# Board of Building Standards

**ELECTRICAL SAFETY INSPECTOR ADVISORY COMMITTEE**
**REQUEST FOR RECOMMENDATIONS**

DATE: JANUARY 13, 2023
TIME: 10:00 AM
LOCATION: NO MEETING THIS MONTH

**Personnel Certification Applications**

P-1 Gelsamino, Michael - PI, ESI
Certification ID:
Current Certifications: None
Staff Notes: Forwarded to ESIAC for review before return to Certification Committee; review experience.
ESIAC Recommendations:
Committee Recommendation:

**Continuing Education Applications for Review**

ER-1 Electric Vehicle Power Transfer Systems and the 2020 NEC Part 1 (Matthews Electrical Services)
All certifications (4 hours)
Staff Notes: Matthews plans to present it at least once per quarter. It is not a multisession course.
ESIAC Recommendation:
Committee Recommendation:

ER-2 Conduit and Box Fill Calculations Based on the 2020 NEC (Master Electrical Contractors Association)
All certifications (5 hours)
Staff Notes:
ESIAC Recommendation:
Committee Recommendation:

ER-3 Understanding the National Electric Code Based on the 2017 NEC (Master Electrical Contractors Association)
All certifications (5 hours)
Staff Notes:
ESIAC Recommendation:
Committee Recommendation:

**File Attachments for Item:**

P-1 Gelsamino, Michael - PI, ESI

Certification ID:

Current Certifications: None

Staff Notes: Forwarded to ESIAC for review before return to Certification Committee; review experience.

ESIAC Recommendations:

Committee Recommendation:

| Gelsomino | Michael | |
|---|---|---|
| *Last Name* | *First Name* | *BBS Certification ID* |

## SECTION 1: CHECK INTERIM CERTIFICATION(S) BEING REQUESTED

| | | | | |
|---|---|---|---|---|
| ☐ Building Official | ☐ Master Plans Examiner | ☐ Building Inspector | ☑ Electrical Safety Inspector | ☐ Fire Protection Inspector |
| ☐ Building Plans Examiner | ☐ Plumbing Plans Examiner | ☐ Mechanical Plans Examiner | ☐ Electrical Plans Examiner | ☐ Fire Protection Plans Examiner |
| | ☑ Plumbing Inspector | ☐ Mechanical Inspector | ☐ Non-Residential Industrial Unit Inspector | |

## SECTION 2: LIST ANY OHIO LICENSE, CERTIFICATE, OR REGISTRATION HELD

*(Mark "T" If Trainee)*

| Description | | | Certificate Number | Date Received |
|---|---|---|---|---|
| Architectural Registration | | | | |
| P.E. Registration | | | | |
| Res | Non-Res | | | |
| ☐ | ☐ | Building Official Certification | | |
| ☐ | ☐ | Plans Examiner Certification | | |
| ☐ | ☐ | Building Inspector Certification | | |
| ☐ | ☐ | Mechanical Inspector Certification | | |
| Building Plans Examiner Certification | | | | |
| Mechanical Plans Examiner Certification | | | | |
| Fire Protection Plans Examiner Certification | | | | |
| Electrical Plans Examiner Certification | | | | |
| Plumbing Plans Examiner Certification | | | | |
| Fire Protection Inspector Certification | | | | |
| Electrical Safety Inspector Certification | | | | |
| Plumbing Inspector Certification | | | | |
| Fire Safety Inspector Certification | | | | |
| Fire Protection System Designer Certification | | | | |
| Medical Gas Piping Inspector Certification | | | | |
| Ohio Home Inspector License # 2022006909 | | | | 11/03/2022 |

Gelsomino — *Last Name*
Michael — *First Name*
*BBS Certification ID*

## SECTION 3: EMPLOYMENT/EDUCATION

| Formal Education | Date Graduated |
|---|---|
| James Ford Rhodes | 1982 |
| | |
| **Related Vocational or Technical Training** | **Years' Experience** |
| West Side Institute of Technology | |
| | |
| **U.S. Military construction experience (MOS or other designation):** | **Years' Experience** |
| | |
| | |
| **Place of Employment:** | **Years' Employed** |
| Cuyahoga Community College | 26 years |
| | |

## SECTION 4: APPLICANTS REQUESTING MEDICAL GAS INSPECTOR CERTIFICATION

***Attach proof** of certification by an ASSE recognized third-party certifier in accordance with ASSE standard 6020.*

## SECTION 5: OBC BUILDING INSPECTION EXPERIENCE PERFORMED FOR A BBS CERTIFIED BUILDING DEPARTMENT

| BBS Certified Building Department | BBS Certified Position/Title | Duties | Date of Service, Length of Time (MM/DD/YY) |
|---|---|---|---|
| | | | |

MICHAEL GELSOMINO
*Last Name*

Michael
*First Name*

*BBS Certification ID*

**SECTION 6: ELECTRICAL SAFETY INSPECTOR (ESI) - SPECIFIC EXPERIENCE QUALIFICATIONS**

Applicants for Electrical Safety Inspector Only Must Complete This Item

Section 3783 of the Ohio Revised Code specifies that an applicant for a Certificate of Competency as an Electrical Safety Inspector must meet on of the following to qualify to take required examination. Please check the qualification that applies:

1. ☑ Have been a journeyman electrician or equivalent for four years, two of which were as an electrician foreman, and have had two years' experