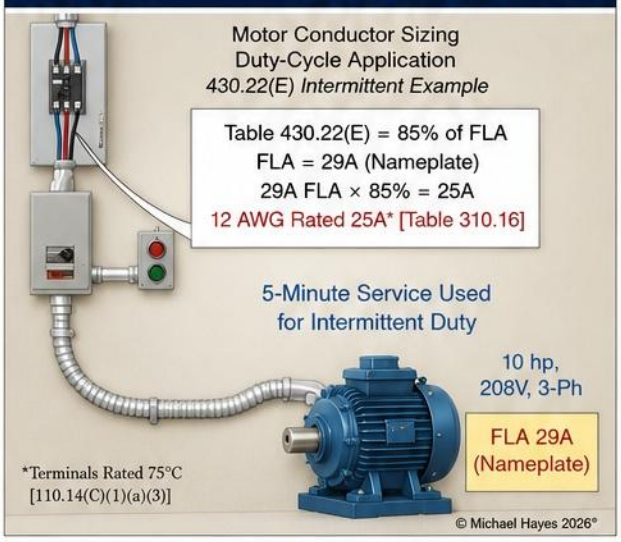
- Motor applications are considered continuous duty unless the nature of the control or apparatus the motor drives is designed so the motor will not operate continuously under load [Table 430.22(E) Note].

▶ Intermittent Duty Motor Conductor Ampacity [430.22(E)] Example

Question: *Where the equipment is rated for 75°C conductor, what size branch-circuit conductors are required for a 10 hp, 208V, three-phase motor with a nameplate FLA of 29A (rated for 5-minute service) used for intermittent duty?* ▶ **Figure 430–10**

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG

Figure 430–10 **430.22(E) Intermittent Example**



SOLUTION:

Step 1: Determine the branch-circuit conductor size based on the motor's FLC [430.6(A)(1), 430.22, and Table 310.16].

The motor nameplate FLA is used for duty-cycle service.

Step 2: *Determine the conductor ampacity.*

The conductor must have an ampacity of not less than 85 percent of the motor FLA [Table 430.22(B)].

Conductor Ampacity = 29A × 85%

Conductor Ampacity = 25A

Step 3: *Determine the conductor size.*

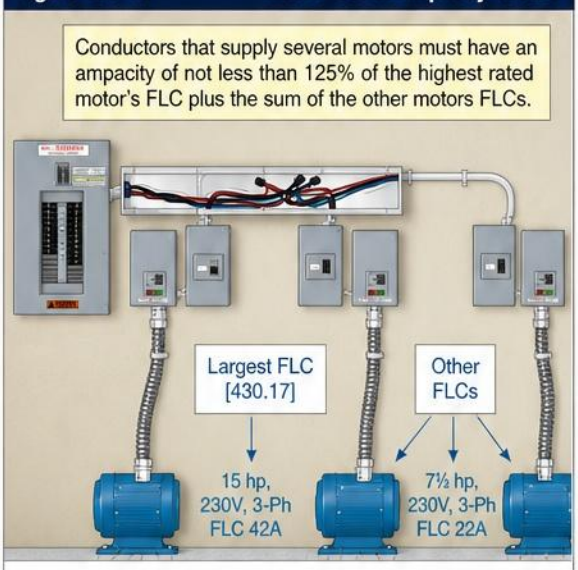
Conductor size is 12 AWG conductors rated 25A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]

Answer: *(b) 12 AWG*

430.24 FEEDER CONDUCTOR AMPACITY

Conductors that supply several motors must have an ampacity of not less than the sum of the following: ▶ **Figure 430–11**

Figure 430–11 **Motor Feeder Ampacity 430.24**



Conductors that supply several motors must have an ampacity of not less than 125% of the highest rated motor's FLC plus the sum of the other motors FLCs.

(1) 125 percent of the highest rated motor's full-load current as listed in Tables 430.248 and 430.250

(2) Full-load current of the other motors as listed in Tables 430.248 and 430.250

AUTHOR'S COMMENT:

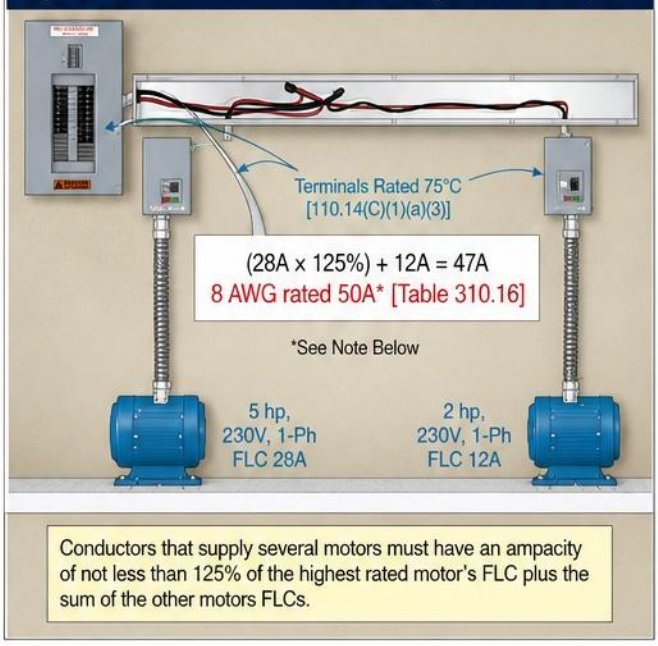
- The motor nameplate full-load ampere (FLA) rating [430.6(A)(2)] is not permitted to be used to determine the motor feeder conductor ampacity.

▶ SINGLE-PHASE MOTOR FEEDER AMPACITY [430.24] EXAMPLE

Question: *Where the equipment is rated for 75°C conductor, what size feeder conductors are required for a 2 hp, single-phase, 230V motor and a 5 hp, single-phase, 230V motor?* ▶ **Figure 430–12**

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

Figure 430–12 **430.24 Single-Phase Example**



SOLUTION:

2 hp FLC = 12A [Table 430.248]

5 hp FLC = 28A [Table 430.248]

Feeder Size = Ampacity of not less than 125 percent of the highest rated motor's FLC, plus the sum of the FLCs of the other motors

Feeder Size = (28A × 125%) + 12A

Feeder Size = 47A

Use 8 AWG rated 50A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].

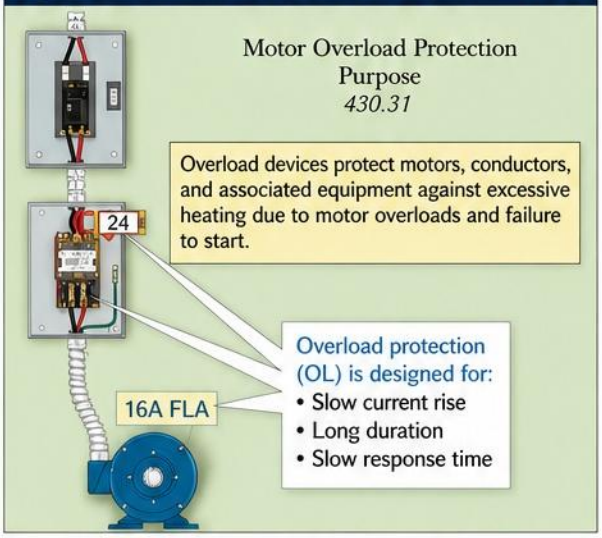
Answer: *(b) 8 AWG*

Part III. Motor and Branch-Circuit Overload Protection

430.31 Overload Protection

Part III of Article 430 contains the requirements for overload devices. These devices are intended to protect motors, motor control equipment, and motor branch-circuit conductors against excessive heating due to motor overloads and failure to start. ▸ Figure 430–13

Figure 430–13 Motor Overload Protection Purpose 430.31



Protects motors, conductors, and related equipment from excessive heating caused by overloads or failure to start.

Overload. Equipment operating above its ampere rating or current more than a conductor's ampacity for a length of time that would cause dangerous overheating. A short circuit or ground fault is not an overload. ▸ Figure 430–14

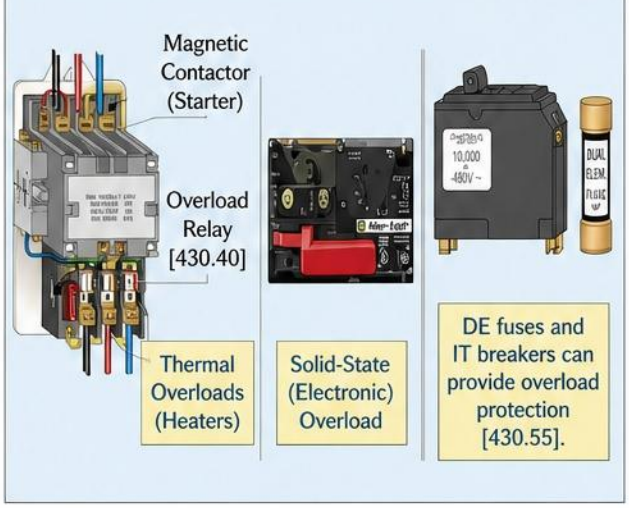
Figure 430–14 Overload—Article 100 Definition 430.31

Equipment operating above its ampere rating or current more than a conductor's ampacity for a length of time that would cause dangerous overheating.

Author's Comment:

- Overload devices can be: ▸ Figure 430–15
  - **Thermal Overloads.** Thermal overloads (heaters) in an overload relay of a motor contactor (starter). These heater units are selected using a chart or size given by the manufacturer.
  - **Solid-State (Electronic) Overloads.** Solid-state overload devices have an adjustment dial that can be used to set the trip level. They are installed in an overload relay of a motor contactor (starter).
  - **Inverse Time Circuit Breaker and Dual-Element Fuses.** Inverse time circuit breakers and dual-element fuses are permitted to serve as the motor overload protection and motor short-circuit ground-fault protection if the requirements of 430.32 are met [430.55].
  - **Fuses.** Fuses can be used for overload protection when sized in accordance with 430.32(A) [430.36].

Figure 430–15 Motor Overload Protection Type of Devices 430.31 Comment



Common types of devices used to provide motor overload protection.

Note 2: An overload occurs when equipment operates above its current rating, or if the current exceeds a conductor's ampacity. A short circuit or ground fault is not an overload.

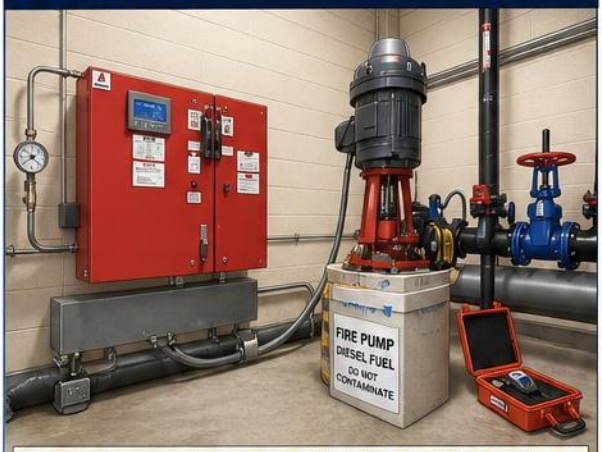
Author's Comment:

- If an overload condition persists long enough, the result can be motor failure or a fire from damaging or dangerous overheating.

(A) Power Loss Hazard. Equipment that provides overload protection is not required when it could introduce additional or increased hazards from a loss of power, such as with fire pumps [695.6(C)].

Figure 430–16

Figure 430–16: Motor Overload Protection Power Loss Hazard 430.31(A)



Overload protection is not needed when it might introduce additional or greater hazards because of power loss, as can occur with fire pumps.

Note: For properly sized overcurrent protective devices on fire pump supply conductors, see 695.4.

430.32 OVERLOAD PROTECTION FOR CONTINUOUS-DUTY MOTORS

(A) Motors Rated More Than 1 hp. Continuous-duty motors with a rating above 1 hp must have overload protection that meets the following:

(1) Separate Overload Device. An overload device cannot be rated above the motor nameplate full-load current (FLA) value.

Service Factor. Motors with a nameplate service factor (SF) of 1.15 or higher must use overload devices sized so they do not exceed 125 percent of the motor nameplate current rating.

Author's Comment:

- Motor service factors are safety factors. They show how much the motor can be briefly overloaded without overheating. For instance, a motor with a service factor of 1.15 can operate at 115 percent of its rated output without overheating. This is important for motors where loads can vary and may peak slightly above the rated torque.

  Figure 430–17

Figure 430–17: Separate Overload Protective Device Over 1 HP, Service Factor 430.32(A)(1)

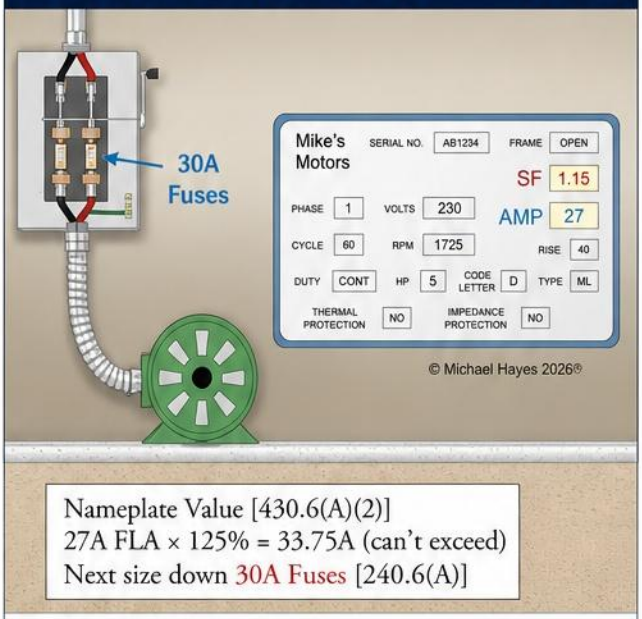
A service factor of 1.15 means the motor is designed to operate periodically at up to 115% of its rated horsepower without damage to the motor.

▶ Motor Overload Device—Service Factor [430.32(A)(1)] Example

Question: *If a dual-element time-delay fuse is used for overload protection, what size fuse is required for a 5 hp, 230V, single-phase motor with a service factor of 1.15 if the motor nameplate current rating is 27A?*

(a) 25A (b) 30A (c) 35A (d) 40A

Figure 430–18: Overload Protective Device Sizing Service Factor 1.15 and Greater Example 430.32(A)(1)



FLA = full-load current

Solution:

Overload protection is sized to the motor nameplate current rating [430.6(A)(2), 430.32(A)(1), and 430.55].

Overload Protection = 27A × 125%

Overload Protection = 33.75A; use a 30A dual-element time-delay fuse.

When using a fuse for overload protection, the values of 430.32(C) must not be exceeded, so round down to the next smaller fuse. Standard fuse sizes are listed in 240.6(A).

Answer: *(b) 30A*

Temperature Rise. Motors with a nameplate temperature rise of 40°C or less must have the overload device sized not to exceed 125 percent of the motor nameplate current rating.

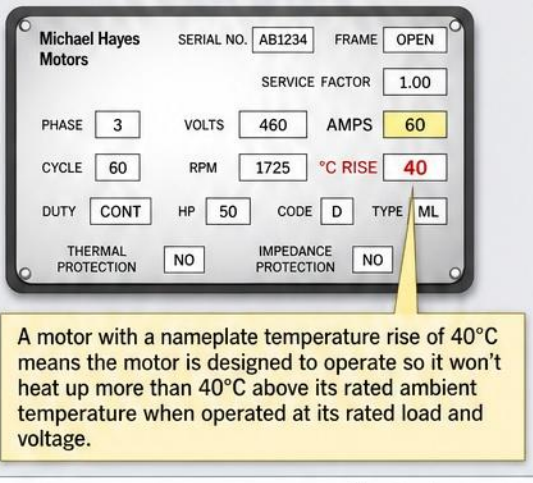
Author's Comment:

A motor with a nameplate temperature rise of 40°C means the motor is designed to operate so it will not heat up more than 40°C above its rated ambient temperature when operated at its rated load and voltage. Studies have shown that when the operating temperature of a motor is increased 10°C above its rating, the anticipated life of the motor winding insulation is reduced by 50 percent.

▶ Figure 430–19

Figure 430–19 — **430.32(A)(1) Comment**

Separate Overload Protective Device Over 1 HP, Temperature Rise 430.32(A)(1) *Comment*



Motors with a nameplate temperature rise of 40°C or less must have the overload device sized not to exceed 125 percent of the motor nameplate current rating.

Motor Overload Device—Temperature Rise [430.32(A)(1)] Example — **430.32(A)(1)**

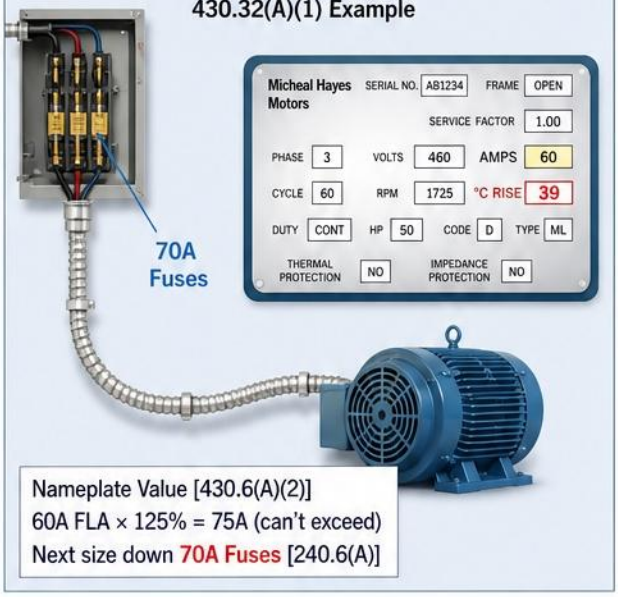
Question: If a dual-element time-delay fuse is used for the overload protection, what size fuse is required for a 50 hp, 460V three-phase motor with a temperature rise of 39°C, and a motor nameplate current rating of 60A (FLA)?

▶ Figure 430–20

(a) 40A *(b)* 50A *(c)* 60A *(d)* 70A

Figure 430–20 — **430.32(A)(1) Example**

Overload Protective Device Sizing Temperature Rise 40°C or Less 430.32(A)(1) Example



Solution:

Overload protection is sized according to the motor nameplate current rating—not the motor FLC rating from the Code book tables.

Overload Protection = 60A × 125% [430.32(A)(1)]

Overload Protection = 75A; use a 70A

**The overload protection can't exceed 125% of the motor nameplate current, so round down to the next smaller overload protective device listed in 240.6(A).*

Answer: *(d) 70A*

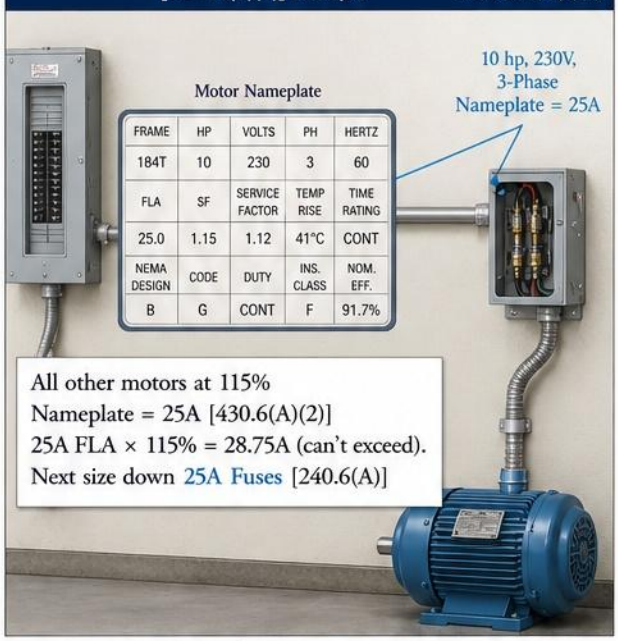
Other Motors. Motors with a nameplate service factor of less than 1.15 or a temperature rise greater than 40°C must have the overload device sized at no more than 115 percent of the motor nameplate current rating.

▶ Motor Overload Device—Other Motors [430.32(A)(1)] Example

Question: A motor has a nameplate with a service factor of 1.12, a temperature rise of 41°C, and a nameplate full-load current rating of 25A. What size dual-element time-delay fuse is required when used for the overload protection of this motor?

(a) 20A (b) 25A (c) 30A (d) 40A

Figure 430–21 Overload Protective Device Sizing—Other Motors [430.32(A)(1)] Example NEC 430.32(A)(1)



FRAME	HP	VOLTS	PH	HERTZ
184T	10	230	3	60
FLA	SF	SERVICE FACTOR	TEMP RISE	TIME RATING
25.0	1.15	1.12	41°C	CONT
NEMA DESIGN	CODE	DUTY	INS. CLASS	NOM. EFF.
B	G	CONT	F	91.7%

Sizing the overload device for motors other than those addressed by 430.32(A)(1).

Solution:

Because the service factor of 1.12 is less than 1.15, and the temperature rise of 41°C is not greater than 40°C, the overload protection is based on 115 percent of the motor nameplate ampere rating [430.6(A)(2)].

Overload Protection = 25A × 115%

Overload Protection = 28.75A, use a 25A dual-element time-delay fuse [240.6(A)]

Answer: (b) 25A

(C) Highest Rating Overload Device. Where the overload device selected in accordance with 430.32(A)(1) is not sufficient to start the motor, the overload is permitted to be sized not to exceed the following:

Service Factor. Motors with a nameplate service factor (SF) of 1.15 or more on the nameplate must have an overload device sized no more than 140 percent of the motor nameplate current rating.

Temperature Rise. Motors with a nameplate temperature rise of 40°C or less must have the overload device sized no more than 140 percent of the motor nameplate current rating.

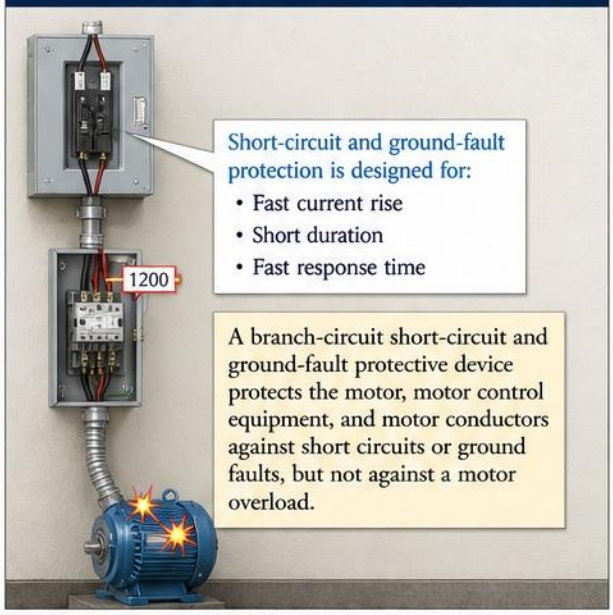
Other Motors. Motors with a nameplate service factor of less than 1.15 or a temperature rise greater than 40°C must have the overload device sized at no more than 130 percent of the motor nameplate current rating.

Part IV. Branch-Circuit Short-Circuit and Ground-Fault Protection

430.51 General

A branch-circuit short-circuit and ground-fault protective device protects the motor, motor control equipment, and motor conductors against short circuits or ground faults—but not against a motor overload.

Figure 430–22 Motor Branch-Circuit Short-Circuit and Ground-Fault Protection NEC 430.51



The purpose of branch-circuit short-circuit and ground-fault protection for motor circuits.

430.52 Branch-Circuit Short-Circuit and Ground-Fault Protection

(B) Motor Starting Current. A motor branch-circuit short-circuit and ground-fault protective device must be capable of carrying the motor's starting current.

Figure 430–23 Motor Starting Current NEC 430.52(B)

Author's Comment:

▶ **Motor-Starting Current.** When voltage is first applied to the field winding of an induction motor, only the motor winding resistance opposes the flow of current during start-up. Since the only resistance during motor start-up is the winding resistance, the motor will typically have a starting current of six times the motor nameplate running amperes.

Figure 430–23 Motor Short-Circuit and Ground-Fault Protection Sized to Allow Starting Current 430.52(B)

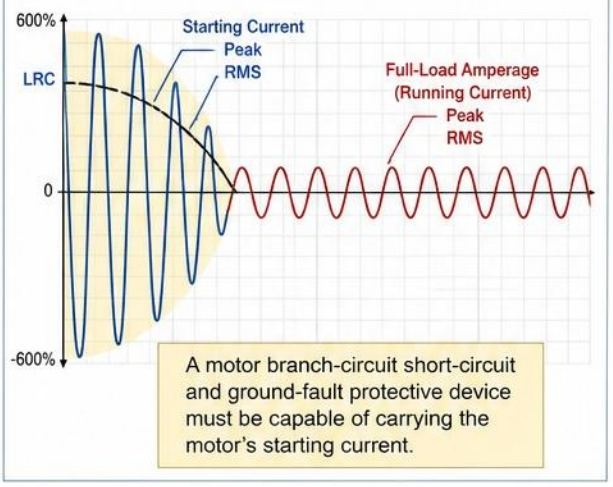


Figure 430–24 Motor-Starting Current Six Times Running Amperes 430.52(B) Comment

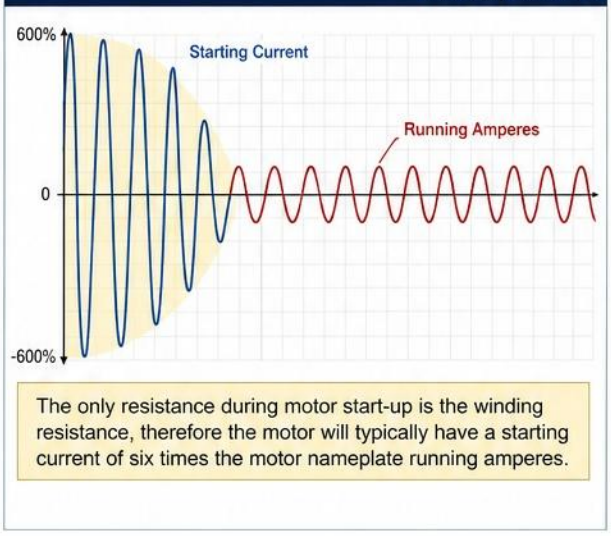


Figure 430–25 Motor-Running Current Counter-Electromotive Force 430.52(B) Comment

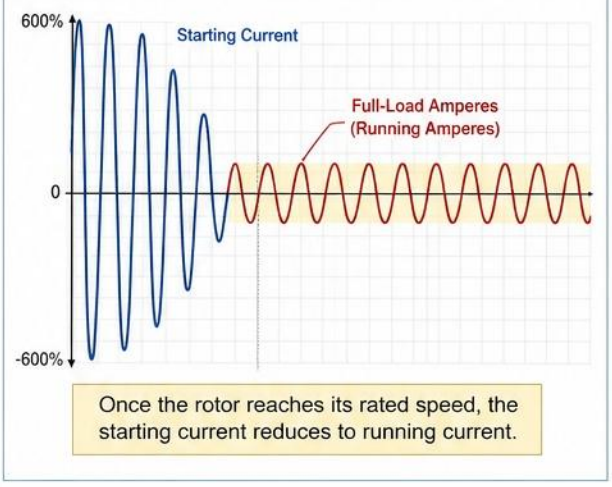
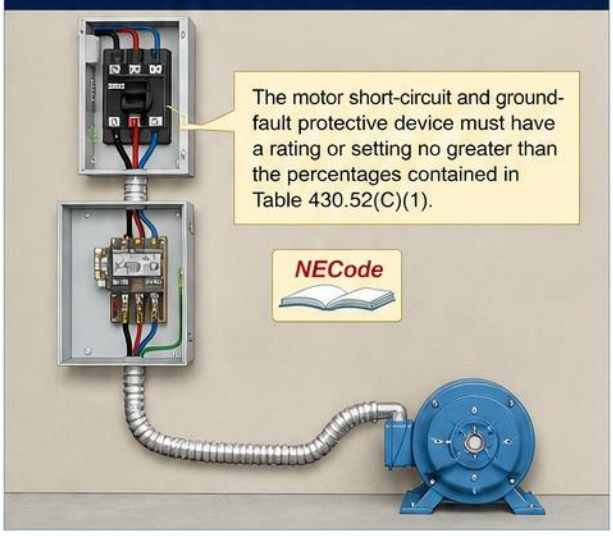


Figure 430–26 Motor Short-Circuit and Ground-Fault Protective Device Rating 430.52(C)(1)



Motor-Running Current. Once the rotor reaches its rated speed, the starting current reduces to running current because of the counter-electromotive force induced in the motor winding. This is caused by the stator's electromagnetic fields cutting across the armature (rotor) motor windings. This increases the inductive reactance (X_L) in the rotor windings, and results in decreasing the motor's starting current to its running current. ▸**Figure 430–25**

(C) Rating or Setting for Individual Motor Circuit.

(1) The motor short-circuit and ground-fault protective device must have a rating or setting no greater than the percentages contained in Table 430.52(C)(1), unless the next size up rule contained in 430.52(C)(1)(a) applies. ▸**Figure 430–26**

Author's Comment:

- The motor nameplate full-load amperes (FLA) rating [430.6(A)(2)] is not permitted to be used to determine the motor short-circuit and ground-fault overcurrent protective device.

Circuit Breaker, Inverse Time. A circuit breaker purposefully designed to delay its tripping action during an overcurrent condition, and the delay decreases as the magnitude of the current increases.

Table 430.52(C)(1) Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices			
Motor Type	Nontime Delay Fuse	Dual-Element (Time-Delay) Fuse	Inverse Time Breaker
Single-Phase Motors	300%	175%	250%
Three-Phase Motors	300%	175%	250%

Author's Comment:

- It bothers many in the electrical industry to see a 14 AWG conductor protected by a 40A circuit breaker, but branch-circuit conductors are protected against overloads by the overload device which is sized between 115 and 125 percent of the motor's nameplate current rating [430.32].
- The rule that limits 15A overcurrent protection for 14 AWG conductors does not apply to motor circuit protection. See 240.4(D) and (G).

► Motor Short Circuit and Ground-Fault Protective Device [430.52(C)(1)] Example

Question: *What size inverse time circuit breaker is required for a 1 hp, 115V, single-phase motor?* ► Figure 430–27

(a) 30A breaker *(b) 35A breaker*
(c) 40A breaker *(d) 45A breaker*

Figure 430–27 430.52(C)(1) Example

1 hp, 115V,
1-Ph, FLC 16A,
[Table 430.248]

Solution:

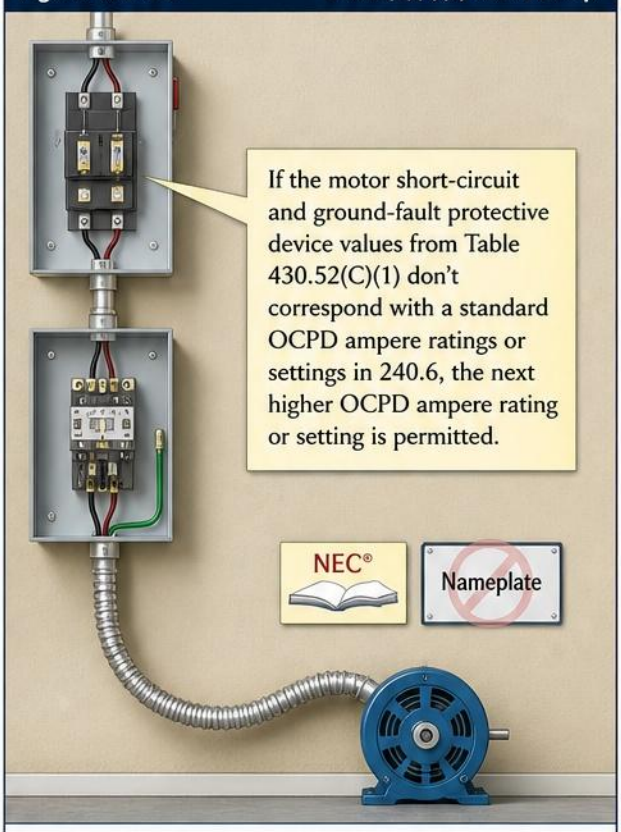
Determine the branch-circuit protection at 250 percent of the motor's FLC (inverse time breaker) [Table 430.52(C)(1) and Table 430.248].

Branch-Circuit Protection = 16A × 250%
Branch-Circuit Protection = 40A [240.6(A)]

Answer: *(c) 40A breaker*

(a) Next Size Up. If the motor short-circuit and ground-fault protective device values from Table 430.52(C)(1) do not correspond with a standard overcurrent protective device ampere ratings or settings provided in 240.6, the next higher overcurrent protective device ampere rating or setting is permitted. ► Figure 430–28

Figure 430–28 430.52(C)(1)(a) Next Size Up



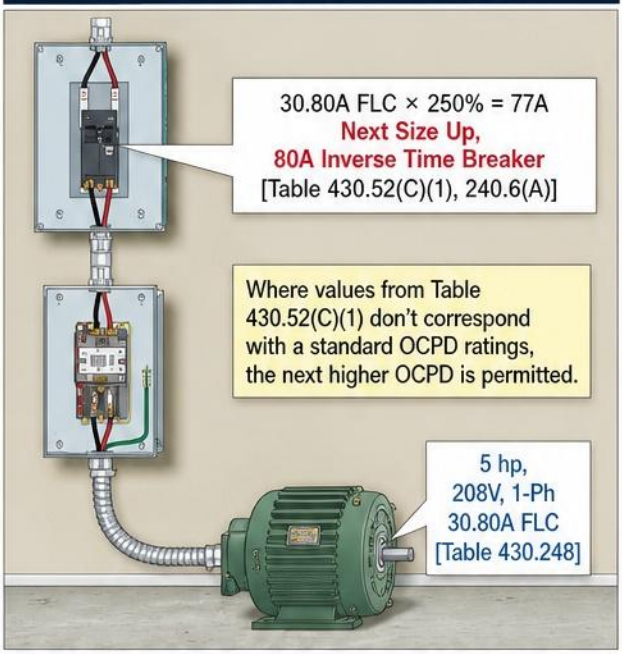
The "next size up" rule allows rounding up to the next standard overcurrent protective device ampere rating or setting when the calculated value from Table 430.52(C)(1) is not an exact match with 240.6.

Motor Short Circuit and Ground-Fault Protective Device [430.52(C)(1)(a)] Example

Question: What size inverse time circuit breaker is required for a 5 hp, 208V, single-phase motor? ▶**Figure 430–29**

(a) 35A (b) 40A (c) 60A (d) 80A

Figure 430–29 | Motor Short Circuit and Ground-Fault Protective Device Rating, Next Size Up 430.52(C)(1)(a) Single-Phase Example 430.55



This illustration shows a single-phase motor circuit with a circuit breaker and contactor, connected by flexible metal conduit, and a 5 hp, 208V, single-phase motor.

Solution:

Determine the branch-circuit protection at 250 percent of the motor's FLC [Table 430.52(C)(1) and Table 430.248].

Branch-Circuit Protection = 30.80A × 250%

Branch-Circuit Protection = 77A, use the next size up: 80A circuit breaker [240.6(A)]

Note: Remember that the 80A circuit breaker is providing short-circuit and ground-fault protection. The motor overload protective device (set at 125 percent or 115 percent of the motor's FLA) will protect the motor, motor equipment, and motor circuit conductors against overloads.

Answer: (d) 80A

430.55 Combined Overcurrent Protective Device

A motor can be protected against overload, short circuits, and ground faults by a single overcurrent protective device sized to the overload protection requirements contained in 430.32.

Combined Overcurrent Protective Device [430.55] Example

Question: What is the maximum size dual-element fuse that can be used to provide overload, short-circuit, and ground-fault protection for a ½ hp, 230V, single-phase motor with a service factor of 1.15 and a nameplate current rating of 4.90A? **Figure 430–30**

(a) 6A (b) 10A (c) 15A (d) 20A

Figure 430–30 | Combined Motor Overcurrent Protective Device 430.55 Example 430.55

A motor can be protected against overload, short circuits, and ground faults by a single overcurrent protective device sized to the overload requirements contained in 430.32.

Solution:

A single overcurrent protective device must be sized in accordance with the percentages contained in 430.32. For this application, the single overcurrent protective device must be sized not greater than 125 percent of the motor nameplate current rating.

Overcurrent Protection = 4.90A FLA × 125%

Overcurrent Protection = 6.13A, use 6A [240.6(A)]

Answer: (a) 6A

Author's Comment:

▶ When using a single protective device to provide combined overcurrent protection, there is no next size up rule. The next size down rating must be selected so the ampacity setting percentages in accordance with 430.32 are not exceeded.

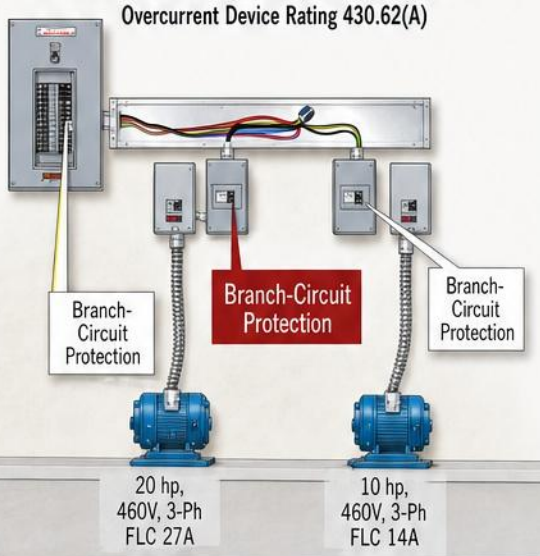
Part V. Feeder Short-Circuit and Ground-Fault Protection

430.62 Motor Feeder Protection

(A) Motors Supplied by a Feeder. Feeder conductors must be safeguarded against short circuits and ground faults by a protective device sized not greater than the largest rating of the branch-circuit short-circuit and ground-fault protective device rating or setting provided in 240.6(A) for any motor—plus the sum of the full-load currents of the other motors in the group as listed in Tables 430.248 and 430.250.
▶ Figure 430–31

Figure 430–31 NEC 430.62(A)

Motor Feeder, Short-Circuit and Ground-Fault Protection Overcurrent Device Rating 430.62(A)



Feeder conductors must be protected against short circuits and ground faults by a protective device sized not greater than the largest rating of the branch-circuit short-circuit and ground-fault protective device plus the sum of the FLCs of the other motors.

Author's Comment:

▶ If the motor branch-circuit short-circuit and ground-fault protective device values from Table 430.52(C)(1) do not correspond with a standard overcurrent protective device ampere ratings or settings provided in Table 240.6(A), the next higher overcurrent protective device ampere rating or setting is permitted [430.52(C)(1)(a)].

▶ Motor Feeder Short-Circuit and Ground-Fault Protection [430.62(A)] Example

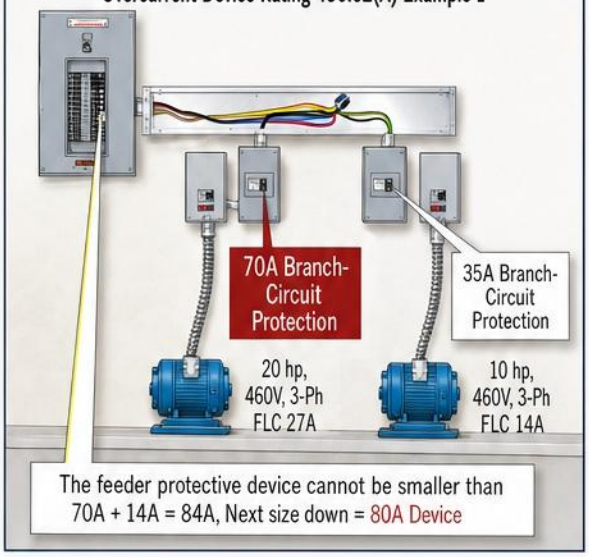
Question: *What is the maximum feeder inverse time breaker permitted for the following two motors where the equipment is rated for 75°C conductor?* ▶ Figure 430–32

- *Motor 1—20 hp, 460V, Three-Phase = 27A FLC [Table 430.250]*
- *Motor 2—10 hp, 460V, Three-Phase = 14A FLC [Table 430.250]*

(a) 30A (b) 40A (c) 50A (d) 80A

Figure 430–32 NEC 430.62(A)

Motor Feeder, Short-Circuit and Ground-Fault Protection Overcurrent Device Rating 430.62(A) Example 1



Solution:

The feeder protective device rating is not permitted to be greater than the rating of the largest branch-circuit ground-fault and short-circuit protective device, plus the FLCs of the other motors [430.62(A)].

Step 1: *Determine the rating of branch-circuit ground-fault and short-circuit protective device for each motor [240.6(A) and 430.52(C)(1)(a)].*

Note: *The "next size up protection" rule for branch circuits [430.52(C)(1)(a)] does not apply to motor feeder OCPD [430.62(A)].*

20 hp Motor = 27A × 250%
20 hp Motor = 68, use the next size up: 70A
10 hp Motor = 14A × 250%
10 hp Motor = 35A

Step 2: *Determine the feeder protective device rating.*
Feeder Protection = Not more than 70A + 14A
Feeder Protection = 84A, use the next size down: 80A [430.62(A), 240.6(A)]*
**The feeder protective device rating is not permitted to be greater than the rating of the largest branch-circuit ground-fault and short-circuit protective device, plus the FLCs of the other motors [430.52(C)(1)(a)].*

Answer: *(d) 80A*

Part VI. Motor Control Circuits

430.72 Overcurrent Protection for Control Circuits

(A) Motor Control Circuit.

Tap conductors. A motor control circuit tapped from the load side of a motor branch-circuit short-circuit and ground-fault protective device must have conductor overcurrent protection in accordance with 430.72(B).

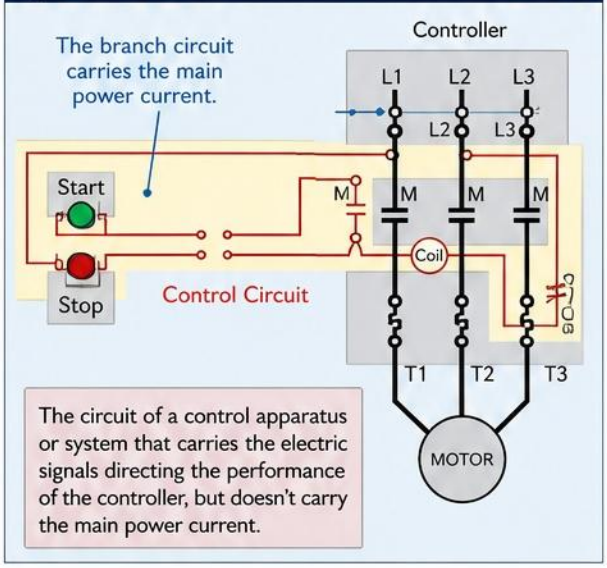
Class 1 Circuit. Class 1 motor control circuits (not over 30V) must have overcurrent protection in accordance with 206.4(D) or 724.43.

Author's Comment:

- Section 724.43 explains that overcurrent protection for conductors 14 AWG and larger must comply with the conductors ampacity from Table 310.16. Overcurrent protection for 18 AWG conductors cannot exceed 7A, and not more than a 10A device can be used to protect 16 AWG conductors.

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 430–33

Figure 430–33 Control Circuit NEC 100



(B) Conductor Protection.

(2) Motor control circuit conductors that are tapped from the motor branch-circuit overcurrent protective device and extend beyond the tap enclosure must have conductor overcurrent protection not greater than the following:

Table 430.72(B)(2) Maximum Rating of Overcurrent Protective Device in Amperes

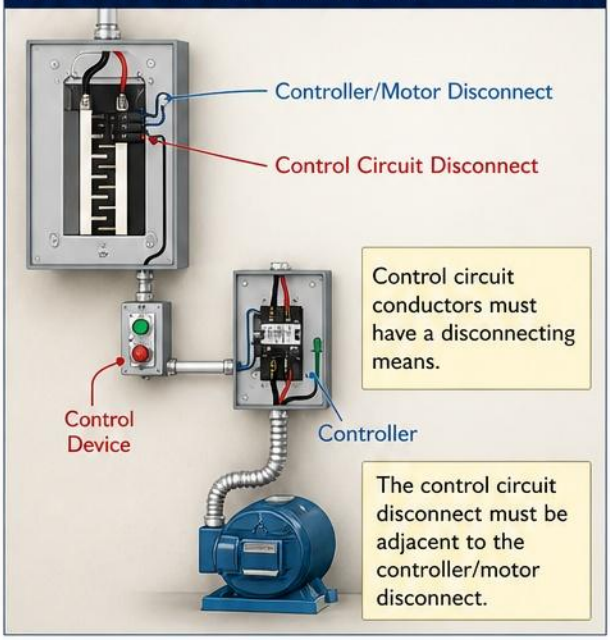
Conductor Size Copper	Column C Overcurrent Protection
18 AWG	7A
16 AWG	10A
14 AWG	45A
12 AWG	60A
10 AWG	90A
>10 AWG	(Note 3)

Note 3: 300 percent of the value specified in Table 310.16 for 60°C conductors.

430.75 Control Circuit Disconnect

(A) Control Circuit Disconnect. Control circuits for motors must have a disconnecting means. Where the disconnecting means is not part of the motor or motor controller disconnect, the disconnect must be located adjacent to the motor disconnect.
▸ Figure 430–34

Figure 430–34 Motor Control Circuit Disconnect NEC 430.75(A)



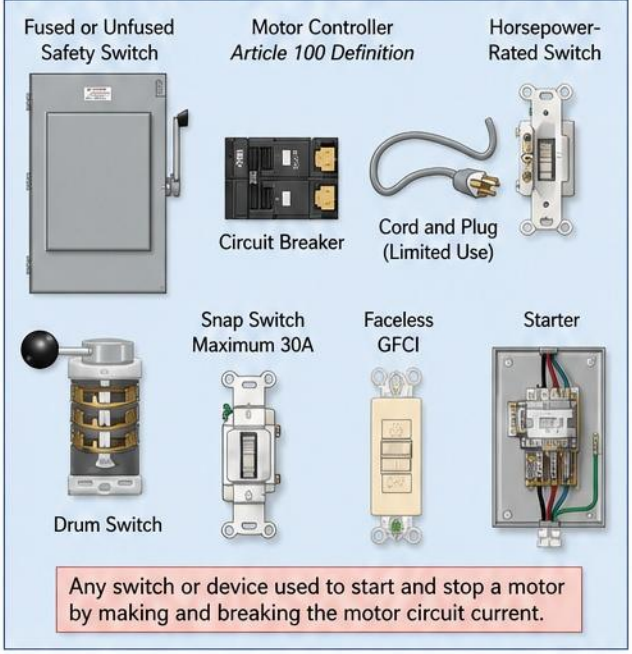
Part VII. Motor Controllers

430.83 Motor Controller Types

(A) General. The motor controller must have one of the following ratings:

Controller, Motor Controller. A device or switch used to start or stop a motor by making or interrupting the motor circuit current. ▶ **Figure 430–35**

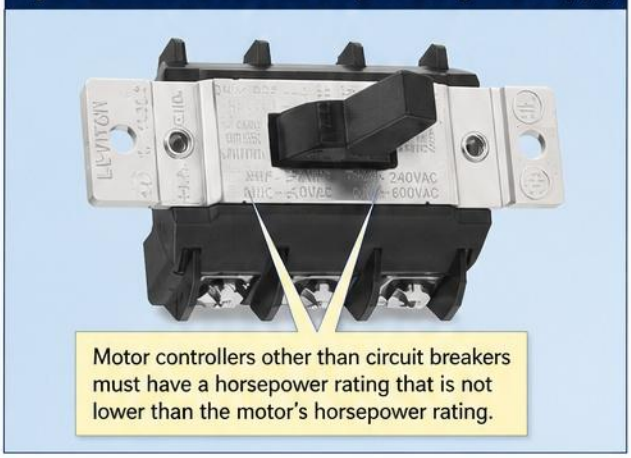
Figure 430–35 Common Controllers and Related Devices 430.102



A variety of controllers and related devices are used to start and stop motors by opening or closing the motor circuit.

(1) Horsepower Rating. Motor controllers other than circuit breakers must have a horsepower rating that is not lower than the motor's horsepower rating. ▶ **Figure 430–36**

Figure 430–36 Motor Controller Horsepower Rating 430.83(A)(1)

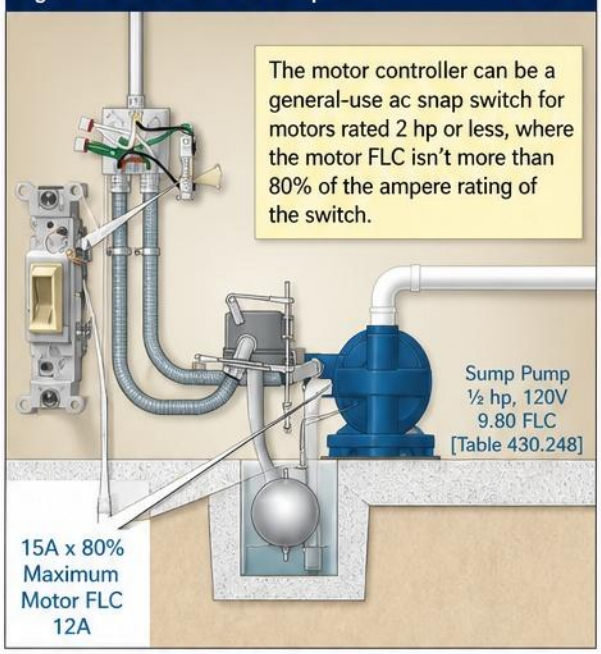


(2) Circuit Breakers. A circuit breaker without a horsepower rating.

(C) Stationary Motors of 2 hp or Less. For stationary motors rated at 2 hp (or less) and 300V (or less), the motor controller can be:

(2) General-Use Snap Switch. A general-use snap switch where the motor full-load current is not more than 80 percent of the switch ampere rating. ▶ **Figure 430–37**

Figure 430–37 General-Use Snap Switch 430.102



A general-use snap switch can serve as a motor controller for motors rated 2 hp or less when the motor FLC does not exceed 80% of the switch's ampere rating.

Part IX. Disconnecting Means

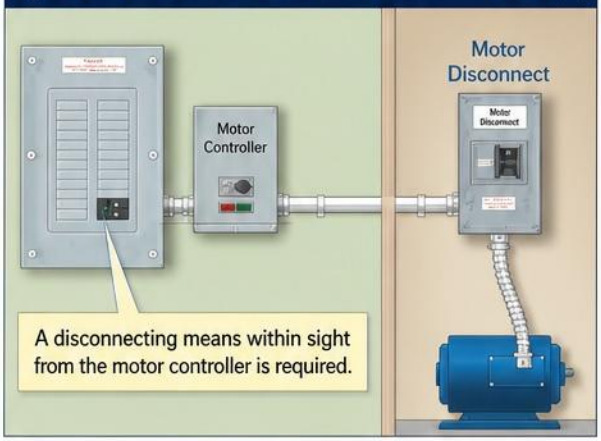
430.101 General

Part IX applies to the disconnecting means for motors and motor controllers.

430.102 Disconnect Location

(A) Motor Controller Disconnect. A disconnecting means is required to be within sight from the motor controller. ▶ **Figure 430–38**

Figure 430–38 Motor Controller Disconnect Location 430.102(A)

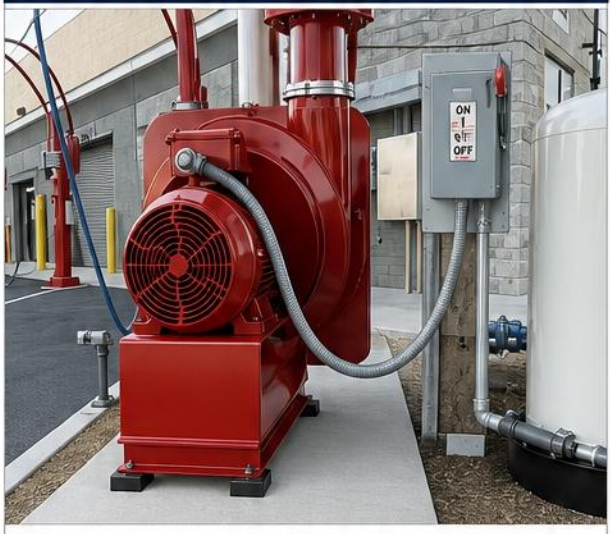


The disconnecting means must be within view of the motor controller.

(B) Motor Disconnect. A disconnecting means is required for a motor as follows:

(1) Separate Motor Disconnect. A disconnecting means is required to be within sight from the motor. ▶Figure 430–39

Figure 430–39 Separate Motor Disconnect 430.107



A disconnecting means within sight from the motor is required.

(2) Controller Disconnect. The motor controller disconnect within sight from the motor location can serve as the disconnecting means for the motor. ▶Figure 430–40

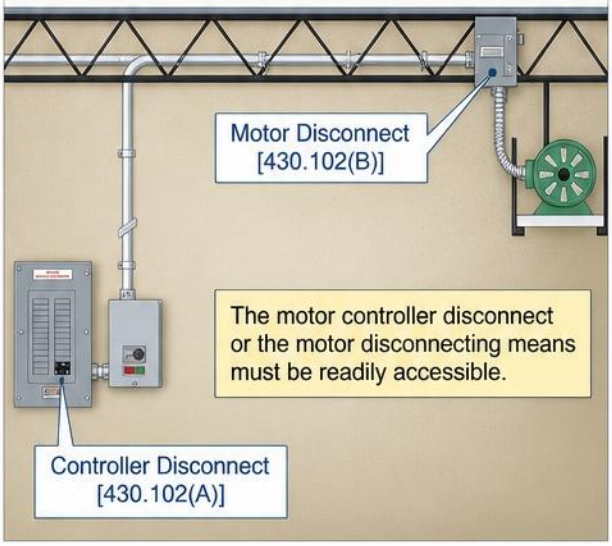
Figure 430–40 Controller Disconnect 430.107

The motor controller disconnect within sight from the motor location can serve as the disconnecting means for the motor.

430.107 Readily Accessible Disconnect

The motor controller disconnect or motor disconnecting means must be readily accessible. ▶Figure 430–41

Figure 430–41 Readily Accessible Disconnect 430.107



Accessible, Readily Accessible. Capable of being reached quickly for operation, renewal, or inspection without those requiring ready access to take actions, such as the use of tools (other than keys), climbing over or under obstructions, removing obstacles, or requiring the use of portable ladders.

430.109 Motor Disconnecting Mean Types

The motor disconnecting means must be a type in accordance with 430.109(A), except as permitted as follows:

(A) General. The motor disconnecting means must be one of the following:

(1) Motor-Circuit Switch. A listed motor-circuit switch rated in horsepower.

(2) Molded Case Circuit Breaker. A listed molded case circuit breaker.

(3) Molded Case Switch. A listed molded case switch.

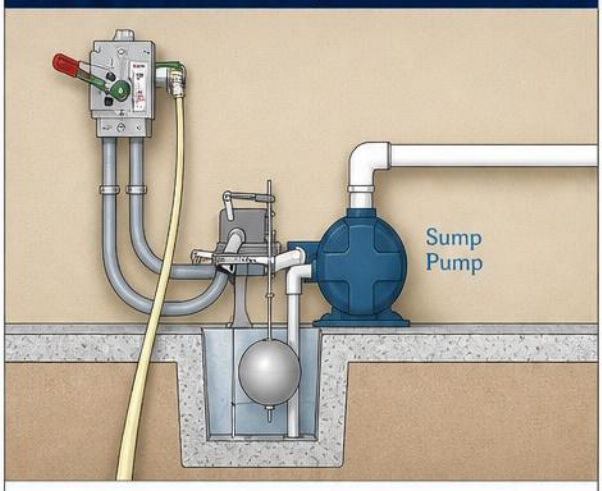
(6) Manual Motor Controller. A listed manual motor controller marked "suitable as motor disconnect."

(B) Stationary Motors of ½ Horsepower or Less. The branch-circuit overcurrent protective device can serve as the motor or motor controller disconnect.

(C) Stationary Motors of 2 hp or Less. The controller disconnect or motor disconnect can be any one of the following:

(2) General-Use Snap Switch. A general-use snap switch can function as a controller disconnect or motor disconnect if the motor's full-load current is not greater than 80 percent of the switch ampere rating.

Figure 430–42 General-Use Snap Switch 430.109(C)(2)



A general-use snap switch can function as a controller disconnect or motor disconnect if the motor's full-load current is not greater than 80 percent of the switch ampere rating.

(3) Manual Motor Controller. A listed manual motor controller marked "suitable as motor disconnect" can function as a controller disconnect or motor disconnect.

(F) Cord-and-Plug-Connected Motors. A horsepower-rated attachment plug and receptacle, flanged inlet and cord connector, or attachment plug and cord connector that has a horsepower rating not less than the motor rating may be used as a motor disconnect.

Figure 430–43 Cord-and-Plug-Connected Motors 430.109(F)

A horsepower-rated attachment plug and receptacle having a horsepower rating not less than the motor rating can be used as the motor disconnect.

Part X. Adjustable-Speed Drive Systems

430.120 General

Article 430 Parts I through IX requirements are applicable to adjustable-speed drive systems.

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

Figure 430–44 Adjustable-Speed Drive System Article 100 Definition

A combination of an adjustable-speed drive, its associated motor(s), and other associated equipment.

Author's Comment:

- An adjustable-speed drive is a piece of equipment that provides a way to adjust the speed of an electric motor. Adjustable-speed drives are often referred to as "variable-speed drives" or "variable-frequency drives" (VFDs).
- A variable-frequency drive is a type of electronic adjustable-speed drive that controls the speed of an alternating-current motor by changing the frequency and voltage of the motor's power supply.

430.122 Conductor Ampacity

(A) Conductors to Adjustable-Speed Drive System. Conductors supplying an adjustable speed-drive system must have an ampacity not less than 125 percent of the equipment nameplate rated input current.

Figure 430-45 Adjustable-Speed Drive Systems Conductor Ampacity 430.122(A)

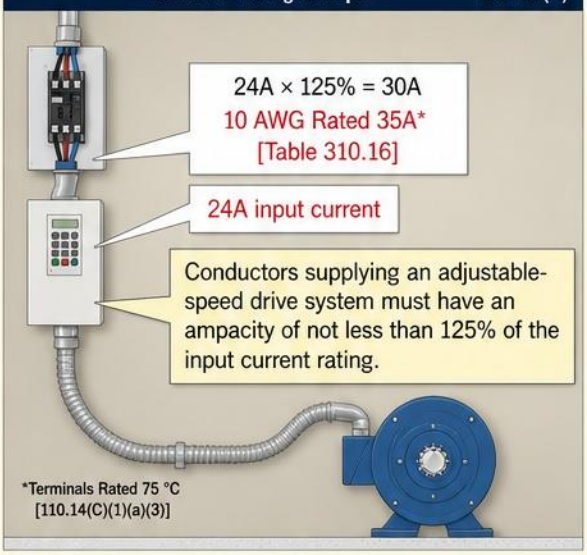
Note: Power conversion equipment can have multiple input current ratings.

Conductors to Adjustable-Speed Drive System [430.122(A)] Example

Question: *Where the equipment is rated for 75 °C conductor, what size conductors are required to supply an adjustable-speed drive system with a nameplate input current rating of 24A?*

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

Figure 430-46 Adjustable-Speed Drive Systems Conductor Sizing Example 430.122(A)



Solution:

Note: *The conductors to the adjustable-speed drive system are sized at 125% of the nameplate input current rating [430.122(A)].*

Step 1: *Determine the conductor ampacity.*

Conductor Ampacity = Input Current Rating × 125%

Conductor Ampacity = 24A × 125%

Conductor Ampacity = 30A

Step 2: *Determine the conductor size.*

Conductor size is 10 AWG rated 35A at 75 °C, [110.14(C)(1)(a)(3) and Table 310.16].

Answer: *(b) 10 AWG*

(B) Conductors to Motor from Adjustable-Speed Drive Equipment

(1) Output Motor Conductors. The conductors from the adjustable-speed drive system to the motor must have an ampacity of not less than 125 percent of the motor's full-load current as listed in Tables 430.248 and 430.250.
[Figure 430-47]

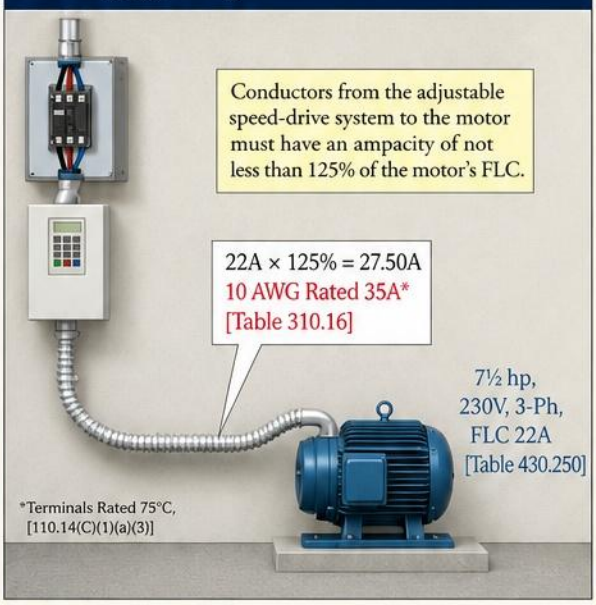
Figure 430-47 Adjustable-Speed Drive Systems Output Motor Conductors 430.122(B)(1)

▶ VFD Output Motor Conductors [430.122(B)(1)] Example

Question: Where the equipment is rated for 75°C conductor, *what size conductor is required for a 7½ hp, 230V, three-phase motor, supplied by an adjustable-speed drive system?* **Figure 430–48**

(a) 12 AWG *(b) 10 AWG*
(c) 8 AWG *(d) 6 AWG*

Figure 430–48 430.122(B)(1)
Adjustable-Speed Drive Systems Output Motor Conductors 430.122(B)(1) Example



Solution:

Step 1: *Determine the conductor size based on 125 percent of the motor's FLC.*

7½ hp, 230V Motor FLC = 22A [Table 430.250]

Step 2: *Determine the conductor ampacity.*

Conductor Ampacity = 22A × 125%
Conductor Ampacity = 27.50A

Step 3: *Determine the conductor size.*

10 AWG is rated 35A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].

Answer: *(b) 10 AWG*

(2) Suitable for Output Motor Protection. If the adjustable speed-driver system is listed and marked as "suitable for output motor conductor protection," the conductor between the adjustable speed-driver system and the motor must have an ampacity equal to/greater than the larger of the following:

(1) 125 percent of the motor's full-load current as listed in Tables 430.248 and 430.250

(2) Ampacity marked on the adjustable speed-driver system

Note 1: The input conductors are sized to 125 percent of the adjustable speed-driver system's rated input current [430.122(A)], whereas the output conductors are sized to 125 percent of the motor FLC [430.122(B)].

(D) Several Motors. Conductors supplying more than one power conversion equipment must have ampacity in accordance with 430.24, based on the rated input current of the power conversion equipment.

430.124 Overload Protection

(A) Included in Equipment. Where the adjustable-speed drive system is marked to indicate that motor overload protection is included, separate overload protection is not required.

(C) Multiple Motor Applications. For multiple motor application, individual motor overload protection must be provided in accordance with Article 430, Part III.

430.128 Disconnecting Means

The disconnecting means for an adjustable speed-drive system must have an ampere rating no less than 115 percent of the rated input current of the adjustable-speed drive system.

430.130 Branch-Circuit Short-Circuit and Ground-Fault Protection

(A) Circuits Containing an Adjustable-Speed Drive System. Branch circuits for an adjustable speed-driver system must be protected by a short-circuit and ground-fault protective device sized in accordance with any one of the following:

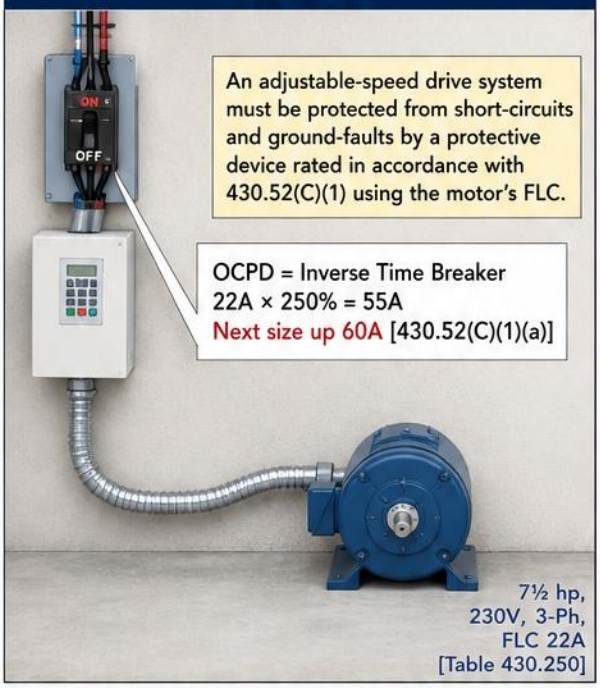
(1) **Motor Full-Load Current.** The short-circuit and ground-fault protective device size to 430.52(C)(1) using the motor's full-load current rating as listed in Tables 430.248 and 430.250.

▶ VFD Short-Circuit and Ground-Fault Protection [430.130(A)(1)] Example

Question: What size inverse time breaker is required to provide short-circuit ground-fault protection for an adjustable-speed drive supplying a 7½ hp, 230V, three-phase motor?

(a) 55A *(b) 60A* *(c) 65A* *(d) 70A*

Figure 430–49 **430.53(C)(1)**
Adjustable-Speed Drive Systems
Short-Circuit and Ground-Fault Protection
430.130(A)(1)



This example shows short-circuit and ground-fault protection for an adjustable-speed drive system using an inverse time breaker sized from the motor's FLC.

Solution:
Find the branch-circuit short-circuit ground-fault protection rating based on 250 percent of the motor's FLC [430.52(C)].

7½ hp, 230V Motor FLC = 22A [Table 430.250]

OCPD = 22A × 250%

OCPD = 55A, next size up: 60A [430.52(C)(1)(a)]

Answer: *(b) 60A*

Ex: The branch-circuit short-circuit and ground-fault protective device size can be determined by Table 430.52(C)(1) using the adjustable speed-driver system's rated input current where the adjustable speed-driver system is listed and marked "suitable for output motor conductor protection."

Note 1: Motor conductor branch-circuit short-circuit and ground-fault protection for the adjustable speed-driver system to the motor is provided by an adjustable speed-driver system that is listed and marked "suitable for output motor conductor protection."

(2) Manufacturer's Instructions. The branch-circuit short-circuit and ground-fault protective device is not permitted to exceed twice the manufacturer's instructions or current rating marked on the adjustable-speed drive.

430.131 Several Motors or Loads on One Branch Circuit Including Power Conversion Equipment

The short-circuit ground-fault protection for two or more motors on the load side of an adjustable-speed drive system is permitted if the branch circuit is protected by an overcurrent protective device is in accordance with 430.53.

Author's Comment:

- According to 430.53(C)(4), the short-circuit ground-fault protection for two or more motors on the load side of an adjustable-speed drive system must have a rating not exceeding the sum of all of the following:
  (1) The value specified in 430.52 for the highest rated motor connected to the branch circuit.
  (2) The sum of the full-load current ratings of all other motors.

▶ VFD Short-Circuit and Ground-Fault Protection [430.131] Example

Question: *What size inverse time breaker is required to provide short-circuit ground-fault protection for an adjustable-speed drive supplying two 7½ hp, 230V, three-phase motors?*

(a) 50A *(b) 60A* *(c) 70A* *(d) 80A*

Solution:

Step 1: *Determine the circuit short-circuit ground-fault protection rating for the largest motor [430.52(C), 430.53(C)(4)(1)].*

7½ hp, 230V Motor FLC = 22A [Table 430.250]

Motor OCPD = 22A × 250%

Motor OCPD = 55A, next size up: 60A [430.52(C)(1)(a)]

Step 2: *Determine the circuit short-circuit ground-fault protection rating for the variable speed drive system [430.53(C)(4)].*

Adjustable-Speed Drive = 60A + 22A

Adjustable-Speed Drive = 82A, next size down: 80A [Table 240.6(A)]

Answer: *(d) 80A*

430.132 GFCI and SPGFCI Between Power Conversion Equipment and Motors

Ground-fault circuit interrupters and special purpose ground-fault circuit interrupters must not be installed between power conversion equipment output terminals and the motor.

Part XIV. Tables

430.248 Full-Load Current, Single-Phase Motors

Table 430.248 lists the full-load current for single-phase alternating-current motors.

Author's Comment:

- These values are used to determine motor conductor sizing and branch-circuit and feeder protection—but not overload protection [430.6(A)(1) and (2)].

Table 430.248 Full-Load Current, Single-Phase Motors

Table 430.248 FLC Single-Phase Alternating-Current Motors

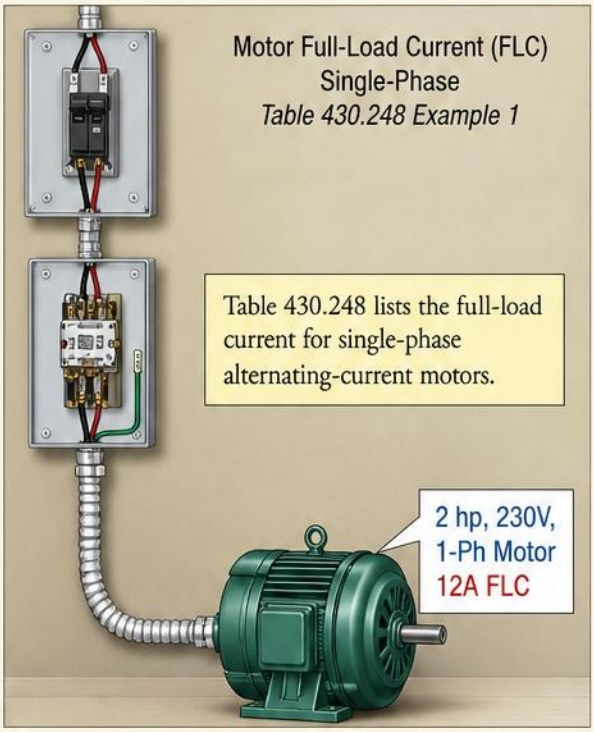
	110–120V*	200V	208V	220–240V*
½ hp	9.80	5.60	5.40	4.90
¾ hp	13.80	7.90	7.60	6.90
1 hp	16.00	9.20	8.80	8.00
1½ hp	20.00	11.50	11.00	11.00
2 hp	24.00	13.90	13.20	12.00
3 hp	34.00	19.60	18.70	17.00
5 hp	56.00	32.20	30.80	28.00
7½ hp	80.00	46.00	44.00	40.00
10 hp	100.00	57.50	55.00	50.00

**The full-load currents contained in this table are permitted for system voltage ranges of 110–120V and 220–240V.*

Figure 430–50 Single-Phase Motor FLC [Table 430.248] Example | **430.248**

Question: *What is the full-load current of a 2 hp, 240V, single-phase motor?*

(a) 12A (b) 13A (c) 14A (d) 16A



The correct answer is 12A from Table 430.248 for a 2 hp, 240V, single-phase motor.

Answer: *(a) 12A [Table 430.248]*

430.250 Full-Load Current, Three-Phase Motors

Table 430.250 lists the full-load current for three-phase alternating-current motors.

Author's Comment:

- The values are used to determine motor conductor sizing, ampere ratings of disconnects, controller rating, and branch-circuit and feeder protection—but not overload protection [430.6(A)(1) and (2)].

Table 430.250 Full-Load Current, Three-Phase Motors

Table 430.250 FLC Three-Phase Alternating-Current Motors				
Motor Rating	200V	208V	220–240V*	440–480V*
½ hp	2.50	2.40	2.20	1.10
¾ hp	3.70	3.50	3.20	1.60
1 hp	4.80	4.60	4.20	2.10
1½ hp	6.90	6.60	6.00	3.00
2 hp	7.80	7.50	6.80	3.40
3 hp	11.00	10.60	9.60	4.00
5 hp	17.50	16.70	15.20	7.60
7½ hp	25.30	24.20	22.00	11.00
10 hp	32.20	30.80	28.00	14.00
15 hp	48.30	46.20	42.00	21.00
20 hp	62.10	59.40	54.00	27.00
25 hp	78.20	74.80	68.00	34.00

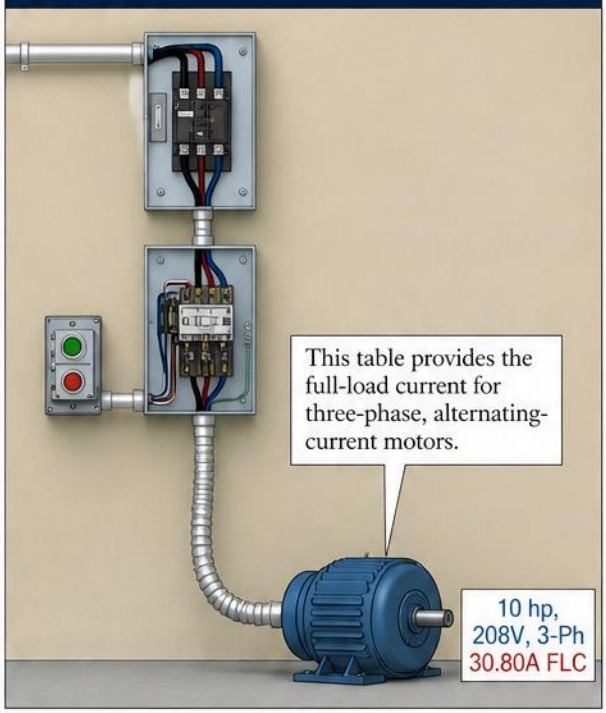
* *Values in this table are allowable full-load currents for three-phase systems with voltage ranges of 220–240V and 440–480V.*

▶ Three-Phase Motor FLC [Table 430.250] Example

Question: What is the full-load current of a 10 hp, 208V, three-phase motor? See Figure 430–51.

(a) 28.80A (b) 30.80A (c) 34.80A (d) 36.80A

Figure 430–51 **430.250**



Refer to Table 430.250 for the full-load current of three-phase, alternating-current motors.

Answer: *(b) 30.80A [Table 430.250]*

ARTICLE 440

Air-Conditioning and Refrigeration Equipment

Introduction to Article 440—Air-Conditioning and Refrigeration Equipment

Article 440 applies to hermetic refrigerant motor-compressors, such as those used for pool heat pumps, air-conditioning, split-systems, and refrigeration equipment. In most cases, the manufacturer has worked out all the details and identifies the minimum conductor ampacity, maximum overcurrent protective device rating, and other information (such as running-load amperes) on the nameplate. Therefore, the rules covered deal with what the installer needs to know.

Hermetic Refrigerant Motor-Compressor. A compressor and motor enclosed in the same housing, with no external shaft or shaft seals, and operating in a refrigerant. ▶ Figure 440–1

Figure 440–1 Hermetic Refrigerant Motor-Compressor 100 Definition

A compressor and motor enclosed in the same housing, with no external shaft or shaft seals, and operating in a refrigerant.

Part I. General

440.1 Scope

This article applies to hermetic refrigerant motor-compressors, such as air-conditioning and refrigeration equipment. ▶ Figure 440–2

Figure 440–2 Air-Conditioning and Refrigeration Equipment 440.1 Scope

Article 440 applies to hermetic refrigerant motor-compressors, such as air-conditioning equipment and refrigeration equipment.

440.4 Marking on Hermetic Refrigerant Motor-Compressors and Equipment

(B) Equipment Nameplate.

(1) General. Multimotor hermetic refrigerant motor-compressor equipment must have a nameplate marked with the following:

(1) Manufacturer's name

(2) Rating in volts

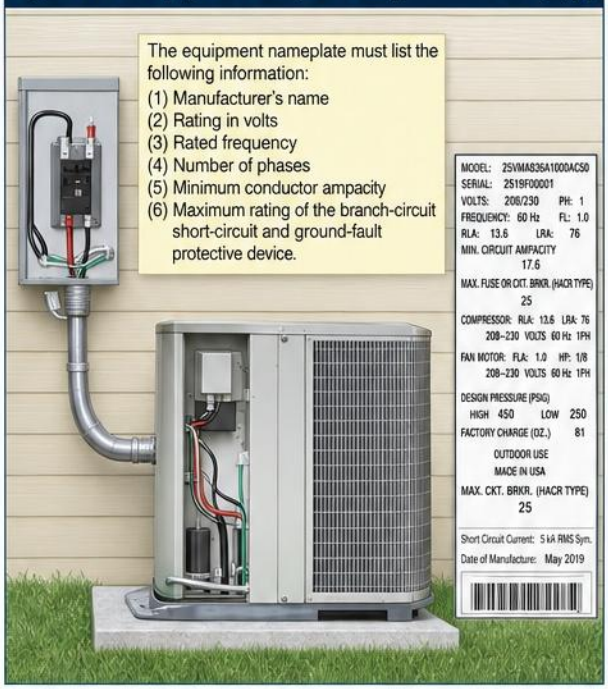
(3) Rated frequency

(4) Number of phases

(5) Minimum conductor ampacity

(6) Maximum rating of the branch-circuit short-circuit and ground-fault protective device **Figure 440–3**

Figure 440–3 Equipment Nameplate Rating **440.4(B)(1)**



The equipment nameplate supplies essential electrical data used to determine conductor size and overcurrent protection.

Author's Comment:

- *Hermetic refrigerant motor compressors typically include an integral thermal device that protects against overload [440.51]. The branch-circuit short-circuit and ground-fault protection is supplied with a circuit breaker or fuse that must be installed by the electrician in accordance with the manufacturer's nameplate marking.*
- *In accordance with UL Guide Information LZFE, heating and cooling equipment terminations are based on the 75°C conductor ampacities in accordance with Table 310.16.*

Multimotor Air-Conditioning Equipment [440.4(B)(1)] Example

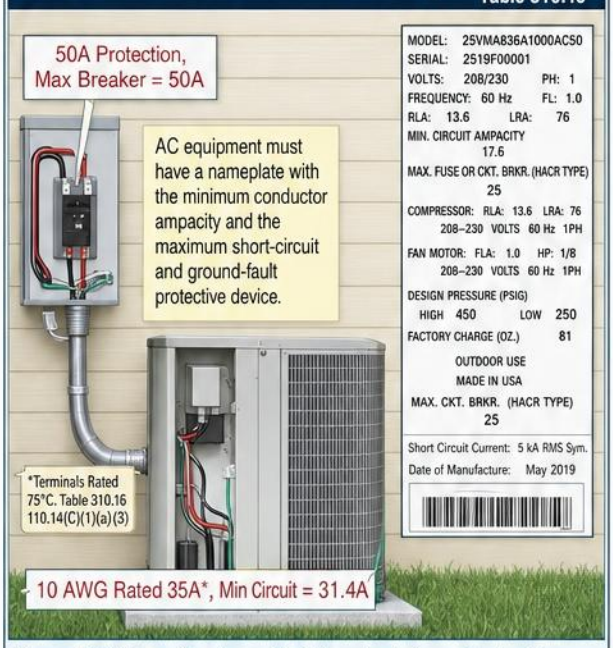
Question:

What size conductor and short-circuit and ground-fault protective device is required for a multimotor air-conditioning compressor equipment? The nameplate minimum circuit ampacity is 31.40A, and the maximum circuit breaker rating is 50A, where the equipment is rated for 75°C conductor. **Figure 440–4**

(a) 10 AWG, 20A breaker *(b) 10 AWG, 50A breaker*

(c) 10 AWG, 60A breaker *(d) 8 AWG, 60A breaker*

Figure 440–4 Conductor and Protection Sizing **440.4(B)(1) Table 310.16**



Nameplate information is used to determine both conductor size and overcurrent protection.

Solution:

Step 1: *Determine the conductor size.*

Since the equipment is rated for 75°C conductors, use 10 AWG rated 35A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].

Step 2: *Determine the circuit breaker.*

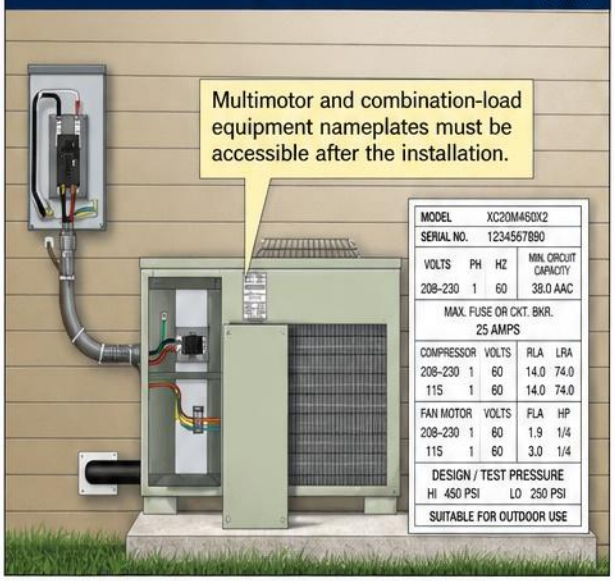
The circuit breaker protection for the air-conditioning compressor equipment must have an ampere rating no more than the 50A marked on the nameplate [440.4(B)].

Use a maximum 50A breaker [240.6(A)].

Answer: *(b) 10 AWG, 50A breaker*

(5) Accessible Nameplate. Multimotor and combination-load equipment nameplates must be accessible after the installation. **Figure 440–5**

Figure 440–5 | Air-Conditioning and Refrigeration Equipment Accessible Nameplate 440.4(B)(5)

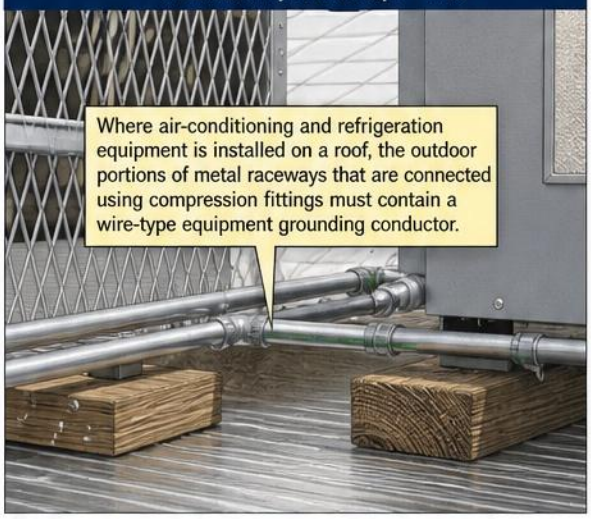


Multimotor and combination-load equipment nameplates must remain accessible after installation.

440.9 Equipment Grounding Conductor

Where air-conditioning and refrigeration equipment is installed on a roof, the outdoor portions of metal raceways that are connected using compression fittings must contain a wire-type equipment grounding conductor. Figure 440–6

Figure 440–6 | Air-Conditioning and Refrigeration Equipment Metal Raceways on Rooftops 440.9



Metal raceways on rooftops connected by compression fittings must include a wire-type equipment grounding conductor in the exposed outdoor sections.

Author's Comment:

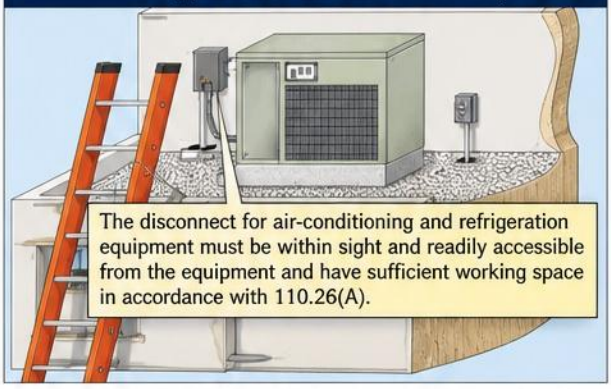
- The outdoor portions of rooftop metal raceways with compression fittings are exposed to a higher likelihood of physical damage. They are often stepped on or broken from roof activities (such as snow removal or roof repair/replacement). The installation of a wire-type equipment grounding conductor within outdoor portions of metal raceways ensures an effective ground-fault current path.

Part II. Disconnecting Means

440.14 Location

The disconnect for air-conditioning and refrigeration equipment must be within sight from and readily accessible from the equipment and have sufficient working space in accordance with 110.26(A). Figure 440–7

Figure 440–7 | Air-Conditioning and Refrigeration Equipment Disconnect Location and Accessibility 440.14

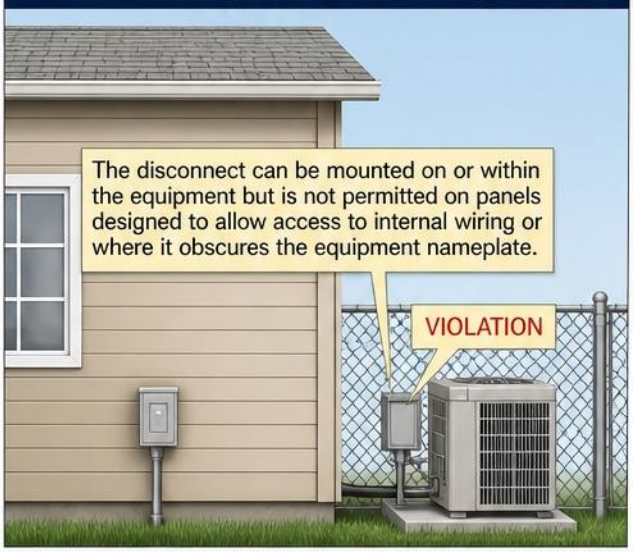


The disconnect must be located so it can be seen from and easily reached from the equipment, with adequate working space.

Accessible, Readily Accessible. Capable of being reached quickly for operation, renewal, or inspection without those requiring ready access to take actions, such as the use of tools (other than keys), climbing over or under obstructions, removing obstacles, or requiring the use of portable ladders.

The disconnect can be mounted on or within the equipment but is not permitted on panels designed to allow access to internal wiring or where it obscures the equipment nameplate. Figure 440–8

Figure 440–8 | Air-Conditioning and Refrigeration Equipment Disconnect Mounting 440.14



The disconnect is mounted where it blocks the nameplate.

440.15 Split-System Indoor Unit Identification

The outdoor disconnecting means for a split-system HVAC in other than one- and two-family dwellings must be marked with the location of all indoor units that it supplies, and the identification must be in accordance with 110.22(A).

Figure 440–9 | Split-System Indoor AC Unit Identification Other Than One- and Two-Family Dwellings 440.15

The outdoor disconnecting means is labeled with the locations of all indoor units supplied, per 110.22(A).

Part III. Overcurrent Protection

440.21 General

Branch-circuit conductors, control equipment, and circuits supplying hermetic refrigerant motor-compressors must be protected against short circuits and ground faults in accordance with 440.22.

440.22 Short-Circuit and Ground-Fault Overcurrent Protective Device Size

(A) Individual Motor Compressor. The short-circuit and ground-fault protective device must be capable of carrying the starting current of the motor. The rating or setting provided in 240.6 must not exceed 175 percent of the rated load current.

Ex 1: *If the motor short-circuit and ground-fault protective device values from 440.22(A) do not correspond with a standard overcurrent protective device ampere ratings or settings provided in 240.6, the next higher overcurrent protective device ampere rating or setting is permitted.*

Ex 2: *If the short-circuit and ground-fault protection in accordance with 440.22(A) or the rating modified by Ex 1 is not sufficient for the starting current of the equipment, the rating or setting provided in 240.6 is permitted to be increased up to 225 percent of the motor rated-load current or branch-circuit selection current, whichever is greater.*

(B) Rating or Setting for Equipment. The equipment short-circuit and ground-fault protective device must be capable of carrying the starting current of the equipment. Where the equipment incorporates more than one hermetic refrigerant motor-compressor or a hermetic refrigerant motor-compressor and other motors, the equipment short-circuit and ground-fault protection must comply with 440.22(B)(1).

(1) Motor-Compressor Largest Load. Where a hermetic refrigerant motor-compressor is the largest load connected to the circuit, the rating or setting of the short circuit and ground-fault protective device is not permitted to exceed the value specified in 440.22(A) for the largest motor-compressor plus the sum of the rated-load current of the other motor loads.

▶ Motor-Compressors and Other Motors [440.22(B)(1) and 440.22(A) Ex 1] Example

Question: *What size short-circuit ground-fault protective device is required for a 23.90A motor-compressor with a 1.20A fan?* **Figure 440–10**

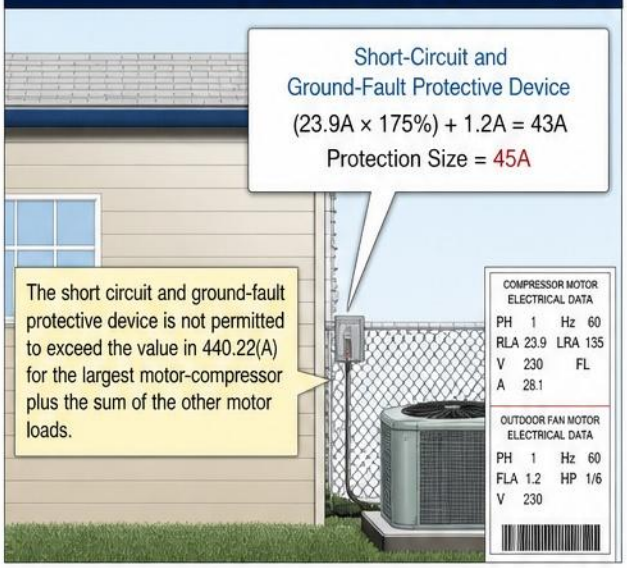
(a) 30A *(b) 35A* *(c) 40A* *(d) 45A*

Solution:

Maximum Short-Circuit Ground-Fault = (23.90A × 175%) + 1.20A
Maximum Short-Circuit Ground-Fault = 43A
Maximum Short-Circuit Ground-Fault = 45A, next size up [440.22(A) Ex 1]

Answer: *(d) 45A*

Figure 440–10 Short-Circuit and Ground-Fault Protective Device Size Example | 440.22(B)(1) and 440.22(A) Ex 1



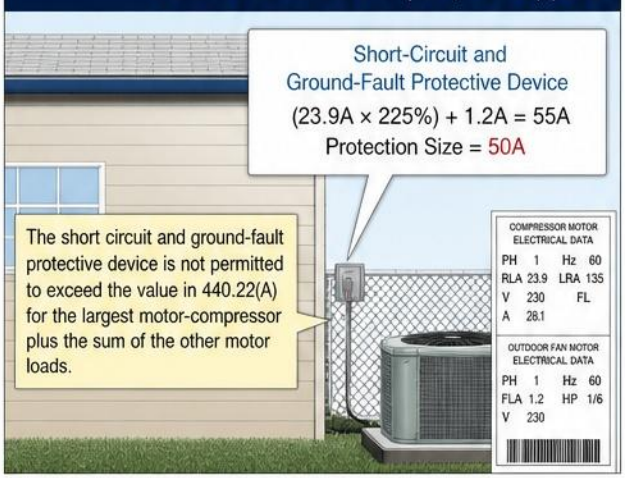
This example shows that the short-circuit and ground-fault protective device is limited by 440.22(A) to the largest motor-compressor plus the sum of other motor loads.

▶ Motor-Compressors and Other Motors [440.22(B)(1) and 440.22(A) Ex 2] Example

Question: Where the short-circuit ground-fault protective device sized at 175 percent does not permit a 23.90A motor-compressor with a 1.20A fan to start, the protection device can be sized at _____.

(a) 35A (b) 40A (c) 45A (d) 50A

Figure 440–11 Short-Circuit and Ground-Fault Protective Device Size Example | 440.22(B)(1) and 440.22(A) Ex 2



Solution:

Maximum Short-Circuit Ground-Fault = (23.90A × 225%) + 1.20A

Maximum Short-Circuit Ground-Fault = 55A

Maximum Short-Circuit Ground-Fault = 50A, *next size down* [440.22(A) Ex 2]

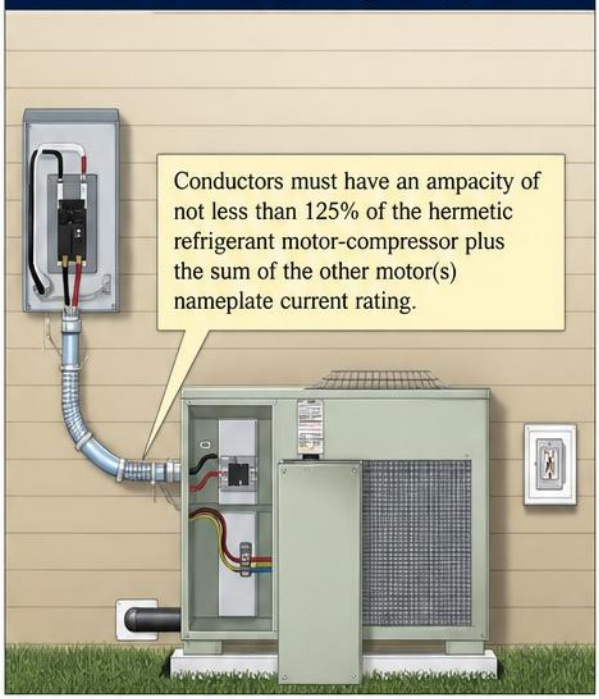
Answer: (c) 50A

Part IV. Conductor Sizing

440.33 Motor-Compressor(s) With or Without Additional Motor Loads

Conductors supplying hermetic refrigerant motor-compressors with other motors must have an ampacity of not less than the sum of the following: ▶ **Figure 440–12**

Figure 440–12 Conductor Ampacity for Air-Conditioning and Refrigeration Equipment | 440.33



(1) The hermetic refrigerant motor-compressor nameplate current rating.

(2) The sum of other motor(s) nameplate current rating.

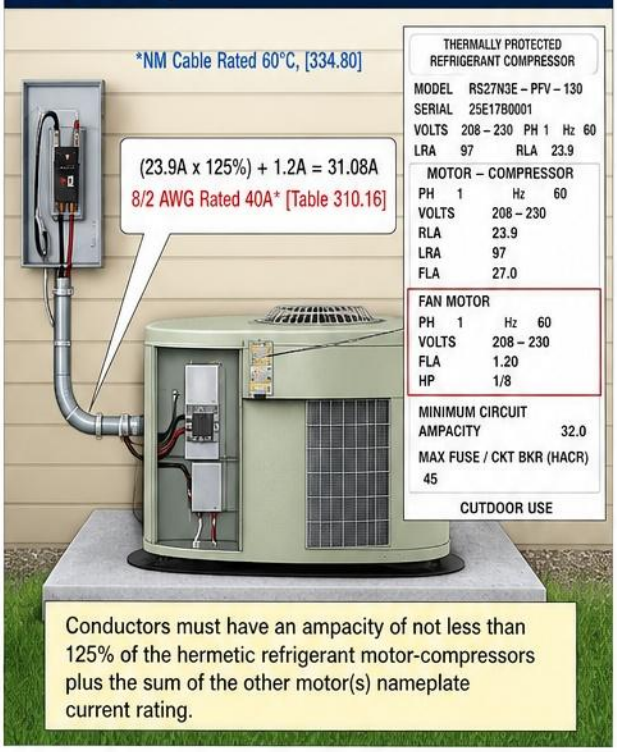
(3) 25 percent of the highest hermetic refrigerant motor-compressor current rating.

Motor-Compressor and Other Motors—Conductor Size Example 1

Question: What size conductor is required for a 23.9A refrigerant motor-compressor with a 1.20A fan, where supplied by NM cable required to be sized at 60°C in accordance 334.80? ▶ **Figure 440–13**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

Figure 440–13
Air-Conditioning and Refrigeration Equipment NM Cable Sizing
NEC 440.33 and 334.80



The conductors shown are NM cable rated 60°C, sized according to 334.80 for the calculated load.

Solution:

Conductor Size = (23.9A × 125%) + 1.20A

Conductor Size = 29.88A + 1.20A

Conductor Size = 31.08A

Use 8 AWG rated 40A at 60°C [334.80 and Table 310.16].

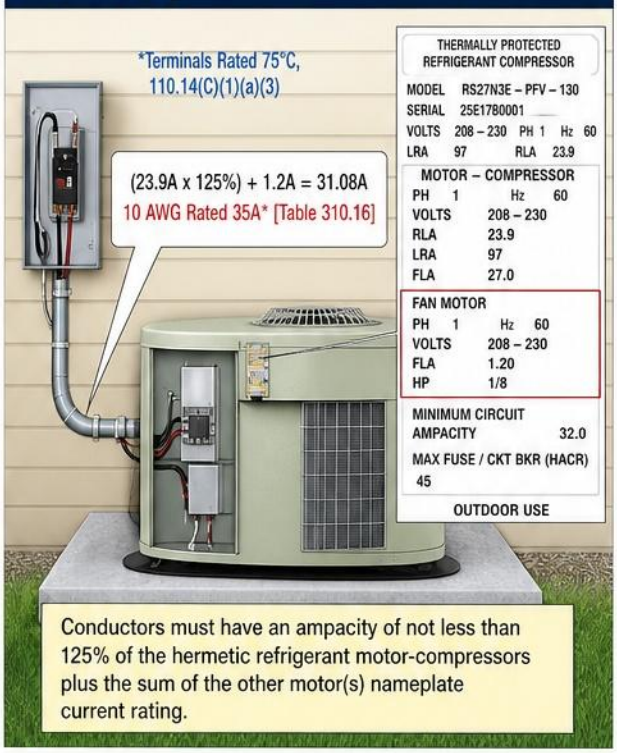
Answer: *(c) 8 AWG*

Motor-Compressor and Other Motors—Conductor Size Example 2

Question: What size conductor is required for a 23.9A refrigerant motor-compressor with a 1.20A fan, where the conductors are permitted to be sized at 75°C in accordance 110.14(C)(1)(a)(3)? ▶ **Figure 440–14**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

Figure 440–14
Air-Conditioning and Refrigeration Equipment Conductor Sizing
NEC 440.33 and Table 310.16



The conductors shown are permitted to be sized at 75°C in accordance with *110.14(C)(1)(a)(3)*.

Solution:

Conductor Size = (23.9A × 125%) + 1.20A

Conductor Size = 29.88A + 1.20A

Conductor Size = 31.08A

Use 10 AWG rated 35A at 75°C [240.4(G), 110.14(C)(1)(a)(3) and Table 310.16].

Answer: *(b) 10 AWG*

ARTICLE

445 Generators

Introduction to Article 445—Generators

Article 445 covers the installation and other requirements for generators. The rules in this article include provisions for where generators may be installed, nameplate markings, conductor ampacity, power transfer, and disconnecting means.

Generator. A machine that converts mechanical energy into electrical energy by means of a prime mover.

Figure 445–1 Article 100 Definition

A machine that converts mechanical energy into electrical energy by means of a prime mover.

445.1 Scope

This article covers requirements for generators.

445.2 Listing Requirements

Stationary generators must be listed.

Figure 445–2 445.1 Scope

Article 445 covers requirements for generators.

Figure 445–3 445.2 Listing Requirements

Stationary generators must be listed.

445.11 Marking

(A) General.

(1) Nameplate. The generator's nameplate must include:

(1) Manufacturer's name

(2) Rated frequency

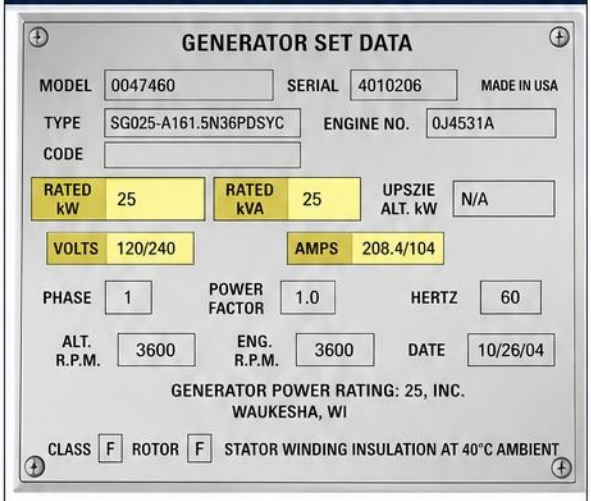
(3) Number of phases

(4) Rating in kilowatts or kilovolt-amperes

(5) Power factor

(6) Volts and amperes ▶Figure 445–4

Figure 445–4 Generators, Nameplate Marking 445.11(A)(1)



The generator's nameplate must list the manufacturer's name, rated frequency, number of phases, rating in kW or kVA, power factor, volts, and amperes.

(2) Neutral Status.

(a) Manufacturer marking must indicate if the neutral is bonded to the frame or not.

(b) Field marking is required to indicate if the neutral is bonded to the frame, if the manufacturer bonding is modified ▶Figure 445–5

445.13 Conductor Minimum Ampacity and Size

(A) Overcurrent Protection Not Provided. The conductor's ampacity from the generator terminals to an overcurrent protective device must not be less than 115 percent of the generator's nameplate current rating. ▶Figure 445–6

Figure 445–5 Generators, Marking Neutral Bonded to Frame 445.11(A)(2)

The manufacturer marking must indicate if the neutral is bonded to the frame or not. If the manufacturer bonding is modified in the field, field marking is required to indicate if the neutral is bonded to the frame.

Figure 445–6 Generators, Conductor Ampacity and Size Overcurrent Protection Not Provided 445.13(A)

The ampacity of the conductors from the generator terminals to the overcurrent protective device must not be less than 115% of the generator's nameplate current rating.

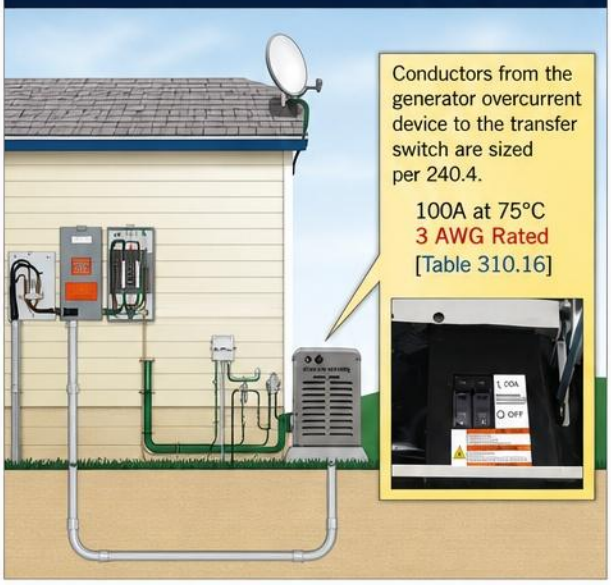
Author's Comment:

- Conductors from the load side of the generator overcurrent protective device to the transfer switch are sized to the generator's overcurrent protective device rating in accordance with 240.4. ▶Figure 445–7

445.18 Disconnecting Means

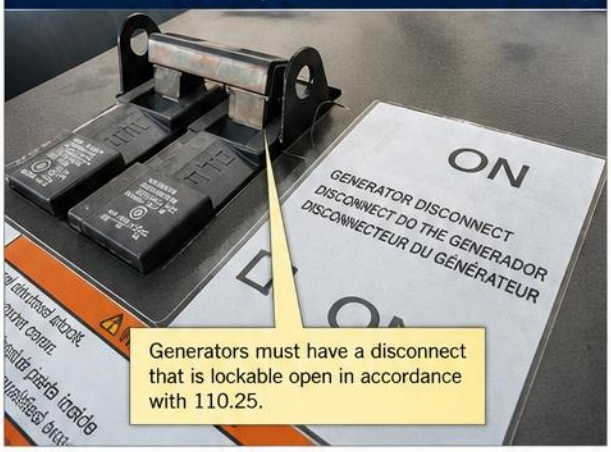
(A) Disconnect Required. Generators must have a disconnect that is lockable open in accordance with 110.25. ▶Figure 445–8

Figure 445–7 Generators, Conductor Ampacity and Size **445.13(A) Comment**



Conductor sizing from the generator overcurrent device to the transfer switch is based on 240.4. Example shown: 100A at 75°C requires 3 AWG rated conductors *[Table 310.16]*.

Figure 445–8 Generators, Disconnecting Means Lockable Open **445.18(A)**



Generators must be equipped with a disconnecting means that can be secured in the open position per 110.25.

The disconnecting means is permitted to be located within the generator behind a hinged cover, door, or enclosure panel.

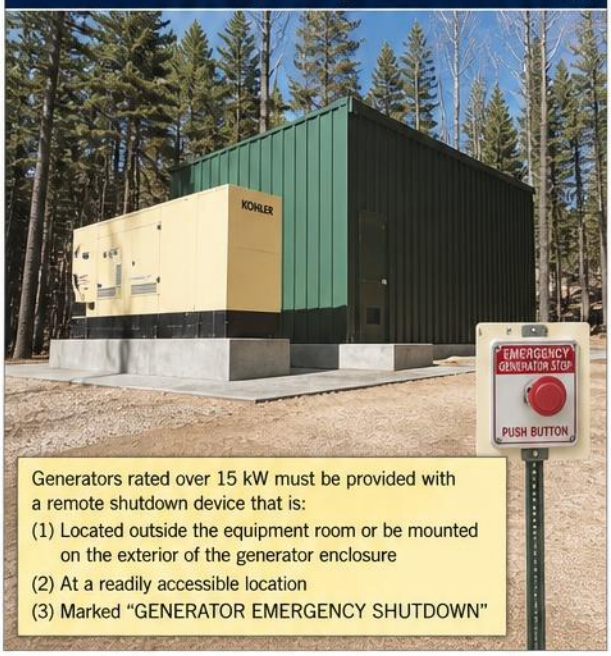
445.19 Prime Mover Emergency Shutdowns

(B) Commercial and Industrial Installations. In other than one- and two-family dwelling units, generators rated over 15 kW must be provided with a remote shutdown device for the prime mover that complies with all of the following: ▶ **Figure 445–9**

(1) Located outside the equipment room or be mounted on the exterior of the generator enclosure

(2) Readily accessible location

Figure 445–9 Generators, Emergency Shutdown of Prime Mover Other than One- and Two-Family Dwelling Units **445.19(B)**



Generators over 15 kW require a remote shutdown device that is outside the equipment room or mounted on the generator enclosure, readily accessible, and clearly marked "GENERATOR EMERGENCY SHUTDOWN."

(3) Marked "GENERATOR EMERGENCY SHUTDOWN," be of sufficient durability to withstand the environment, cannot be handwritten, and must be permanently affixed to the equipment [110.21(B)]

Prime Mover. A machine that supplies mechanical horsepower to a generator. ▶ **Figure 445–10**

Figure 445–10 Prime Mover **Article 100 Definition**

(C) One- and Two-Family Dwelling Units. The generator prime mover emergency shutdown device must comply with the following: ▶ **Figure 445–11**

Figure 445–11 Generators, Emergency Shutdown of Prime Mover One- and Two-Family Dwelling Units **445.19(C)**

Generators must be provided with an emergency shutdown device that is:

1. Located outside the dwelling unit
2. At a readily accessible location
3. Marked "GENERATOR EMERGENCY SHUTDOWN"

1. The emergency shutdown device must be installed outside the dwelling unit.
2. The device must be placed in a location that is readily accessible.
3. The device must be identified by the marking "GENERATOR EMERGENCY SHUTDOWN," which must be durable enough to resist environmental conditions, must not be handwritten, and must be permanently affixed to the equipment [110.21(B)].

ARTICLE

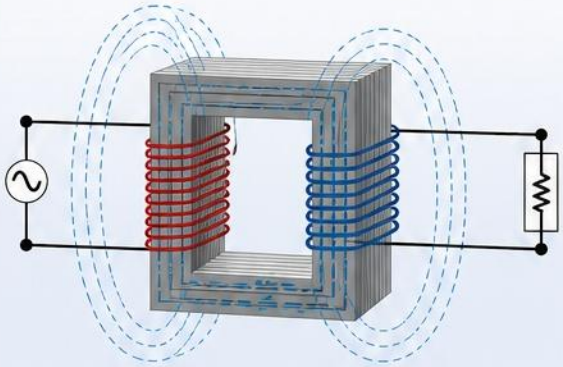
450 Transformers

INTRODUCTION TO ARTICLE 450—TRANSFORMERS

Article 450 sets forth the rules governing transformers that supply power and lighting loads. While the *NEC* does not establish design criteria for transformers, it provides comprehensive provisions to ensure that a transformer selected for installation and operation performs as intended by the designer.

Transformer. Equipment having one or more windings that uses electromagnetic induction to change current and voltage in a primary circuit to different current and voltage values in a secondary circuit. Figure 450–1

Figure 450–1 Transformer Definition NEC 100



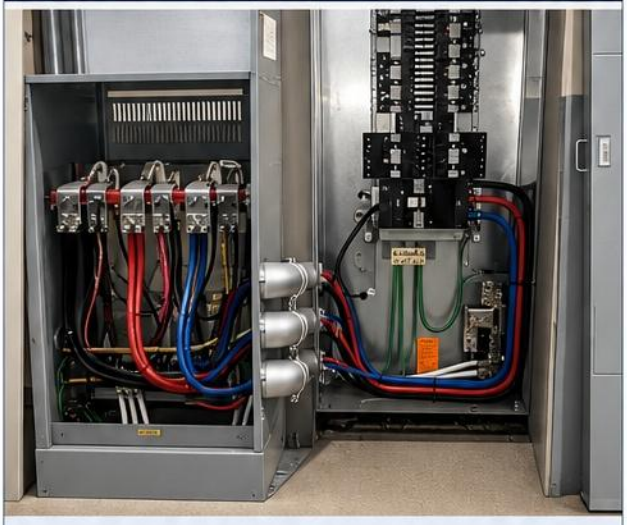
Single- or three-phase equipment that uses electromagnetic induction to convert current and voltage in a primary circuit into current and voltage in a secondary circuit.

450.1 Scope

This article contains the requirements for transformers other than the following:

Figure 450–2

Figure 450–2 Scope NEC 450.1



This article sets forth the requirements for transformers.

(1) Current transformers

(2) Dry-type that constitutes a component part of another apparatus

(3) Integral part of an X-ray, high-frequency, or electrostatic-coating apparatus

(4) Class 2 and 3 power-limited circuits

(5) Signs

(6) Electric-discharge lighting

(7) Power-limited fire alarm circuits

(8) Research, development, or testing

450.5 PRIMARY OVERCURRENT PROTECTION

(B) Transformer 1000V or Less. Transformers are required to have a primary overcurrent protective device in accordance with Table 450.5(B) and any applicable notes.

TABLE 450.5(B)
PRIMARY PROTECTION ONLY

PRIMARY CURRENT RATING	MAXIMUM PROTECTION
Less than 2A	300%
2A to 9A	167%
More Than 9A	125%[1]

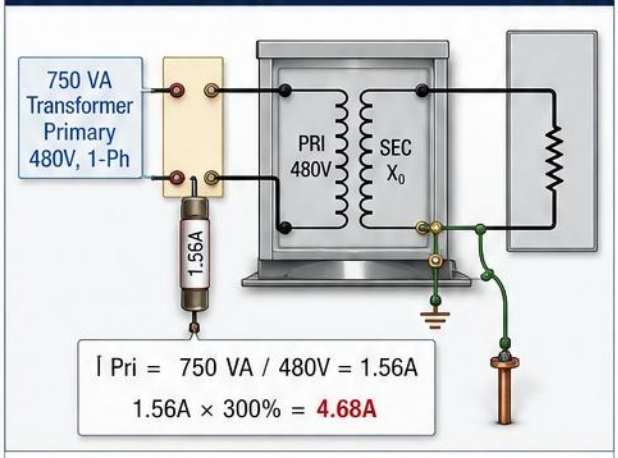
Note 1: *Transformers with a primary current rating of 9A (or more) may use the "next size up" rule when 125 percent of the primary current does not match the standard rating of a fuse or circuit breaker listed in 240.6(A).*

▶ Primary Only Protection—Current Less than 2A [Table 450.5(B)] Example

Question: *What is the maximum primary only overcurrent* protective device rating for a 750 VA, single-phase, 480V transformer? ▶ **Figure 450–3**

(a) 3A *(b) 6A* *(c) 10A* *(d) 15A*

Figure 450–3 Primary Overcurrent Protection Only—Current Less than 2A Example **450.5(B)**



For a 750 VA, 480V primary, the primary current is 1.56A. The maximum primary overcurrent protective device rating is 4.68A.

Solution:

Primary Current = Transformer VA Rating/Primary Voltage

Primary Current = 750 VA/480V

Primary Current = 1.56A

Primary Protection = Primary Current × Table 450.5(B) Percentage

Primary Protection No Greater Than = 1.56A × 300%

Primary Protection No Greater Than = 4.68A

Use a 3A overcurrent protective device [240.6(A) and Table 450.5(B)].

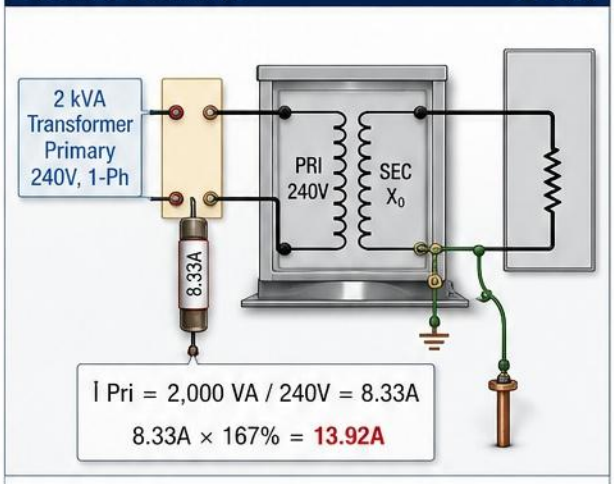
Answer: *(a) 3A*

▶ Primary Only Protection—Current 2A to 9A [Table 450.5(B)] Example

Question: *What is the maximum primary only overcurrent* protective device rating for a 2 kVA, single-phase, 240V transformer? ▶ **Figure 450–4**

(a) 3A *(b) 6A* *(c) 10A* *(d) 15A*

Figure 450–4 Primary Overcurrent Protection Only—Current 2A to 9A Example **450.5(B)**



For a 2 kVA, 240V primary, the primary current is 8.33A. The maximum primary overcurrent protective device rating is 13.92A.

Solution:

Primary Current = Transformer VA Rating/Primary Voltage

Primary Current = 2,000 VA/240V

Primary Current = 8.33A

Primary Protection = Primary Current × Table 450.5(B) Percentage

Primary Protection No Greater Than = 8.33A × 167%

Primary Protection No Greater Than = 13.92A

Use a 10A overcurrent protective device [240.6(A) and Table 450.5(B)].

Answer: *(c) 10A*

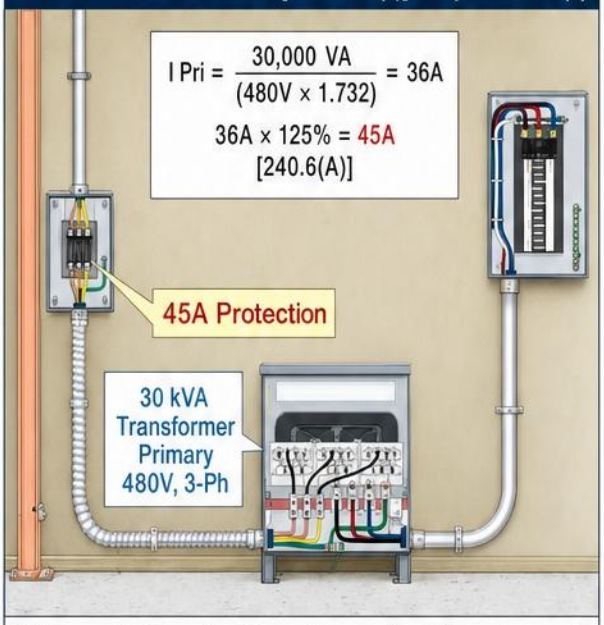
▶ Primary Only Protection—Primary Current Greater than 9A [Table 450.5(B)] Example

Question: *What is the maximum primary only overcurrent protective device rating for a 30 kVA, three-phase, 480V to 208Y/120V transformer?*

See Figure **450–5**.

(a) 40A *(b) 45A* *(c) 50A* *(d) 60A*

Figure 450–5 Primary Only Protection—Primary Current Greater than 9A [Table 450.5(B)] Example 450.5(B)



This example determines the maximum rating of the primary only overcurrent protective device for the transformer shown.

Solution:

First, calculate the primary current using transformer VA rating and primary voltage:

I Pri = *Transformer VA Rating/(Primary Voltage × 1.732)*

I Pri = *30,000 VA/(480V × 1.732)*

I Pri = *30,000 VA/831.36V*

I Pri = *36A*

Next, determine the primary protection using the 125 percent factor from Table 450.5(B):

Primary Protection = Primary Current × 125%

Primary Protection = 36A × 125%

Primary Protection = 45A

Select a 45A overcurrent protective device from [240.6(A)] and Table 450.5(B).

Answer: *(b) 45A.*

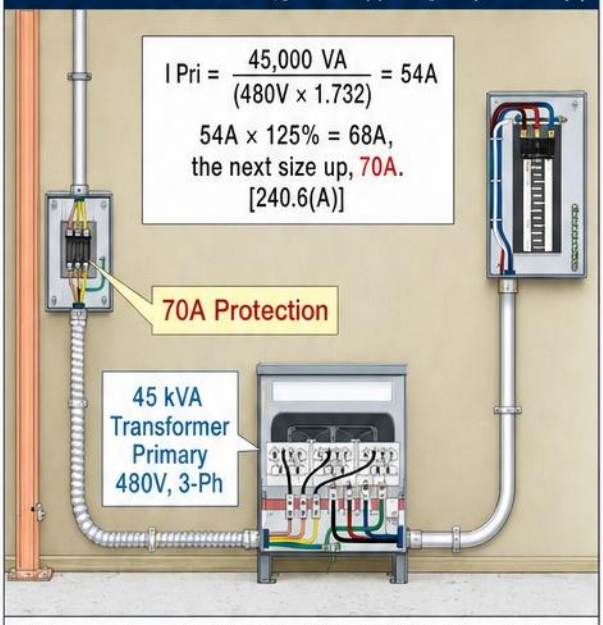
▶ Primary Only Protection—Primary Current Greater than 9A, [Table 450.5(B) Note 1] Example

Question: *What is the maximum primary only overcurrent protective device rating for a 45 kVA, three-phase, 480V to 208Y/120V transformer?*

See Figure **450–6**.

(a) 50A *(b) 60A* *(c) 70A* *(d) 100A*

Figure 450–6 Primary Only Protection—Primary Current Greater than 9A, [Table 450.5(B) Note 1] Example 450.5(B)



This example applies Note 1 to Table 450.5(B) when selecting the primary protection.

Solution:

First, calculate the primary current using transformer VA rating and primary voltage:

I Pri = *Transformer VA Rating/(Primary Voltage × 1.732)*

I Pri = *45,000 VA/(480V × 1.732)*

I Pri = *45,000 VA/831.36V*

I Pri = *54A*

Next, determine the primary protection using the 125 percent factor from Table 450.5(B):

Primary Protection = Primary Current × 125%

Primary Protection = 54A × 125%

Primary Protection = 68A

Use a 70A overcurrent protective device from [240.6(A)] and Table 450.5(B) Note 1.

Answer: *(c) 70A.**

**According to Note 1 of Table 450.5(B), transformers having a primary current rating of 9A or more are permitted to use the "next size up" rule when 125 percent of the primary current does not correspond to the standard rating of a fuse or nonadjustable circuit breaker listed in 240.6(A). This Note does not require the next size up protection, it permits the use of the next size up protective device.*

450.6 AUTOTRANSFORMERS

(A) Overcurrent Protection. Overcurrent protective devices for autotransformers must be:

(2) Sized at not more than 125 percent of the rated full-load input current

(3) Where this calculation does not correspond to a standard rating of a fuse or circuit breaker and the rated input current is 9A or more, use the next higher standard rating in accordance with Table 240.6(A)

▶ Overcurrent Protection for Autotransformer [450.6(A)] Example

Question: *What is the maximum overcurrent protective device size permitted for a 112.5 kVA, 480V to 416V three-phase autotransformer having a primary input current rating of 135A?*

(a) 150A (b) 175A (c) 200A (d) 225A

Solution:

Input Current = 135A

Overcurrent Protection = Input Current × 125%
Overcurrent Protection = 135A × 125%
Overcurrent Protection = 169A

Primary overcurrent protection is 175A, next size up [Table 240.6(A) and 450.6(A)].

Answer: *(b) 175A*

450.11 VENTILATION

(B) Ventilation Openings. Transformers with ventilating openings must be installed so that the ventilating openings are not blocked by walls or other obstructions. ▶ Figure 450–7

(C) Marking. Transformers must maintain the ventilation clearances marked on the transformer. ▶ Figure 450–8

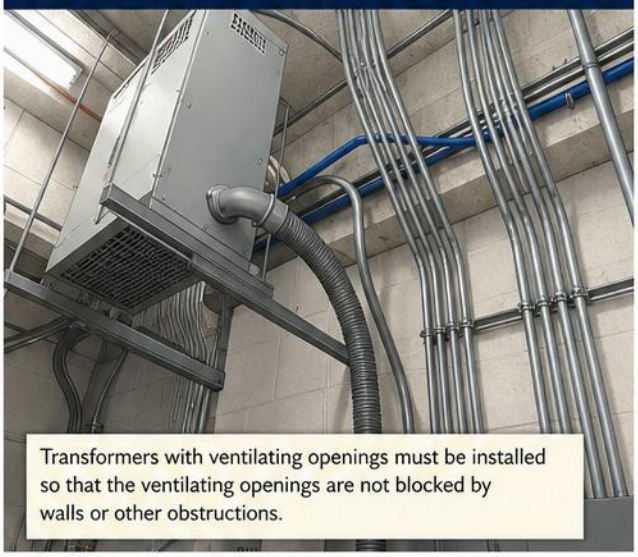
450.12 GROUNDING AND BONDING

(A) Dry-Type Transformer Enclosures. The grounding terminal bar must be installed:

(1) Inside the transformer enclosure

(2) Bonded to the enclosure in accordance with 250.12

Figure 450–7 Ventilation Openings Cannot Be Blocked 450.11(B)



(3) Where it does not obstruct any ventilation openings. ▶ Figure 450–9

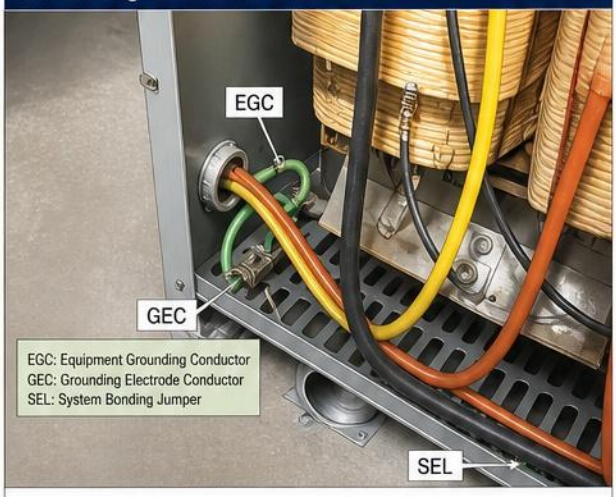
Figure 450–8 Transformer Ventilation Clearance Marking 450.11(C)

(4) Multiple terminal bars must be interconnected with a bonding jumper sized not less than the largest conductor connected to either interconnected terminal bar. ▶ Figure 450–10

Author's Comment:

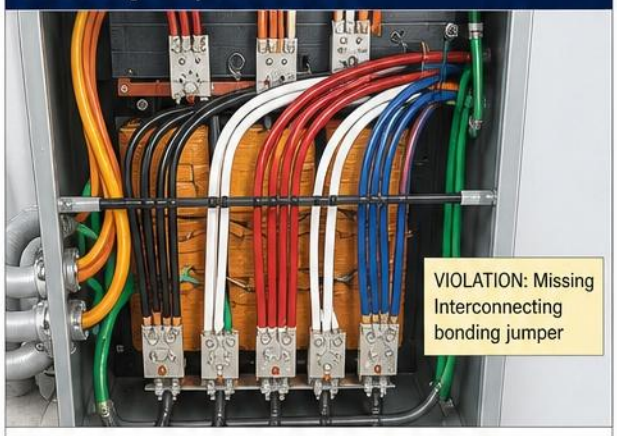
▶ The grounding electrode conductor required for a transformer must not pass through any ventilation openings in the transformer enclosure in accordance with 250.64(G).

Figure 450–9 Transformers, Grounding and Bonding Terminal Bar at Enclosure 450.12(A)



The grounding terminal bar must be installed:
(1) Inside the transformer enclosure
(2) Bonded to the enclosure per 250.12
(3) Where it does not obstruct any ventilation openings

Figure 450–10 Transformers, Grounding and Bonding Multiple Terminal Bars 450.12(4)



Multiple terminal bars must be interconnected with a bonding jumper sized not less than the largest conductor connected to either interconnected terminal bar.

Figure 450–11 Transformer Accessibility, Open Walls or Columns 450.15(A)

Figure 450–12 Transformer Accessibility, Suspended Ceilings 450.15(B)

450.15 Transformer Accessibility

(A) Open Installations. Dry-type transformers are required to be readily accessible, unless located on open walls or columns.

▶ Figure 450–11

(B) Above Suspended Ceilings. Dry-type transformers rated not more than 50 kVA are permitted to be installed in hollow spaces of a building such as above a suspended ceiling.

▶ Figure 450–12

450.16 Disconnecting Means

Within Sight. The disconnect for a transformer is required to be within sight and not more than 50 ft from the transformer in accordance with 110.29.

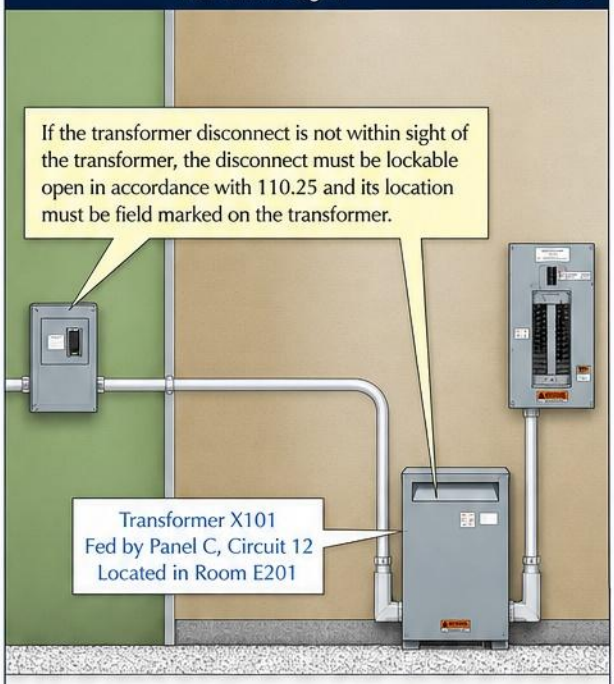
▶ Figure 450–13

Not Within Sight. If the transformer disconnect is not within sight and not more than 50 ft of the transformer, the transformer disconnect must be lockable open in accordance with 110.25. The location of the transformer disconnect must be field marked on the transformer. ▶ Figure 450–14

Figure 450–13 Transformer Disconnect Within Sight 450.16

The disconnect for a transformer must be within sight and not more than 50 ft from the transformer in accordance with 110.29.

Figure 450–14 Transformer Disconnect Not Within Sight 450.16



When the transformer disconnect is not within sight of the transformer, the disconnect must be lockable open per 110.25 and the transformer must be field marked to identify the location of that disconnect.

The disconnecting means for a transformer must be installed within sight of the transformer and not farther than 50 ft from it, in accordance with 110.29.

If the disconnecting means is not within sight, it must be capable of being locked in the open position in accordance with 110.25. The transformer must be permanently and legibly marked to indicate the location of the disconnecting means.

ARTICLE 480 Stationary Batteries

Introduction to Article 480—Stationary Batteries

The provisions of this article apply to the requirements for stationary batteries having a capacity greater than 1 kWh. Systems such as uninterruptible power supplies, emergency power and lighting systems, and stand-alone power systems are a few of the many applications of this article.

480.1 Scope

This article covers the requirements for stationary batteries having a capacity greater than 1 kWh. **Figure 480-1**

Figure 480-1 Stationary Batteries 480.1

This article establishes the requirements for stationary batteries with a capacity greater than 1 kWh.

Note 1: See Article 706 for listed energy storage systems.

480.4 Battery and Cell Terminations

(A) Corrosion Prevention for Batteries with Acidic or Caustic Electrolyte. Connections to and within a battery with acidic or caustic electrolytes must be assembled using an approved corrosion inhibitor in accordance with the battery manufacturer's instructions. **Figure 480-2**

Figure 480-2 Corrosion Prevention for Batteries with Acidic or Caustic Electrolyte 480.4(A)

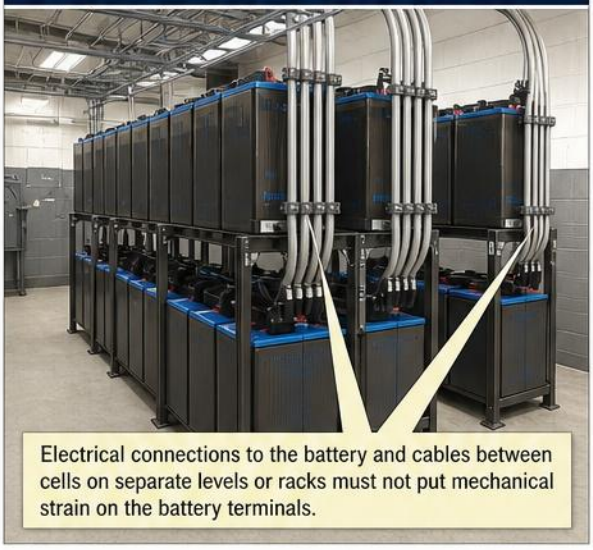
Connections to and within a battery with acidic or caustic electrolytes must be assembled using an approved corrosion inhibitor in accordance with the battery manufacturer's instructions.

(C) Mechanical Strain. Electrical connections to the battery and cables between cells on separate levels or racks to the battery must not put mechanical strain on the battery terminals. **Figure 480-3**

Figure 480-3 Mechanical Strain 480.4(C)

Electrical connections to the battery and cables between cells on separate levels or racks to the battery must not put mechanical strain on the battery terminals.

Figure 480–3 480.4(C)
Battery and Cell Terminations Mechanical Strain



Note: Conductors are commonly pre-formed to eliminate stress on battery terminations. Fine-stranded cables may also eliminate the stress on battery terminations. See the manufacturer's instructions for guidance.

480.9 Battery Support Systems

For battery chemistries with corrosive electrolytes, the structure that supports the battery must be resistant to deterioration caused by the electrolyte. Metallic structures must have nonconductive support members for the cells or be built with a continuous insulating material.

Figure 480–4 480.9
Battery Support Systems

The battery support structure must be resistant to deterioration caused by the electrolyte and must have nonconductive support members or be constructed with a continuous insulating material.

480.10 Battery Locations

(A) Ventilation. Provisions must permit sufficient diffusion and ventilation of battery gases to prevent the accumulation of an explosive mixture. ▶ **Figure 480–5**

Figure 480–5 480.10(A)
Battery Ventilation

Provisions must permit sufficient diffusion and ventilation of battery gases to prevent the accumulation of an explosive mixture.

(C) Working Space for Stationary Batteries. Sufficient working space, including access to and egress from must be provided in accordance with 110.26. Working space is measured from the edge of the battery cabinet, rack, or tray, must be in accordance with 110.26(A). ▶ **Figure 480–6**

Figure 480–6 480.10(C)
Battery Working Space—How to Measure

Sufficient working space must be provided around stationary batteries. The working space is measured from the edge of the battery cabinet, rack, or tray, must be in accordance with 110.26(A).

(D) Top Terminal Batteries. Where top terminal batteries are installed on tiered racks, working space in accordance with the battery manufacturer's instructions must be provided between the highest point on a cell and the row or ceiling above that point. ▸ *480.10(D)*

Figure 480-7 Top Terminal Batteries **480.10(D)**

Where top terminal batteries are installed on tiered racks, working space in accordance with the battery manufacturer's instructions must be provided between the highest point on a cell and the row or ceiling above that point.

(E) Egress. Personnel doors intended for entrance to or egress from rooms designated as battery rooms must open 90 degrees in the direction of egress. The doors must be equipped with listed panic or listed fire exit hardware.

(F) Illumination. The working space around a stationary battery must have illumination that is not controlled by automatic means only.

480.12 Battery Interconnections

Minimum Size. Flexible cables are permitted within the battery enclosure from battery terminals to a nearby junction box. These cables must be connected to an approved wiring method.

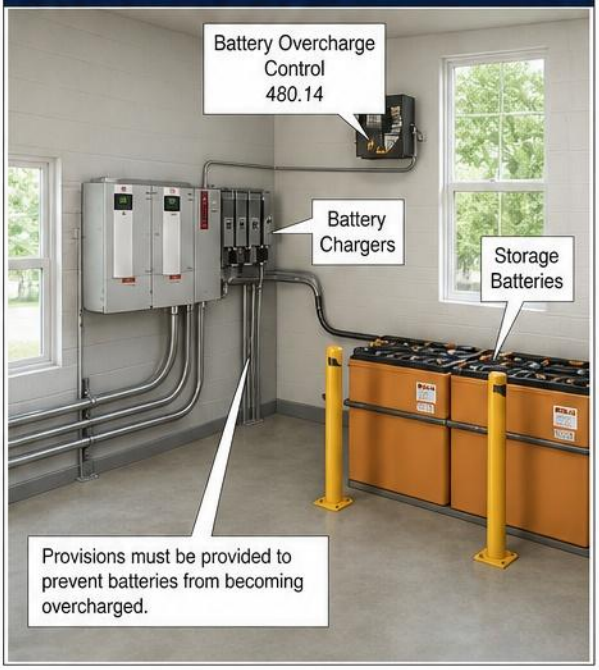
Listed and Identified. Battery cables must be listed and identified for the conditions of use and location.

Fine-Stranded Cables. Terminals for flexible fine-stranded cables must be identified for use in accordance with 110.14.

480.14 Overcharge Control

Provisions must be provided to prevent batteries from becoming overcharged. ▸ 480.8

Figure 480-8 Overcharge Control **480.14**



Location of Service Disconnecting Means

The service disconnecting means must be located where it is readily accessible and within sight from the service equipment. If the disconnecting means is not within sight, it must be lockable in the open (off) position. (See Figure 230.70.)

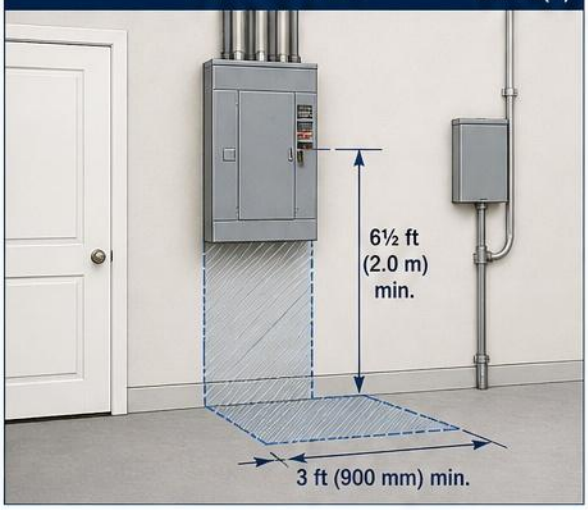
Figure 230.70 Service Disconnect Within Sight 230.70

A service disconnecting means must be located within sight and readily accessible from the service equipment.

Working Space at Service Equipment

A minimum working space must be provided and maintained in front of service equipment to permit ready and safe operation and maintenance of the equipment. (See Figure 230.72(A).)

Figure 230.72(A) Working Space in Front of Service Equipment 230.72(A)

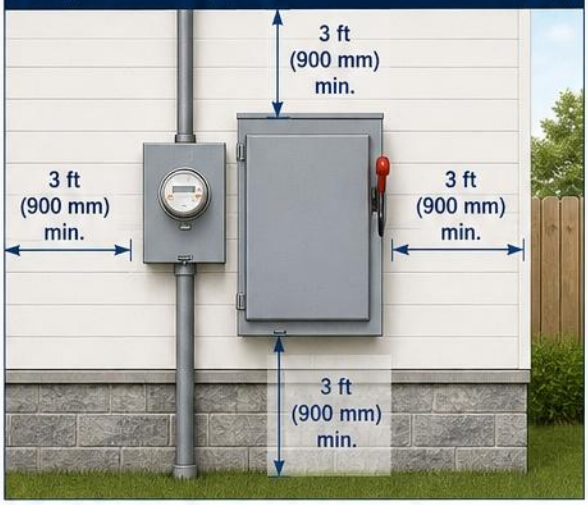


A minimum working space must be provided and maintained in front of service equipment.

Clearances to Service Equipment

Adequate clearances must be provided and maintained about service equipment for safe operation and maintenance. (See Figure 230.72(B).)

Figure 230.72(B) Clearance About Service Equipment 230.72(B)

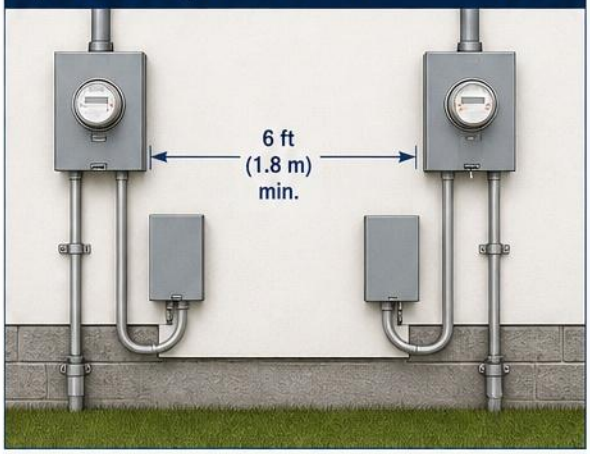


Adequate clearances must be provided and maintained about service equipment.

Separation of Services

Services supplying different buildings or structures must have service conductors and equipment separated from each other by not less than 6 feet (1.8 m), measured as a straight-line distance between the points of closest approach. (See Figure 230.74.)

Figure 230.74 Separation of Services 230.74

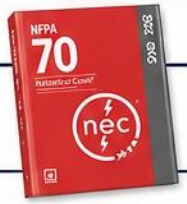


Service conductors and equipment supplying different buildings or structures must be separated by not less than 6 feet (1.8 m) measured as a straight-line distance between the points of closest approach.

CHAPTER

4

REVIEW QUESTIONS



Please use the 2026 *Code* book to answer the following questions.

1. General-use and motor-circuit switches, circuit breakers, and molded case switches shall indicate whether they are in the _____ position.

Figure 4-1 Switch Positions 110.12

(a) up or down (b) open (off)
(c) closed (on) (d) open (off) or closed (on)

2. Switches and circuit breakers used as switches installed adjacent to motors, appliances, or equipment that they supply shall be permitted to be located _____ than 6 ft 7 in. above the floor, finished grade, or working platform.

Figure 4-2 Location of Switches 110.26(A)(1)

(a) lower (b) higher
(c) no further (d) less

3. Where in the off position, a switching device with a marked OFF position shall completely disconnect all _____ conductors of the load it controls.

Figure 4-3 Switching Device in Off Position 110.7(A)

(a) grounded (b) ungrounded
(c) grounding (d) all of these

4. The enclosures and cover for receptacles installed outdoors in damp locations protected from weather shall be _____ when the cover is closed without an attachment plug cap inserted.

Figure 4-4 Weatherproof Cover 406.8(B)(1)

(a) weatherproof (b) rainproof
(c) waterproof (d) any of these

5. Where 15A and 20A receptacles are installed in a wet location, the outlet box hood shall be listed and identified as _____ use.

Figure 4-5 Wet Location Outlet Box Hood 406.8(B)(1)

(a) heavy-duty (b) extra-duty
(c) varying-duty (d) continuous-duty

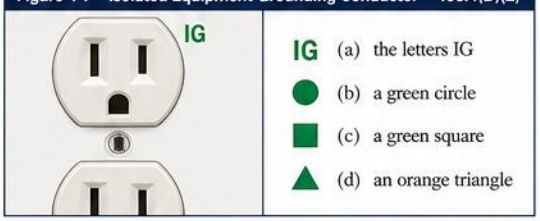
6. Wiring devices with terminals not marked CO/ALR are not permitted to terminate to _____ conductors.

Figure 4-6 Terminal Marking 110.14(C)

(a) aluminum (b) copper
(c) copper-clad aluminum (d) any of these

7. Receptacles incorporating an isolated equipment grounding conductor shall be identified by _____ located on the face of the receptacle.

Figure 4-7 Isolated Equipment Grounding Conductor 406.4(D)(2)



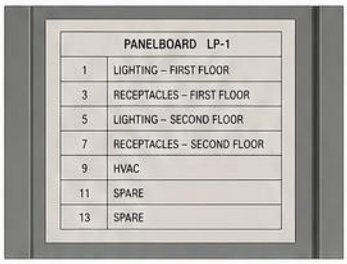
IG (a) the letters IG
● (b) a green circle
■ (c) a green square
▲ (d) an orange triangle

8. 15A and 20A, 125V receptacles that are controlled by an automatic control device for energy management or building automation shall be permanently marked with the word _____.

(a) power
(b) controlled
(c) energy management
(d) any of these

9. The panelboard circuit description shall not be dependent on _____ conditions of occupancy.

(a) special
(b) transient
(c) random
(d) any of these



10. Switchboards and panelboards in other than one- and two-family dwelling units, shall be field marked in a(n) _____ location on the enclosure with the available fault current and the date the calculation was performed.

(a) accessible
(b) readily accessible
(c) visible
(d) readily visible

11. Recessed incandescent or LED luminaires with a completely enclosed light source shall have a minimum clearance of _____ from the clothes closet storage space.

(a) 3 in.
(b) 6 in.
(c) 8 in.
(d) 12 in.

12. Surface-mounted fluorescent or LED luminaires shall be permitted to be installed within the clothes closet storage space where _____ for this use.

(a) identified
(b) listed
(c) approved
(d) marked

13. Electric-discharge and LED luminaires supported independently of the outlet box shall be connected to the branch circuit through _____.

(a) metal or nonmetallic raceways
(b) MC, AC, or NM cable
(c) flexible cords
(d) any of these

14. Metal raceways shall be bonded to the metal pole supporting luminaires with a(n) _____.

(a) grounding electrode
(b) grounded conductor
(c) equipment grounding conductor
(d) grounding electrode conductor

15. Where no equipment grounding conductor exists at the outlet, replacement luminaires that are _____ or do not have exposed conductive parts shall not be required to be connected to an equipment grounding conductor.

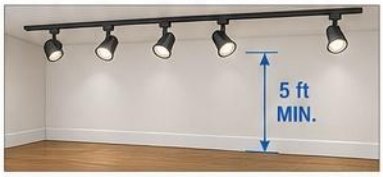
(a) AFCI protected
(b) GFPE protected
(c) SPGFCI protected
(d) GFCI protected

16. Track lighting shall not be installed _____.

(a) where likely to be subjected to physical damage
(b) in wet or damp locations
(c) where concealed
(d) all of these

17. Track lighting shall not be installed less than _____ above the finished floor except where protected from physical damage.

(a) 4 ft
(b) 5 ft
(c) 5½ ft
(d) 6 ft



18. The luminaires, power supply, and luminaire fittings of a low-voltage lighting system shall be _____.

(a) approved
(b) listed
(c) marked
(d) labeled

19. A lighting system assembled from _____ listed parts shall be permitted.

(a) low-voltage luminaires identified for the use
(b) power supply identified for the use
(c) low-voltage luminaire fittings identified for the use
(d) all of these

20. Low-voltage lighting system conductors can be concealed or extended through _____.

(a) walls
(b) floors
(c) ceilings
(d) any of these

21. The overcurrent protection rating for nonmotor-operated appliances shall not exceed _____ of the appliance rated current if the overcurrent protection rating is not marked and over 13.30A.

(a) 100 percent (b) 125 percent
(c) 150 percent (d) 160 percent

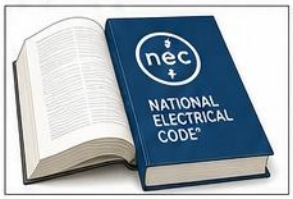
22. Power-supply cords for appliances are permitted to be used to _____.

(a) connect appliances to facilitate their frequent interchange
(b) prevent the transmission of noise
(c) facilitate the removal or disconnection of appliances that are fastened in place and identified for flexible cord connection
(d) any of these

23. A dishwasher shall be permitted to be cord-and-plug-connected with a power-supply cord not less than 3 ft and not exceeding _____ in length.

(a) 6½ ft
(b) 7 ft
(c) 7½ ft
(d) 8 ft

24. The _____ shall be used to determine separate motor overload protection.



(a) *NEC* Tables 430.248 and 430.250
(b) the manufacturer's instructions
(c) the motor disconnect current rating
(d) the motor nameplate current rating

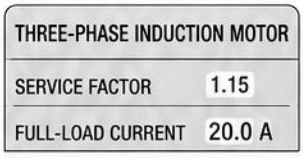
25. Branch-circuit conductors supplying a single continuous-duty motor shall have an ampacity not less than _____ rating.

(a) 125 percent of the motor's nameplate current
(b) 125 percent of the motor's full-load current
(c) 125 percent of the motor's full locked-rotor current
(d) 80 percent of the motor's full-load current

26. Overload devices are intended to protect motors, motor control apparatus, and motor branch-circuit conductors against _____.

(a) excessive heating due to motor overloads
(b) excessive heating due to failure to start
(c) short circuits and ground faults
(d) excessive heating due to motor overloads and excessive heating due to failure to start

27. A separate overload device shall be selected to trip at no more than _____ of the motor nameplate full-load current rating if marked with a service factor of 1.15 or greater.

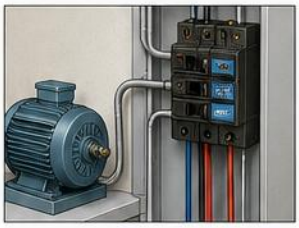


(a) 100 percent
(b) 115 percent
(c) 125 percent
(d) 140 percent

28. Motor branch-circuit short-circuit and ground-fault protective devices are intended to protect _____ against short circuits or ground faults.

(a) motor branch-circuit conductors
(b) motor control apparatus
(c) motors
(d) all of these

29. The motor branch-circuit short-circuit and ground-fault protective device shall be capable of carrying the _____ current of the motor.



(a) ampacity
(b) time delay
(c) thermal protection
(d) starting

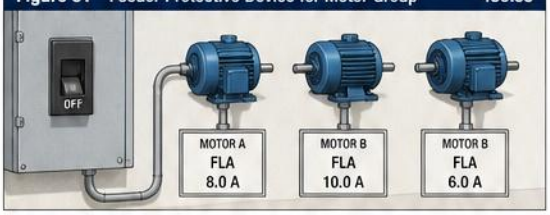
30. The maximum rating or setting inverse time breaker used as the branch-circuit short-circuit and ground-fault protective device for a single-phase motor is _____ of the full-load current given in Table 430.248.

Figure 30 Inverse Time Breaker for Single-Phase Motor 430.52

(a) 125 percent
(b) 130 percent
(c) 175 percent
(d) 250 percent

31. A feeder supplying motor load(s) shall have a protective device with a rating or setting _____ branch-circuit short-circuit and ground-fault protective device for any motor in the group, plus the sum of the full-load currents of the other motors of the group.

Figure 31 Feeder Protective Device for Motor Group 430.53



(a) not greater than the largest rating or setting of the
(b) 125 percent of the largest rating of any
(c) equal to the largest rating of any
(d) at least 80 percent of the

32. For stationary motors of 2 hp or less and 300V or less on ac circuits, the motor controller can be a general-use snap switch where the motor full-load current rating is not more than _____ of the rating of the switch.

Figure 32 General-Use Snap Switch 430.102

(a) 50 percent
(b) 60 percent
(c) 70 percent
(d) 80 percent

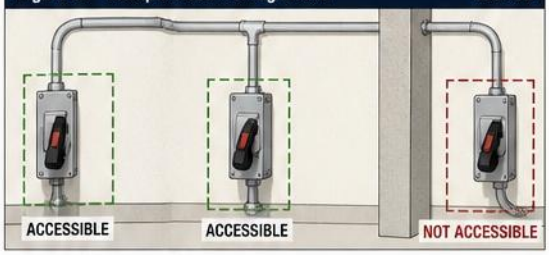
33. A(An) _____ shall be located in sight from the motor location.

Figure 33 In Sight of Motor 430.102

(a) overload device
(b) protective device
(c) disconnecting means
(d) all of these

34. Where more than one motor disconnecting means is provided in the same motor branch circuit, at least one of the disconnecting means shall be _____.

Figure 34 Multiple Disconnecting Means 430.102



(a) readily accessible
(b) accessible
(c) within sight
(d) within 25 ft

35. If a motor disconnecting means is a listed motor-circuit switch, it shall be rated in _____.

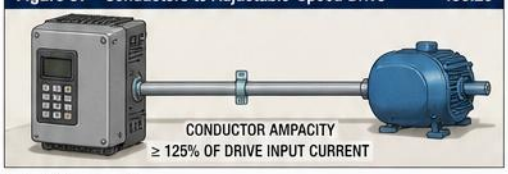
(a) horsepower
(b) watts
(c) amperes
(d) locked-rotor current

36. A horsepower-rated _____ having a horsepower rating not less than the motor rating is permitted to serve as the disconnecting means.

(a) attachment plug and receptacle
(b) flanged surface inlet and cord connector
(c) attachment plug and cord connector
(d) any of these

37. Circuit conductors supplying an adjustable-speed drive system shall have an ampacity not less than _____ of the rated input current to the power conversion equipment.

Figure 37 Conductors to Adjustable-Speed Drive 430.25



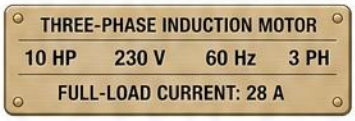
(a) 100 percent
(b) 115 percent
(c) 125 percent
(d) 150 percent

38. The conductors between the adjustable-speed drive system and the motor shall have an ampacity equal to or larger than _____ of the motor full-load current as determined by 430.6(A) or (B).

(a) 100 percent
(b) 115 percent
(c) 125 percent
(d) 150 percent

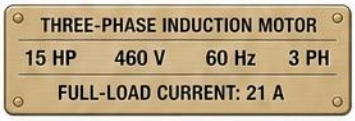
39. The full-load current of a three-phase 10 hp, 230V motor is _____.

(a) 19A
(b) 22A
(c) 28A
(d) 33A



40. The full-load current of a three-phase 15 hp, 460V motor is _____.

(a) 19A
(b) 21A
(c) 29A
(d) 31A



41. _____ applies to air-conditioning and refrigerating equipment that has a hermetic refrigerant motor-compressor.

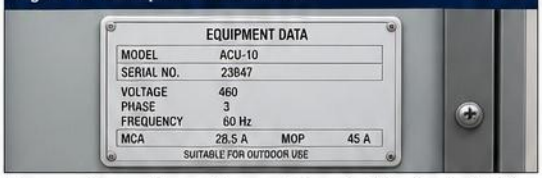
Figure 41 Hermetic Refrigerant Motor-Compressor **Art. 440**

Hermetic refrigerant motor-compressors are covered by Article 440.

(a) Article 440 (b) Article 445
(c) Article 450 (d) Article 460

42. Multimotor and combination-load air-conditioning and refrigeration equipment nameplates shall be _____ after the installation.

Figure 42 Nameplate After Installation **Art. 445**

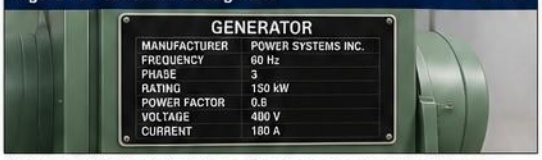


The nameplate must be readily accessible and visible after installation.

(a) accessible (b) readily accessible
(c) visible (d) readily visible

43. Generators shall be provided with a _____ giving the manufacturer's name, the rated frequency, the number of phases, the rating in kilowatts or kilovolts, the power factor, the volts, and amperes.

Figure 43 Generator Rating Plate **Art. 450**



The rating information must be shown on a permanent document.

(a) document (b) nameplate
(c) label (d) marking

44. The required clearances for transformer ventilating openings shall be _____ on the transformer.

Figure 44 Transformer Clearances **Art. 450**

Clearance requirements must be identified on the transformer.

(a) labeled (b) marked
(c) identified (d) any of these

45. Dry-type transformers not exceeding ____ shall be permitted in hollow spaces of buildings and not permanently closed in by the structure.

Figure 45 Dry-Type Transformer **Art. 450**

Only transformers within the rating limit are allowed in these spaces.

(a) 10 kVA (b) 25 kVA
(c) 50 kVA (d) 112.50 kVA

46. Transformers shall have a disconnecting means located either _____ of the transformer in accordance with 110.29 or in a remote location.

Figure 46 Transformer Disconnect Location **Art. 450**

The disconnect must be either within sight of the transformer or located remotely.

(a) within sight (b) visible
(c) outside (d) inside

47. Electrical _____ to a stationary battery, and the cable(s) between cells on separate levels or racks, shall not put mechanical strain on the battery terminals.

Figure 47 Battery Electrical Connection **Art. 480**

Connections must allow for movement without stressing terminals.

(a) connections (b) continuity
(c) conductivity (d) accessibility

48. Conductors are commonly _____ to eliminate stress on stationary battery terminations.

Figure 48 Flexible Conductor Loop **Art. 480**

Flexible conductors help prevent stress and damage to terminals.

(a) prefabricated (b) reinsulated
(c) pre-formed (d) pre-evaluated

49. Metallic structures for stationary battery support systems shall be provided with nonconducting support members for the cells or shall be constructed with a continuous _____ material.

Figure 49 Battery Support Structure **Art. 480**

Supports must be insulating or the structure must be of continuous insulating material.

(a) insulating (b) conductive
(c) semiconductive (d) none of these

50. For stationary batteries, provisions shall be provided to prevent batteries from becoming _____.

Figure 50 Battery Overcharge Protection **Art. 480**

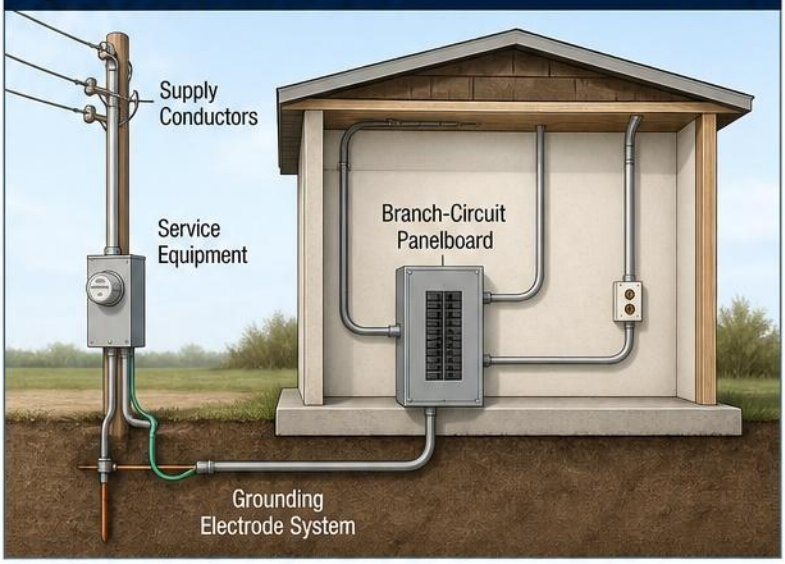
Overcharge protection helps prevent damage and extend battery life.

(a) overcharged (b) undercharged
(c) damaged (d) none of these

Article 100
Definitions, Scope, and General Requirements

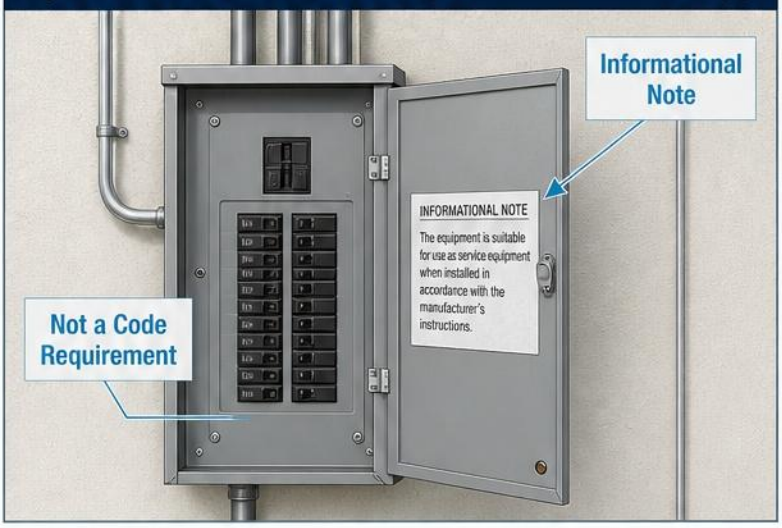
Article 100 introduces the *National Electrical Code®* and establishes its purpose, scope, and general application. It includes definitions of key terms used throughout the *Code* and outlines general requirements that apply to all electrical installations.

Figure 100.1 Application of the NEC 100.1(A)



The *NEC* applies to the installation of electrical wiring and equipment in buildings and structures, mobile homes, recreational vehicles, and related areas. It covers conductors, raceways, equipment, and associated materials used to supply, control, communicate, or use electric energy.

Figure 100.3 Informational Note Example 100.3(A)



Informational notes are provided for guidance, clarification, or background information. They are not mandatory and do not establish Code requirements.

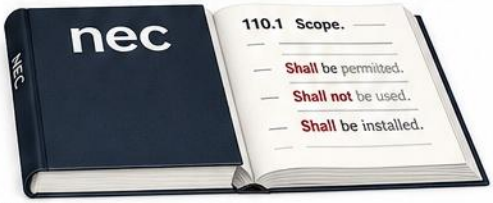
FINAL EXAM

A

FINAL EXAM A—STRAIGHT ORDER

Please use the 2026 *Code* book to answer the following questions.

1. In the *NEC*, the word(s) _____ indicate a mandatory rule.



(a) permitted
(b) not permitted
(c) shall or shall not
(d) approved and accepted

2. Capable of being removed or exposed without damaging the building is the definition of being _____.

(a) accessible as applied to wiring methods
(b) accessible as applied to equipment
(c) readily accessible
(d) serviceable

3. Bonded is defined as _____ to establish electrical continuity and conductivity.

(a) coupled
(b) joined
(c) connected
(d) attached

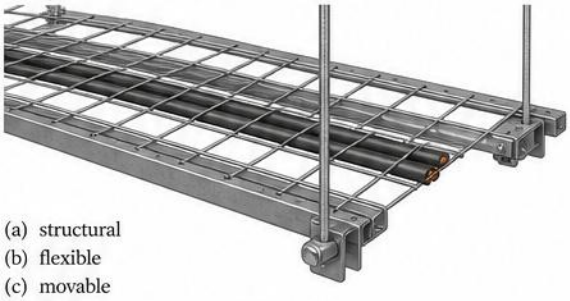
4. A component of the effective ground-fault current path that is the connection between the grounded circuit conductor and the equipment grounding conductor is the definition of _____.

(a) main bonding jumper/conductor
(b) system bonding jumper/conductor
(c) equipment bonding jumper/conductor
(d) electrode bonding jumper/conductor

5. A(An) _____ has a flame-retardant, moisture-resistant covering in accordance with Article 100.

(a) service entrance cable
(b) underground feeder cable
(c) tray cable
(d) nonmetallic sheath cable

6. A cable tray system is an assembly of units or sections and associated fittings forming a _____ system used to securely fasten or support cables and raceways.



(a) structural
(b) flexible
(c) movable
(d) secure

7. A circuit breaker is a device designed to open and close by nonautomatic means and to _____ automatically during an overcurrent condition.

(a) energize
(b) reset
(c) connect
(d) open

8. A(n) _____ circuit breaker is a qualifying term indicating that there is a delay purposely introduced in the tripping action of the device.

Figure 8 Time-Delay Circuit Breaker NEC 100

(a) adverse time
(b) inverse time
(c) time delay
(d) timed unit

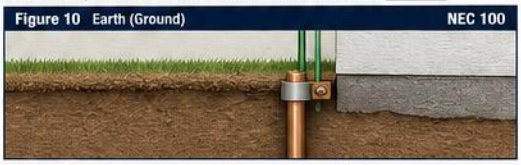
9. The *NEC* defines a _____ as all circuit conductors between the service equipment and the final branch-circuit overcurrent protective device.

Figure 9 Branch Circuit Conductors NEC 100

(a) service
(b) feeder
(c) branch circuit
(d) all of these

10. The Earth, as used in the *NEC* defines the term _____.

Figure 10 Earth (Ground) NEC 100



(a) bonded
(b) ground
(c) effective ground-fault current path
(d) guarded

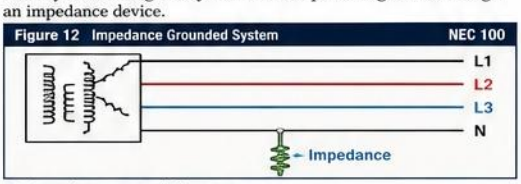
11. A system or circuit conductor that is intentionally grounded is defined as a(an) _____.

Figure 11 Grounded Conductor NEC 100

(a) equipment grounding conductor
(b) ungrounded conductor
(c) grounded conductor
(d) grounding electrode conductor

12. A(n) _____ is an electrical system that is grounded by intentionally connecting the system neutral point to ground through an impedance device.

Figure 12 Impedance Grounded System NEC 100



(a) impedance grounded system
(b) solidly grounded system
(c) isolated grounded system
(d) separately grounded system

13. A room in a building for _____, but excluding bathrooms, toilet rooms, closets, hallways, storage or utility spaces, and similar areas is the definition of a habitable room.

Figure 13 Habitable Room (Example: Living Room) NEC 100

(a) living
(b) sleeping
(c) eating or cooking
(d) any of these

14. The definition of a power supply cord is an assembly consisting of an attachment plug and a length of _____ cord connected to utilization equipment.

Figure 14 Power Supply Cord NEC 100

(a) durable
(b) retractable
(c) flexible
(d) heat-resistant

15. A contact device installed at an outlet for the connection of an attachment plug of electrical utilization equipment is the definition of a(an) _____.

Figure 15 Receptacle NEC 100

(a) attachment point
(b) tap
(c) receptacle
(d) wall plug

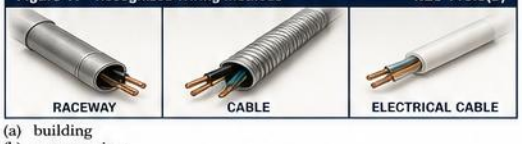
16. The frame of a wiring device, such as a receptacle or switch, which serves as the mounting means is defined as a _____.

Figure 16 Device Frame NEC 100

(a) mounting bracket
(b) device frame
(c) support brace
(d) yoke

17. The only wiring methods that are suitable to be installed in _____ are those recognized by the *NEC*.

Figure 17 Recognized Wiring Methods NEC 110.3(B)



(a) building
(b) occupancies
(c) premises
(d) all of these

18. Some _____ can cause severe deterioration of many plastic materials used for insulating and structural applications in equipment.

Figure 18 Deterioration of Plastics NEC 110.3(C)

(a) cleaning and lubricating compounds
(b) protective coatings
(c) paints and enamels
(d) detergents

19. Conductors shall not be intermixed in a terminal or splicing connector where physical contact occurs between dissimilar conductors unless the device is _____ for the purpose and conditions of use.

Figure 19 Listed Device for Dissimilar Conductors NEC 110.14(C)

(a) identified (b) listed
(b) listed (d) designed

20. All _____ shall be covered with an insulation equivalent to that of the conductors or an identified insulating device.

Figure 20 Insulation of Conductors — 300.4(A)

(a) splices (b) joints
(c) free ends of conductors (d) all of these

21. _____ and access to and egress from working space shall be provided and maintained about all electrical equipment.

Figure 21 Working Space — 110.26

(a) Ventilation (b) Unrestricted movement
(c) Circulation (d) Working space

22. Illumination shall be provided for all working spaces about service equipment, switchboards, enclosed panelboards, or motor control centers _____.

Figure 22 Illumination of Working Spaces — 110.26(A)/ 408.14(C)(1)

(a) over 600V (b) installed indoors
(c) rated 1200A or more (d) using automatic means of control

23. For purposes of calculating branch-circuit and feeder loads, _____ system voltages of 120V, 120/240V, 208Y/120V, 240V, 347V, 416Y/240V, 480Y/277V, 480V, 600Y/347V, and 600V shall be used.

Figure 23 System Voltages Used for Calculations — 220.3

120V	120/240V	208Y/120V	240V	347V
416Y/240V	480Y/277V	480V	600Y/347V	600V

(a) nominal (b) separately derived
(c) utility (d) secondary

24. For two or more noncoincident loads, it shall be permitted to use the single _____ of these loads in the calculation of the total load.

Figure 24 Noncoincident Loads — 220.4

(a) largest (b) smallest
(c) least (d) lowest

25. For standard method dwelling unit calculations, a load of not less than _____ for each 2-wire small-appliance branch circuit shall be applied.

Figure 25 Small-Appliance Branch Circuit Load — 220.52

(a) 1000 VA (b) 1200 VA
(c) 1500 VA (d) 2000 VA

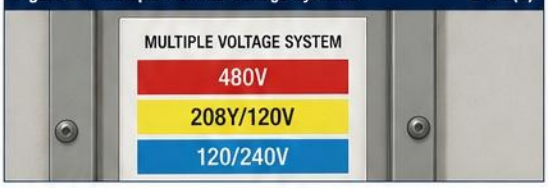
26. For standard method dwelling unit calculations, a load of not less than _____ for the laundry branch circuit shall be applied.

Figure 26 Laundry Branch Circuit Load — 220.53

(a) 1000 VA (b) 1200 VA
(c) 1500 VA (d) 2000 VA

27. Where the premises wiring system has branch circuits supplied from _____ nominal voltage system(s), branch circuit ungrounded conductors shall be identified in accordance with 310.6(A)(3).

Figure 27 Multiple Nominal Voltage Systems — 210.5(C)



(a) one (b) two
(c) three (d) four

28. For the purposes of section 210.8, the distance from receptacles shall be measured as the shortest path the power supply cord connected to the receptacle would follow without piercing a _____ or fixed barrier.

Figure 28 Path of Power Supply Cord — 210.8

(a) floor (b) wall
(c) ceiling (d) any of these

29. All 125V through 250V receptacles installed in dwelling unit _____ shall have GFCI protection.

Figure 29 GFCI Protection—Bedrooms — 210.8(A)(3)

(a) hallways (b) bedrooms
(c) closets (d) bathrooms

30. All 125V through 250V receptacles installed in dwelling unit _____ shall have GFCI protection.

Figure 30 GFCI Protection—Garages — 210.8(A)(3)

(a) attics (b) garages
(c) utility rooms (d) dens

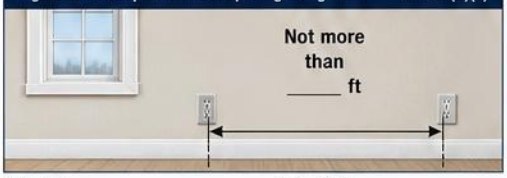
31. Beyond dwelling units, all single-phase receptacle outlets rated 150V to ground or less, 50A or less and three-phase receptacle outlets rated 150V to ground or less, 100A or less in _____ areas of the basement shall be GFCI protected.

Figure 31 Basement Areas Requiring GFCI Protection 210.8(A)

(a) unfinished
(b) finished
(c) wet
(d) dry

32. In dwelling units, a receptacle outlet shall be installed so no point along the floor line of any wall is more than _____, measured horizontally along the floor line, from a receptacle outlet.

Figure 32 Receptacle Outlet Spacing Along Walls 210.52(A)(1)



(a) 6 ft
(b) 8 ft
(c) 10 ft
(d) 14 ft

33. In dwelling units, when determining the spacing of receptacle outlets, _____ on exterior walls shall not be considered wall space.

Figure 33 Exterior Walls—Not Wall Space 210.52(A)(2)

(a) fixed panels
(b) sliding panels
(c) portable room dividers
(d) none of these

34. Kitchen and dining room countertop receptacle outlets in dwelling units shall be installed on or above the countertop not more than _____ above the countertop.

Figure 34 Countertop Receptacle Height 210.52(C)(1)

(a) 12 in.
(b) 18 in.
(c) 20 in.
(d) 24 in.

35. For a one-family dwellings, one receptacle outlet shall be installed in each _____.

(a) attached garage and/or detached garage with electric power
(b) accessory building with electric power
(c) separate unfinished portion of a basement
(d) all of these

36. Hallways in dwelling units that are _____ or longer require a receptacle outlet.

(a) 6 ft
(b) 8 ft
(c) 10 ft
(d) 12 ft

37. At least one 15A or 20A, 125V receptacle outlet shall be installed within 18 in of the top of each show window. No point along the top of the window shall be farther than _____ from a receptacle outlet.

Figure 37 Show Window Receptacle 210.52(F)

(a) 3 ft
(b) 4 ft
(c) 6 ft
(d) 8 ft

38. Where a portion of a feeder is connected at both ends to separately installed pressure connections in accordance with 110.14(C)(2), it shall be permitted to have an allowable ampacity _____ the sum of the continuous load plus the noncontinuous load.

(a) not less than
(b) equal to
(c) not greater than
(d) 150 percent of

39. Overhead feeder conductors shall have a minimum vertical clearance of _____ over residential property.

Figure 39 Overhead Feeders Over Residential Property 230.24(C)

(a) 10 ft
(b) 12 ft
(c) 15 ft
(d) 18 ft

40. Overhead feeder conductors installed over roofs shall have a vertical clearance of not less than _____ above the roof surface.

Figure 40 Overhead Feeders Over Roofs 230.24(D)

(a) 6 ft 6 in.
(b) 8 ft 6 in.
(c) 12 ft 6 in.
(d) 15 ft 6 in.

41. If a set of 120/240V overhead feeder conductors terminates at a through-the-roof raceway, with no more than 6 ft of conductors passing, 4 ft horizontally over the roof overhang, the minimum clearance above the roof for these conductors shall not be less than _____.

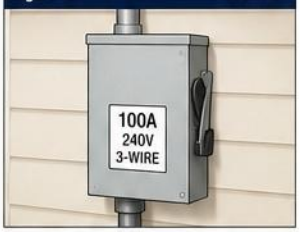
Figure 41 Service Conductors Over Roof Raceway 230.24(E)

(a) 12 in.
(b) 18 in.
(c) 24 in.
(d) 36 in.

42. A building disconnecting means in accordance 225.31 that supplies a one-family dwelling shall have a rating of not less than _____, 3-wire.

(a) 60A
(b) 100A
(c) 150A
(d) 200A

Figure 42 NEC 225.31



Example of a building disconnect for a one-family dwelling.

43. Circuit conductors other than service conductors, shall not be installed in the same _____ as the service conductors.

(a) raceway or cable
(b) handhole enclosure
(c) underground boxes
(d) all of these

Figure 43 NEC 230.24(B)

Other circuit conductors must not share the same raceway, handhole, or box with service conductors.

44. The minimum size overhead service conductor permitted is _____ copper or _____ aluminum or copper-clad aluminum.

(a) 8 AWG, 8 AWG
(b) 8 AWG, 6 AWG
(c) 6 AWG, 8 AWG
(d) 6 AWG, 6 AWG

Figure 44 NEC 230.42

Minimum overhead service conductor sizes.

45. The minimum point of attachment of overhead service conductors to a building shall not be less than _____ above finished grade.

(a) 8 ft
(b) 10 ft
(c) 12 ft
(d) 15 ft

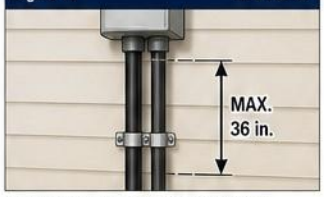
Figure 45 NEC 230.24(A)

Minimum clearance at point of attachment.

46. Service-entrance cables shall be supported by straps or other approved means within 12 in. of every service head and at intervals not exceeding _____.

(a) 24 in.
(b) 30 in.
(c) 36 in.
(d) 48 in.

Figure 46 NEC 230.43



Support intervals for service-entrance cables.

47. For other than one- and two-family dwellings, service disconnects must be installed in a(an) _____ location, either outside of a building or inside nearest the point of entrance of the service conductors.

(a) accessible
(b) readily accessible
(c) convenient
(d) identified

Figure 47 NEC 225.31

Service disconnect location options for buildings other than one- and two-family dwellings.

48. There shall be no more than _____ service disconnects installed for each service.

(a) two
(b) four
(c) six
(d) eight

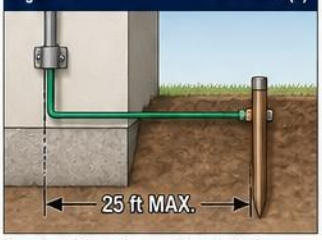
Figure 48 NEC 230.71

Limit of service disconnects per service.

49. An important consideration to note for limiting the imposed voltage on electrical systems, is the routing of bonding and grounding electrode conductors should not be any longer than _____ to complete the connection.

(a) necessary
(b) 10 ft
(c) 25 ft
(d) 50 ft

Figure 49 NEC 250.64(B)



Keep bonding and grounding electrode conductors as short as practical.

50. For grounded systems, the earth _____ considered an effective ground-fault current path.

(a) shall be
(b) shall not be
(c) is
(d) is not

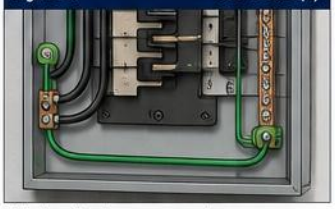
Figure 50 NEC 250.4(A)(1)

The earth is an effective path for fault current in grounded systems.

51. A main bonding jumper shall be a _____ or similar suitable conductor.

(a) wire
(b) bus
(c) screw
(d) any of these

Figure 51 NEC 250.28(A)

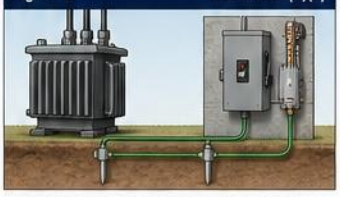


Main bonding jumper examples.

52. For separately derived systems, the building grounding electrode system shall be used as the _____ electrode.

(a) grounding
(b) bonding
(c) grounded
(d) bonded

Figure 52 NEC 250.30(A)(1)



Building grounding electrode system used as the grounding electrode.

53. An equipment grounding conductor shall be run with feeder supply conductors and be connected to the enclosure containing the building _____ and to the grounding electrode conductor.

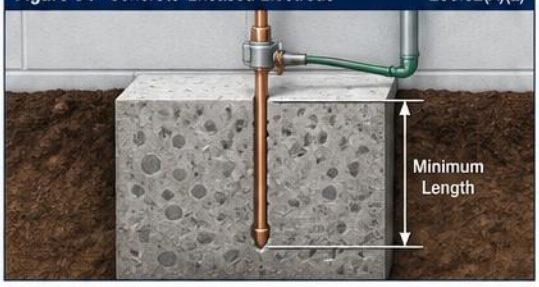
(a) rebar
(b) disconnecting means
(c) structural steel
(d) ground rod

Figure 53 NEC 250.118

Equipment grounding conductor connected to enclosure and grounding electrode conductor.

54. A 4 AWG bare copper conductor used as a concrete-encased electrode shall be at least _____ or greater in length.

Figure 54 Concrete-Encased Electrode 250.52(A)(2)



(a) 10 ft
(b) 20 ft
(c) 30 ft
(d) 40 ft

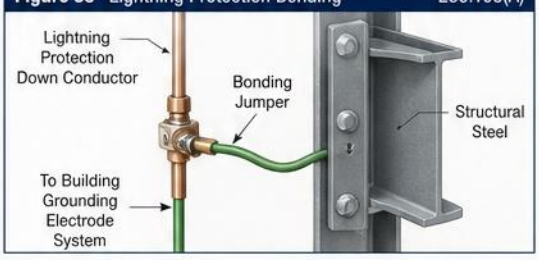
55. Bonding jumpers for service metal raceways and enclosures shall be used around impaired connections such as _____.

Figure 55 Impaired Connection Examples 250.96

(a) oversized concentric knockouts
(b) oversized eccentric knockouts
(c) reducing washers
(d) any of these

55. Lightning protection system ground terminals shall be bonded to the building _____.

Figure 56 Lightning Protection Bonding 250.106(A)



(a) grounding electrode system
(b) metal water piping system
(c) metal gas piping system
(d) metal structural steel

57. A 60A feeder supplying an electrically powered irrigation machine will require a(an) _____ copper equipment grounding conductor.

Figure 57 Equipment Grounding Conductor Size 250.122

(a) 14 AWG
(b) 12 AWG
(c) 10 AWG
(d) 8 AWG

58. For existing installations where an equipment grounding conductor is not present, the frames of ranges, wall-mounted ovens, counter-mounted cooking units, and clothes dryers, shall be permitted to be connected to the _____ circuit conductor in accordance with 250.140(b)(1) through (5).

Figure 58 Connection in Existing Installations 250.140(C)

(a) grounded
(b) ungrounded
(c) phase
(d) any of these

59. A(An) _____ shall be used to connect the grounding terminal of a grounding-type receptacle to a metal box that is connected to an equipment grounding conductor.

Figure 59 Receptacle Grounding Connection 250.148

(a) equipment bonding jumper
(b) main bonding jumper
(c) supply-side bonding jumper
(d) system bonding jumper

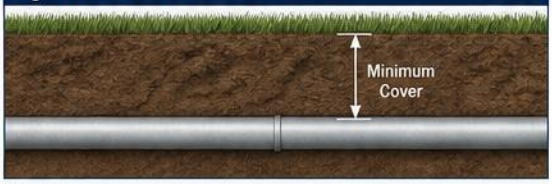
60. An equipment bonding jumper is not required if the metal box for a receptacle is surface mounted, has direct metal-to-metal contact between the device yoke and the box if at least _____ of the insulating washers of the receptacle yoke is removed.

Figure 60 Equipment Bonding Not Required 250.148(D)

(a) one
(b) two
(c) three
(d) four

61. Rigid metal conduit that is directly buried outdoors shall have at least _____ of cover.

Figure 61 Direct Burial Cover 300.5



(a) 6 in.
(b) 12 in.
(c) 18 in.
(d) 24 in.

65. Surface extensions shall be made by securing one or more rings over the box.

Figure 65 Surface Extension 314.16

(a) extension
(b) device
(c) cover
(d) blank

66. A luminaire that weighs more than _____ can be supported by an outlet box that is listed for the weight of the luminaire.

Figure 66 Luminaire Support 410.36(A)(1)

(a) 20 lb
(b) 30 lb
(c) 40 lb
(d) 50 lb

67. Utilization equipment weighing not more than 6 lb can be supported to any box or plaster ring secured to a box, provided the equipment is secured with at least two _____ or larger screws.

Figure 67 Equipment Support 314.27(C)

(a) No. 6
(b) No. 8
(c) No. 10
(d) No. 12

68. Underground raceways and cables entering a handhole enclosure shall extend into the enclosure, but they are not required to be _____.

Figure 68 Handhole Raceway Entry 300.27(C)

(a) bonded
(b) insulated
(c) mechanically connected to the enclosure
(d) electrically connected to the enclosure

69. Handhole enclosure covers shall require the use of tools to open, or they shall weigh over _____.

Figure 69 Handhole Cover 300.28

(a) 45 lb
(b) 70 lb
(c) 100 lb
(d) 200 lb

70. AC cable, cable ties, staples, straps, hangers and fittings use to connect AC cable to boxes, cabinets, or equipment shall be _____.

Figure 70 AC Cable Supports and Fittings 334.30

(a) identified
(b) listed
(c) listed and identified
(d) labeled

71. Where a raceway protects NM cable from physical damage, the conduit or tubing shall be provided with a(an) _____ that provides protection from abrasion at the point the cable enters and exits the raceway.

Figure 71 Raceway Abrasion Protection 334.15(B)

(a) adapter
(b) bushing
(c) bushing or adapter
(d) sealant

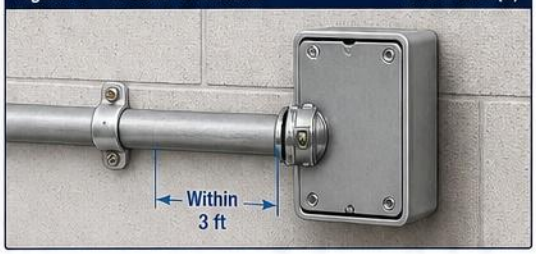
72. Where TC-ER-JP cable is used to connect a generator and associated equipment having terminals rated _____, the cable shall not be limited in ampacity by 334.80 or 340.80.

Figure 72 TC-ER-JP Cable 695.12(C)

(a) 30°C
(b) 60°C
(c) 75°C
(d) 90°C

77. Intermediate metal conduit shall be securely fastened within _____ of each conduit termination.

Figure 77 Conduit Termination NEC 342.30(A)



(a) 3 ft (b) 6 ft (c) 10 ft (d) 12 ft

78. Intermediate metal conduit shall be securely fastened within _____ of a box or termination fitting when structural members do not readily permit the conduit to be secured within 3 ft of the termination.

Figure 78 Conduit Fastening NEC 342.30(A)(2)

(a) 5 ft (b) 10 ft (c) 15 ft (d) 20 ft

79. Article 344 covers the use and installation for _____ and associated fittings.
(a) intermediate metal conduit (IMC)
(b) rigid metal conduit (RMC)
(c) electrical metallic tubing (EMT)
(d) aluminum metal tubing

80. Rigid metal conduit shall be securely fastened within _____ of each outlet box, junction box, device box, cabinet, conduit body, or other conduit termination.

Figure 80 Rigid Metal Conduit Fastening NEC 344.30(A)

(a) 3 ft (b) 4 ft (c) 5 ft (d) 6 ft

81. A straight run of Trade Size 2 rigid metal conduit with threaded couplings shall be supported at intervals not exceeding _____.

Figure 81 Rigid Metal Conduit Support NEC 344.30(B)

(a) 10 ft (b) 12 ft (c) 14 ft (d) 16 ft

82. Where rigid metal conduit enters a box, fitting, or other enclosure, _____ shall be provided to protect the wire from abrasion, unless the design of the box, fitting, or enclosure affords equivalent protection.
(a) a bushing
(b) duct seal
(c) electrical tape
(d) seal fittings

Figure 82 Conduit Entry Protection

83. Cable ties used to secure and support liquidtight flexible nonmetallic conduit shall be _____ for the application and for securing and supporting.

Figure 83 Cable Tie Marking NEC 350.30

(a) identified (b) labeled (c) listed (d) marked

84. Electrical metallic tubing couplings and connectors shall be made up _____.

Figure 84 EMT Coupling Made Up NEC 358.30(A)

(a) loose (b) firmly secured (c) tight (d) properly fastened

85. Electrical metallic tubing shall be permitted as a(an) _____.
(a) grounding electrode conductor
(b) equipment grounding conductor
(c) grounded conductor
(d) any of these

86. Article _____ contains the requirements for the use and installation of multioutlet assemblies.
(a) 380
(b) 386
(c) 390
(d) 392

87. Multioutlet assemblies and associated fittings shall be _____.

Figure 87 Multioutlet Assembly Marking NEC 380.4(A)

(a) listed (b) identified (c) marked (d) field evaluated

88. Splices and taps shall not fill the surface metal raceway to more than _____ of its area at that point.

Figure 88 Raceway Fill at Splices and Taps NEC 390.19(A)

(a) 75 percent (b) 80 percent
(c) 85 percent (d) 90 percent

Figure 89 Transition means in surface metal raceway 250.118

Surface metal raceways that transition to other wiring methods shall include a means for connecting a(n) _____.

(a) grounded conductor
(b) ungrounded conductor
(c) equipment grounding conductor
(d) all of these

Figure 90 Damp location receptacle covers 406.9(B)(1)

Receptacle outlet box hoods in damp locations must open to at least 90 degrees, or to a full open position if the cover does not open to 90 degrees from the closed position after installation.

(a) flush
(b) hinged
(c) surface mounted
(d) any of these

Figure 91 Terminal markings for conductor types 110.14(A)

Wiring devices with terminals marked _____ may be used with aluminum, copper, and copper-clad aluminum conductors.

(a) AL
(b) AL/CU
(c) CU
(d) CO/ALR

Figure 92 Switches controlling line-to-neutral loads 404.2(C)

Switches that control line-to-neutral lighting loads are not required to have a grounded conductor where the switch controls a _____.

(a) ceiling fan
(b) bathroom exhaust fan
(c) fluorescent fixture with integral disconnect
(d) receptacle load

Figure 93 Device mounting in boxes 314.27(C)

General-use snap switches, dimmers, and control switches mounted in boxes set back from the finished surface shall be installed so that the _____ is(are) seated against the surface.

(a) extension plaster ears
(b) body
(c) toggle
(d) all of these

Figure 94 Panelboard short-circuit current rating 110.10

Switchboards and panelboards shall have a short-circuit current rating not less than the _____ on the line side of the equipment.

(a) equipment rated current
(b) available fault current
(c) overcurrent protection rated current
(d) ground-fault protection current

Figure 95 Lighting track connected load 410.64(C)

The connected _____ on lighting track shall not exceed the rating of the track.

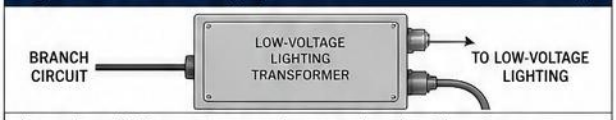
(a) volt-ampere
(b) load
(c) watts
(d) any of these

Figure 96 Pool low-voltage lighting placement 680.21(B)

Low-voltage lighting systems in pools shall be installed not less than _____ horizontally from the nearest edge of the water, unless permitted by Article 680.

(a) 5 ft
(b) 6 ft
(c) 10 ft
(d) 20 ft

Figure 97 Transformer supply maximum 411.4(B)



Low-voltage lighting system transformers other than Class 2 power sources shall be supplied from a maximum _____ branch circuit.

(a) 15A
(b) 20A
(c) 25A
(d) 30A

Figure 98 GFCI protection for appliances 422.5(A)

The GFCI protective device required for appliances shall be readily accessible, listed, and located _____.

(a) Within the branch-circuit OCPD
(b) In a device or outlet within the supply circuit
(c) In an integral part of the attachment plug
(d) any of these

Figure 99 OCP rating for cord-and-plug appliances 400.7(A)(3)

The overcurrent protection rating for nonmotor-operated appliances shall not exceed _____ if the overcurrent protection rating is not marked and the appliance is rated 13.3A or less.

(a) 15A
(b) 20A
(c) 25A
(d) 30A

100. The full-load current of a three-phase 7½ hp, 208V motor is _____.

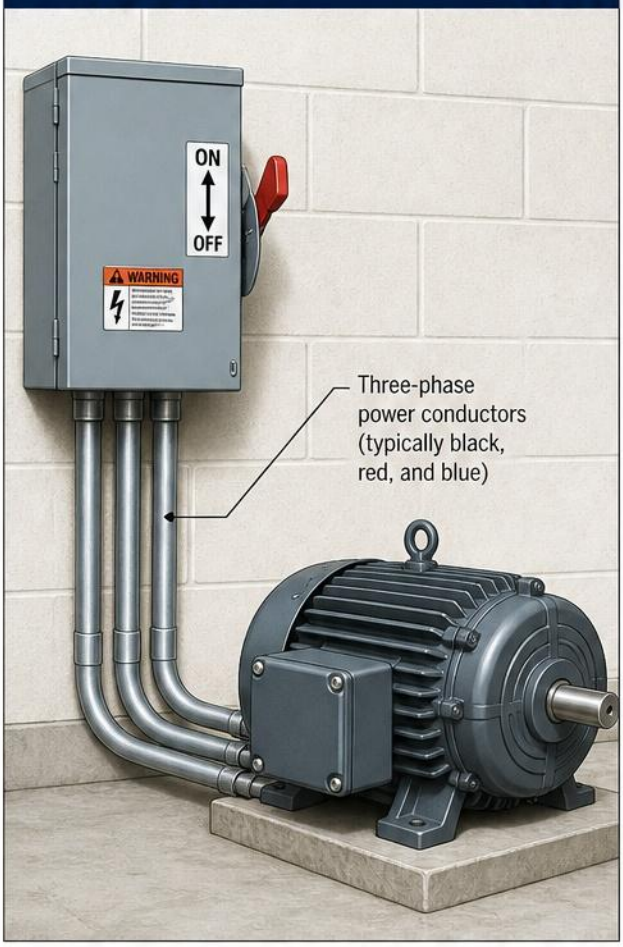
(a) 19.20A

(b) 22.20A

(c) 24.20A

(d) 28.20A

FIGURE 100 NEC® 430.250
Three-Phase Motor Installation



A three-phase motor connected to a 208V system. The full-load current depends on the motor horsepower rating, voltage, and efficiency as listed in Table 430.250.

SPACE FOR ANSWER

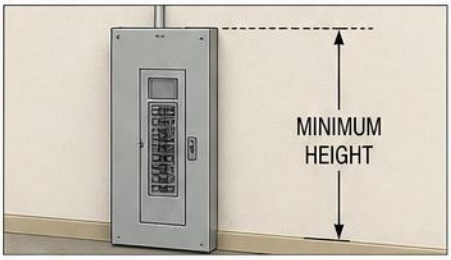
FINAL EXAM

B

FINAL EXAM B– RANDOM ORDER

Please use the 2026 *Code* book to answer the following questions.

1. The minimum height of dedicated electrical equipment space for a panelboard installed indoors is _____ above the enclosure, or the structural ceiling, whichever is lower.



(a) 4 ft
(b) 5 ft
(c) 6 ft
(d) 7 ft

2. In accordance with 250.94(A) or 250.94(b), the intersystem bonding termination device for connecting intersystem bonding conductors shall _____.

(a) be accessible for connection and inspection
(b) consist of a set of terminals with the capacity for connection of not less than three intersystem bonding conductors
(c) not interfere with opening the enclosure for a service, building disconnecting means, or metering equipment
(d) all of these

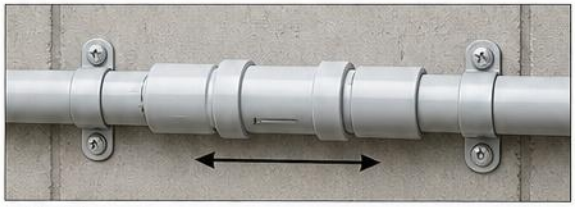
3. Other local metal underground piping systems and underground metal well casings that are not bonded to a metal _____ are permitted as grounding electrodes.

(a) gas pipe
(b) fire-sprinkler pipe
(c) water pipe
(d) none of these

4. A flexible cord is defined as _____ or more flexible insulated conductors enclosed in a flexible covering.

(a) two
(b) three
(c) four
(d) five

5. Expansion fittings for PVC shall be provided to compensate for thermal expansion and contraction where the length change is expected to be _____ or greater in a straight run between securely mounted conduit terminations.



(a) 1⁄16 in.
(b) 1⁄8 in.
(c) 1⁄4 in.
(d) 1⁄2 in.

6. The full-load current of a single-phase 1½ hp, 230V ac motor is _____.

(a) 10A
(b) 12A
(c) 14A
(d) 16A

7. A grounded circuit conductor for lighting control must be installed at the point where switches control lighting loads supplied by a branch circuit that serves bathrooms, hallways, stairways, and _____.

   (a) habitable rooms or occupiable spaces
   (b) attics
   (c) crawlspaces
   (d) basements

Figure 7 Lighting Control Location 210.70(A)(1)

Grounded conductor required where switches control lighting loads for bathrooms, hallways, stairways, and listed areas.

8. A dormitory is a building or space in a building in which group sleeping accommodations are intended for more than _____ persons who are not members of the same family in one room, or a series of closely associated rooms, under joint occupancy and single management, with or without meals, but without individual cooking facilities.

   (a) 6
   (b) 10
   (c) 12
   (d) 16

Figure 8 Dormitory 100

Group sleeping accommodations for more than the allowed number of unrelated persons.

9. Underground service conductors shall not be smaller than _____ copper.

   (a) 3 AWG
   (b) 4 AWG
   (c) 6 AWG
   (d) 8 AWG

Figure 9 Underground Service Conductors 230.42

Minimum size requirement for underground service conductors.

10. Conductors in raceways shall not contain any _____ within the raceway unless otherwise permitted in the *Code*.

    (a) splice
    (b) tap
    (c) splice or tap
    (d) none of these

Figure 10 No Splices or Taps in Raceway 300.13

Splices or taps are not permitted inside raceways unless specifically allowed.

11. Where nails or screws are likely to penetrate nonmetallic-sheathed cable or ENT installed through metal framing members, a steel sleeve, steel plate, or steel clip not less than _____ in thickness shall be used to protect the cable or tubing.

    (a) 1/16 in.
    (b) 1/8 in.
    (c) 1/2 in.
    (d) 3/4 in.

Figure 11 Protection for Cable or ENT 300.4(G)

Use steel protection of the specified minimum thickness where penetration is likely.

12. Metal raceways, cable armor, and other metal enclosures shall be _____ joined together and connected to all boxes, fittings, and cabinets to provide an effective ground-fault current path.

    (a) electrically
    (b) permanently
    (c) metallically
    (d) physically

Figure 12 Bonding Metal Raceways 250.8(A)

Metal parts must be bonded to ensure an effective ground-fault current path.

13. A kitchen is defined as an area with a sink and _____ provisions for food preparation and cooking.

    (a) portable
    (b) movable
    (c) temporary
    (d) permanent

Figure 13 Kitchen Definition 100

Kitchen requires a sink and permanent provisions for food preparation and cooking.

14. Provisions to the stationary battery shall be made for sufficient diffusion and ventilation of gases from the battery, if present, to prevent the accumulation of a(n) _____ mixture.

    (a) explosive
    (b) noxious
    (c) toxic
    (d) chemical

Figure 14 Battery Ventilation 480.81

Adequate ventilation prevents accumulation of gases that could form an explosive mixture.

15. The power control system (PCS) of an energy management system (EMS) shall include monitoring and automatic controls to prevent overload of _____ associated with the PCS.

    (a) conductors
    (b) power sources
    (c) distribution equipment
    (d) all of these

Figure 15 PCS Overload Protection 750.30

Monitoring and automatic controls prevent overload of items associated with the PCS.

16. The emergency disconnecting means enclosure for one- and two-family dwellings supplied by an outside feeder shall be marked as "EMERGENCY DISCONNECT" and the marking or labels shall _____.

    (a) be located on the outside front of the disconnect enclosure
    (b) have a red background with white text
    (c) have lettering at least 1/2 in. high
    (d) all of these

Figure 16 Emergency Disconnect Marking 705

Marking must meet location, color, and size requirements.

17. Equipment grounding conductors of the wire-type are not required to be _____ than the circuit conductors.

    (a) larger
    (b) smaller
    (c) less
    (d) none of these

Figure 17 Equipment Grounding Conductors 250.122

Wire-type equipment grounding conductors need not be larger than circuit conductors.

18. Sections of reinforcing bar located in concrete must be connected together using ___, tie wires, exothermic welding, welding, or other effective methods.

Figure 18 – Rebar Splice Connection NEC 250.52(A)(1)

(a) steel (b) plastic (c) aluminum (d) fiber glass

19. An abnormal connection made unintentionally between two or more points of different potential is known as _____.

Figure 19 – Faulted Connection NEC 100

(a) ground fault (b) arc fault (c) system fault (d) short circuit

20. Devices that reduce vibration transfer from equipment must be installed where flexible metal conduit is used, such as _____.

Figure 20 – Flexible Metal Conduit Support NEC 250.24(A)(4)

(a) equipment grounding conductor (b) expansion fitting
(c) flexible nonmetallic connector (d) adjustable support

21. Except for dwelling units, GFCI protection must be provided for all outdoor receptacles supplied by branch circuits rated _____ or less to ground.

Figure 21 – GFCI Outdoor Receptacle NEC 210.8(A)(3)

(a) 125V (b) 150V (c) 208V (d) 277V

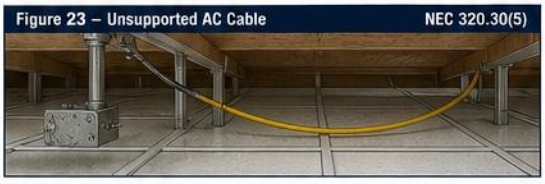
22. MC cable is permitted for installation in _____.

Figure 22 – MC Cable Installation NEC 330.10

(a) branch circuits (b) feeders (c) services (d) any of these

23. AC cable may be left unsupported and unsecured for a length of up to _____ when used to connect luminaires or equipment within an accessible ceiling.

Figure 23 – Unsupported AC Cable NEC 320.30(5)



(a) 2 ft (b) 3 ft (c) 4½ ft (d) 6 ft

24. The total number of bends in a run of rigid metal conduit must not be more than _____ between pull points.

Figure 24 – Conduit Bends NEC 358.26

(a) 120 degrees (b) 180 degrees
(c) 270 degrees (d) 360 degrees

25. Motor controllers must have horsepower ratings at the application voltage _____ the horsepower rating of the motor.

Figure 25 – Motor Controller Nameplate NEC 430.52(A)

(a) not lower than (b) not higher than
(c) equal to (d) six times

26. AC cable is allowed to be installed in _____.

Figure 26 – AC Cable in Wet Location NEC 334.10(B)

(a) wet locations (b) corrosive conditions
(c) damp locations (d) cable trays

27. Raceways, cable armor, and cable sheaths must be _____ between cabinets, boxes, conduit bodies, fittings, wireways, or other enclosures or outlets.

Figure 27 – Continuity of Raceway and Cable Sheath NEC 300.7(A)

(a) continuous (b) protected (c) buried (d) encased in concrete

28. Barriers must be arranged so that no energized, uninsulated, unguarded busbar or terminal is accessible to inadvertent contact at terminations in _____ supplied by feeder taps or transformer secondary conductors.

Figure 28 – Barrier in Switchboard NEC 408.33

(a) panelboards (b) switchboards
(c) motor control centers (d) any of these

29. Article 110 establishes the general requirements for _____.

Figure 29 – General Scope NEC 110.1

(a) examination and approval of equipment
(b) installation and use of equipment
(c) access to and space about equipment
(d) all of these

30. If a disconnecting means is required to be lockable open, it shall be capable of being locked in the open position.

(a) the closed
(b) the open
(c) either the open or closed
(d) vertical

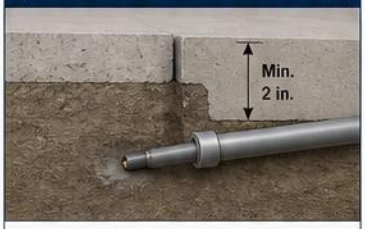
Figure 30 Lockable Disconnect in Open Position 110.25

Disconnecting means capable of being locked in the open position.

31. Service conductors shall be considered outside of a building where installed under not less than 2 in. of concrete beneath a building.

(a) 2 in.
(b) 4 in.
(c) 5 in.
(d) 6 in.

Figure 31 Service Conductors Under Concrete 230.6(A)

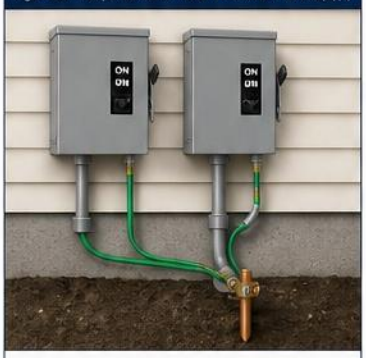


Minimum 2 in. of concrete cover beneath a building.

32. If a building contains two or more service or feeder disconnects, an individual grounding electrode conductor shall be connected between the grounding electrode system and _____.

(a) grounded conductor in each service equipment disconnecting means enclosure
(b) equipment grounding conductor installed with the feed-er(s) or branch circuit for other than services
(c) supply-side bonding jumper
(d) any of these

Figure 32 Multiple Service or Feeder Disconnects 250.30(A)(1)



Each service disconnect enclosure connected to the grounding electrode system.

33. The voltage between conductors in a surface metal raceway shall not exceed _____ unless the metal has a thickness of not less than 0.040 in. nominal.

(a) 150V
(b) 300V
(c) 600V
(d) 1000V

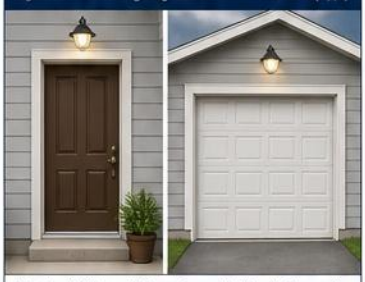
Figure 33 Surface Metal Raceway Voltage Limit 368.10(B)

Voltage in surface metal raceway shall not exceed 600V unless 0.040 in. nominal thickness is provided.

34. For dwelling units, attached garages, detached garages with electric power, at least _____ exterior lighting outlet(s) shall be installed to provide illumination on the exterior side of outdoor entrances or exits.

(a) one
(b) two
(c) three
(d) one or two

Figure 34 Exterior Lighting Outlets 210.70(A)(1)



Exterior lighting outlets must provide illumination on the outside of outdoor entrances or exits.

35. Wires are considered _____ if rendered inaccessible by the finish of the building.

(a) inaccessible
(b) concealed
(c) hidden
(d) enclosed

Figure 35 Inaccessible Wires 300.3(B)

Wires rendered inaccessible by the building finish are considered inaccessible.

36. Service masts shall be of _____ strength or be supported by braces or guy wires to withstand safely the strain imposed by the service-drop or overhead service conductors.

(a) adequate
(b) mechanical
(c) heavy-duty
(d) maximum

Figure 36 Service Mast Support 230.24(A)

Service masts must be adequately strong or supported to withstand strain.

37. The *NEC* defines a(an) _____ enclosure to be constructed or protected so that exposure to the weather will not interfere with successful operation.

(a) weatherproof
(b) weathertight
(c) weather-resistant
(d) all weather

Figure 37 Weathertight Enclosure 110.3

Enclosure protected so weather will not interfere with successful operation.

38. The grounding and bonding of electrical systems shall be installed and arranged in a manner that will prevent _____.

(a) objectionable current
(b) voltage transients
(c) neutral to earth voltage
(d) an arc flash

Figure 38 Proper Bonding and Grounding 250.4(A)(1)

Bonding and grounding must be arranged to prevent objectionable current, voltage transients, neutral to earth voltage, and arc flash.

39. Unless otherwise permitted in the *Code*, MC cable shall be secured at intervals not exceeding _____.

(a) 3 ft
(b) 4 ft
(c) 6 ft
(d) 8 ft

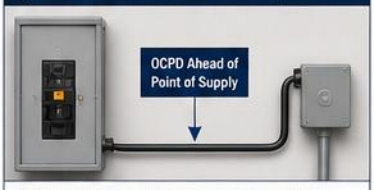
Figure 39 MC Cable Secured 330.30(A)

MC cable must be supported at intervals not exceeding 4 ft.

40. A conductor, other than a service conductor which has overcurrent protection ahead of its point of supply that exceeds the value permitted for similar conductors that are protected as described elsewhere in 240.4 is the definition of a _____.

(a) feeder conductor
(b) service conductor
(c) tap conductor
(d) conductor extension

Figure 40 Overcurrent Protection Ahead of Tap 240.4



A conductor with OCPD ahead of its point of supply, exceeding values in 240.4, is a tap conductor.

Figure 41 Helically Wound Metal Raceway NEC 350.6

41. A raceway of circular cross section made from a helically wound, interlocked metal strip is called a _____.
(a) IMC (b) RMC
(c) LFMC (d) FMC

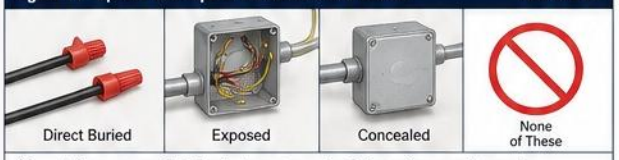
Figure 42 Motor Disconnecting Means NEC 430.102

42. A motor disconnecting means can be a listed _____.
(a) molded case circuit breaker (c) molded case switch
(b) motor-circuit switch rated in horsepower (d) any of these

Figure 43 GFCI Protection for Certain Receptacles NEC 210.8

42. All 125V through 250V receptacles in dwelling units _____ (not intended as habitable rooms) and with limited storage, work, and other similar use areas shall have GFCI protection.
(a) remote buildings (c) building supplied feeders
(b) accessory buildings (d) any of these

Figure 44 Splices and Taps in Conductors and Cables NEC 314.29



44. A box or conduit body is not required for splices and taps in _____ conductors and cables.
(a) direct buried (c) concealed
(b) exposed (d) none of these

Figure 45 Nonmetallic Tubing Above Suspended Ceilings NEC 300.22(C)

45. Electrical nonmetallic tubing may be used above suspended ceilings in buildings exceeding _____ floor area, provided the building is protected throughout by an approved automatic fire protective system.
(a) one (c) three
(b) two (d) four

Figure 46 Horizontal AC Cable Runs in Framing Members NEC 334.30

46. Horizontal runs of AC cable installed in framing members shall be supported and secured where such support does not exceed _____ intervals.
(a) 2½ ft (c) 4½ ft
(b) 3½ ft (d) 5½ ft

Figure 47 Metal Piping and Appliance Grounding Conductor NEC 250.104(A)(1)

47. Metal piping systems, including gas piping, if installed in or attached to a building which is likely to become energized, shall be considered _____ when connected to the appliance circuit equipment grounding conductor.
(a) isolated (c) grounded
(b) connected to Earth (d) bonded

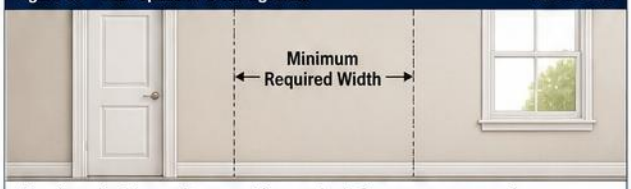
Figure 48 Rigid Metal Conduit Connections NEC 250.120(A)

48. Running threads shall not be used on rigid metal conduit for connection at _____.
(a) boxes (c) couplings
(b) cabinets (d) meter sockets

Figure 49 Conductor Sizes NEC 310.4

49. Conductor sizes are expressed in American Wire Gauge (AWG) or in _____.
(a) inches (c) square inches
(b) circular mils (d) cubic inches

Figure 50 Wall Space in Dwelling Units NEC 210.52



50. In a dwelling unit, any wall space including space measured around corners and unbroken along the floor line by doorways, fireplaces, fixed cabinets, and similar openings shall be considered wall space when the wall space is at least _____ wide.
(a) 2 ft (c) 4 ft
(b) 3 ft (d) 5 ft

Figure 51 Branch Circuit Load per Mounting Yoke NEC 210.21(B)(3)

General-Use Receptacle Outlets per Mounting Yoke	
Branch Circuit Rating	VA per Receptacle Outlet
15A	90 VA
20A	120 VA
30A	180 VA
40A	200 VA

51. For other than dwelling units, the branch circuit load for 15A or 20A, 125V general-use receptacle outlets is based on _____ per mounting yoke.
(a) 90 VA (c) 180 VA
(b) 120 VA (d) 200 VA

52. When evaluating equipment, factors such as cybersecurity for network-connected equipment, its ability to resist unauthorized updates, and susceptibility to malicious attacks must be considered.

Art. 110.2

(a) normal equipment
(b) emergency equipment
(c) standby power equipment
(d) life safety equipment

53. A ground ring encircling the building is allowed to be used as a grounding electrode when the _____.

250.52(A)(1)

(a) ring is in direct contact with the earth
(b) ring consists of at least 20 ft of bare copper conductor
(c) bare copper conductor is not smaller than 2 AWG
(d) all of these

54. For equipment rated 800A or more that contains overcurrent devices, switching devices, or control devices and where the entrance to the working space has a personnel door(s) less than 25 ft from the nearest edge of the working space, the door shall open at least 90° in the direction of egress and _____.

110.34(A)

(a) shall not have any lock
(b) be equipped with listed panic or fire exit hardware
(c) be equipped with a locking means
(d) be equipped with an electronic opener

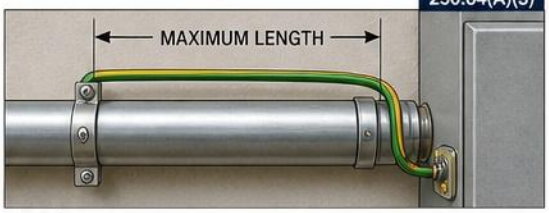
55. SE cable can be used for _____ wiring if it complies with the installation requirements of Part II of Article 334, excluding 334.80.

334.10

(a) interior
(b) outside
(c) exterior
(d) underground

57. An equipment bonding jumper shall be permitted to be installed on the outside of a raceway, provided the equipment bonding jumper is not more than _____ long and is routed with the raceway.

250.64(A)(3)



(a) 3 ft
(b) 4 ft
(c) 5 ft
(d) 6 ft

58. The *NEC* defines a(an) _____ as an electrical power supply output, other than a service, having no connections to circuit conductors of any other electrical source other than those established by grounding and bonding connections.

100

(a) separately derived system
(b) classified system
(c) direct system
(d) emergency system

59. The bonding jumper(s) required for the metal water piping system(s) installed in or attached to a building supplied by a feeder shall be sized in accordance with _____.

250.104(B)

(a) 250.66
(b) 250.102(D)
(c) 310.4
(d) 310.16

60. If a single rod grounding electrode has a resistance to earth of _____ or less, the supplemental electrode shall not be required.

250.53(A)(2)

(a) 15 ohms
(b) 20 ohms
(c) 25 ohms
(d) 50 ohms

61. A system that monitors and controls power within an electrical system is defined as _____.

100

(a) energy management system
(b) power distribution system
(c) energy distribution system
(d) interconnected system

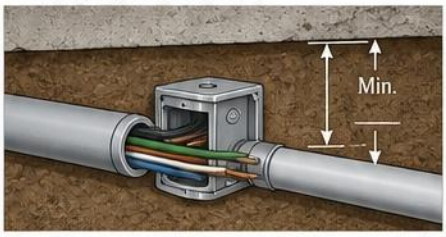
62. In dwelling units, the required bathroom receptacle outlet can be installed on the side or face of the sink cabinet and shall not be located more than _____ below the top of the sink countertop.

(a) 12 in.
(b) 18 in.
(c) 20 in.
(d) 24 in.

63. Each run of cable tray shall be _____ before the installation of cables.

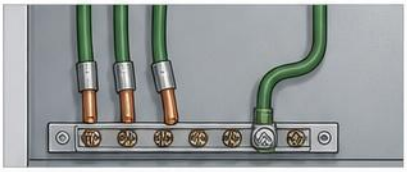
(a) tested for 25 ohms of resistance
(b) insulated
(c) completed
(d) all of these

64. Metal components that are installed in a run of underground nonmetallic raceway(s) and are isolated from possible contact by a minimum cover of _____ to all parts of the metal components shall not be required to be connected to the grounded conductor.



(a) 12 in.
(b) 18 in.
(c) 24 in.
(d) 30 in.

65. The equipment grounding conductor for a 70A circuit supplying fixed equipment in the patient care area of a health care facility shall not be smaller than _____ copper.



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

66. _____ covers the general requirements for overcurrent protection and overcurrent protective devices not over 1000V ac, 1500V dc.

(a) Article 230
(b) Article 240
(c) Article 242
(d) Article 250

67. Conductors insulation marked _____ are rated 90°C in a wet location.

(a) USE
(b) RHW
(c) XHWN
(d) THWN-2

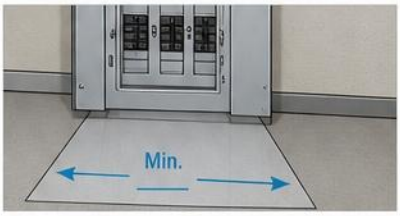
68. A guest suite is an accommodation with two or more contiguous rooms, with or without doors between such rooms, that provides _____ facilities.

(a) living
(b) sleeping
(c) sanitary
(d) all of these

69. Raceways exposed to different temperatures shall be provided with expansion, expansion-deflection, or deflection fittings where necessary to compensate for thermal expansion, deflection, and _____.

(a) contraction
(b) warping
(c) bending
(d) cracking

70. The width of the working space shall not be less than _____ wide, or the width of the equipment, whichever is greater.



(a) 15 in.
(b) 30 in.
(c) 40 in.
(d) 60 in.

71. A guest room is an accommodation combining living, sleeping, sanitary, and _____ within a compartment.

(a) storage
(b) cooking facilities
(c) laundry
(d) internet services

72. Conductors insulation marked TW are rated _____.

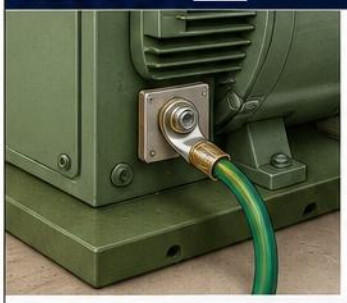
(a) 60°C
(b) 75°C
(c) 90°C
(d) 110°C

FIGURE 73 Article _____ **362.10**

This article specifies requirements for the use and installation of nonmetallic tubing (ENT) and related fittings.

(a) 358
(b) 362
(c) 366
(d) 392

FIGURE 74 Article _____ **250.146**



Nonconductive coatings such as paint, lacquer, or enamel on equipment that must be grounded or bonded shall be removed from contact areas to ensure electrical _____.

(a) power
(b) resistance
(c) conductivity
(d) continuity

FIGURE 75 Article _____ **210.70(A)(1)**

At least one lighting outlet _____ shall be positioned at the entry point to an attic, underfloor space, utility room, or basement used for storing items or housing equipment that requires servicing.

(a) that is unswitched
(b) containing or controlled by a switch or listed wall-mounted control device
(c) that is GFCI protected
(d) that is shielded from damage

FIGURE 76 Article _____ **230.6**

The service conductors between the terminals of the service equipment and the service drop, overhead service conductors, service lateral, or underground service conductors are referred to as _____ conductors.

(a) service-entrance
(b) utility-supply
(c) secondary-service
(d) primary-service

FIGURE 77 Article _____ **450.3(B)**

For primary protection only, transformers having a primary current rating of _____ shall be set at not more than 125 percent or a higher rating that does not exceed the next higher standard rating permitted in accordance with 240.6(A).

(a) 9A or more
(b) less than 9A
(c) 2A or more
(d) less than 2A

FIGURE 78 Article _____ **406.12**

GFCI protection is not required for factory-installed receptacles in _____ unless required by the installation instructions or listing.

(a) surface-mounted luminaire
(b) exhaust fans
(c) electric baseboard heat
(d) all of these

FIGURE 79 Article _____ **368.10**

This article covers the use, installation, and construction specifications for metal wireways and related fittings.

(a) 360
(b) 366
(c) 368
(d) 376

FIGURE 80 Article _____ **250.28(D)(2)**

The minimum size supply-side bonding jumper for a service raceway containing 4/0 AWG aluminum conductors is _____.

(a) 6 AWG aluminum
(b) 4 AWG aluminum
(c) 4 AWG copper
(d) 3 AWG copper

FIGURE 81 Article _____ **702.12(D)**

For one- and two-family dwelling units, the generator prime mover remote shutdown device shall be _____.

(a) located outside the dwelling unit
(b) at a readily accessible location
(c) marked "Generator Emergency Shutdown" and meet the requirements of 110.21(b)
(d) all of these

FIGURE 82 Article _____ **312.4(A)**

For cabinets, cutout boxes, and meter socket enclosures in wet locations, raceways or cables entering above the level of uninsulated live parts shall use fittings _____ for wet locations.

(a) approved
(b) identified
(c) listed
(d) labeled

FIGURE 83 Article _____ **314.29**

_____ conductors or cables can be spliced or tapped without the use of splice boxes when the splice or tap is made in accordance with 110.14(b).

(a) Direct-buried
(b) Wet location
(c) Ungrounded
(d) Grounded

84. For large equipment rated 1200A or that contains overcurrent devices, switching devices, or control devices, there shall be one entrance to and egress from the working space not less than 24 in. wide and _____ high at each end of the working space.

Figure 84 Large Equipment Working Space 110.34(A)

(a) 5½ ft (b) 6 ft (c) 6½ ft (d) 7 ft

85. All services supplying areas for sleeping quarters in _____ shall be provided with a surge-protective device (SPD).

Figure 85 Surge-Protective Device (SPD) 230.67(A)

(a) fire stations and police stations
(b) ambulance stations and rescue stations
(c) ranger stations and similar locations
(d) all of these

86. Overhead feeder conductor spans must maintain a vertical clearance of not less than _____ over public streets, alleys, roads, and parking areas subject to truck traffic.

Figure 86 Overhead Feeder Clearance 230.24(A)

(a) 10 ft
(b) 12 ft
(c) 15 ft
(d) 18 ft

87. Connected (connecting) to ground or to a conductive body that extends the ground connection is the definition of _____.

Figure 87 Equipment Grounding 250.12

(a) equipment grounding
(b) bonded
(c) grounded
(d) all of these

88. Surface metal raceways and associated fittings shall be supported _____.

Figure 88 Surface Metal Raceway Support 358.30(A)

(a) in accordance with the manufacturer's installation instructions
(b) at intervals appropriate for the building design
(c) at intervals not exceeding 4 ft
(d) at intervals not exceeding 8 ft

89. AC cable shall provide an adequate path for fault current to act as a(an) _____.

Figure 89 AC Cable Fault Current Path 250.119

(a) equipment grounding conductor
(b) grounded conductor
(c) grounding electrode conductor
(d) any of these

90. Electrical equipment containing _____ parts, or those that have been deteriorated by corrosion, chemical action, or overheating are not permitted to be installed.

Figure 90 Deteriorated Electrical Equipment 110.3(B)

(a) damaged
(b) refurbished
(c) reconditioned
(d) reconstructed

91. Where liquidtight flexible nonmetallic conduit is installed in lengths exceeding _____, the conduit shall be securely fastened at intervals not exceeding 3 ft and within 12 in. on each side of every outlet box, junction box, cabinet, or fitting.

Figure 91 Liquidtight Flexible Nonmetallic Conduit 350.42

(a) 2 ft
(b) 3 ft
(c) 6 ft
(d) 10 ft

92. The full-load current of a three-phase 2 hp, 208V motor is _____.

Figure 92 Three-Phase Motor Nameplate 430.250

THREE-PHASE INDUCTION MOTOR	
HP	2
VOLTS	208
PH	3
Hz	60
RPM	1750
FULL LOAD AMPS	11.50

(a) 7.50A
(b) 9.50A
(c) 11.50A
(d) 13.50A

93. A device that establishes a connection between the conductors of the attached flexible cord and a receptacle, is the definition of a(an) _____.

Figure 93 Attachment Plug (Male Plug) 400.2

(a) attachment plug
(b) male plug
(c) female plug
(d) cord set

94. In accordance with Article 120, _____ are permitted to be used for branch-circuit, feeder, or service load calculations.

Figure 94 Energy Management System 120.2(A)

(a) load management systems
(b) energy management systems
(c) energy control systems
(d) power control systems

95. Underground service conductors shall have an ampacity not less than the _____.

Figure 95 Underground Service Conductors 230.42

(a) rating of the overcurrent protective device
(b) largest motor load
(c) total connected load without demand factors
(d) calculated load

96. Working space is not required at the back or sides of equipment where _____ and renewable, adjustable, or serviceable parts are accessible from the front.

Figure 96 Access from the Front — NEC 110.26(A)(1)

No working space is required at the back or sides when the accessible parts can be reached from the front.

(a) screws
(b) connections
(c) bolts
(d) doors

97. Circuit breakers and switches containing fuses shall be readily accessible and installed so the center of the grip of the operating handle is not more than _____ above the grade, floor, or working platform.

Figure 97 Maximum Handle Height — NEC 110.26(A)(1)

(a) 6 ft 4 in.
(b) 6 ft 5 in.
(c) 6 ft 6 in.
(d) 6 ft 7 in.

98. Independent support wires above a suspended ceiling used to support wiring systems shall be secured at _____ end(s).

Figure 98 Support Wires Above Suspended Ceiling — NEC 300.11(C)

(a) one
(b) both
(c) the line and load
(d) at the attachment to the structural member

99. The _____ in the working space shall be as level and flat as practical for the entire required depth and width of the working space.

Figure 99 Level and Flat Working Space — NEC 110.26(A)(3)

(a) grade
(b) floor
(c) platform
(d) all of these

100. Normally noncurrent-carrying conductive materials enclosing electrical conductors or equipment, shall be connected to earth such that _____ on these materials is limited.

Figure 100 Bonding Enclosure to Earth — NEC 250.4(A)(5)

(a) the voltage to ground
(b) current
(c) arcing
(d) resistance

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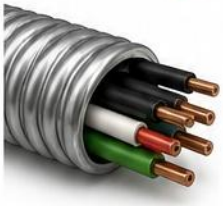

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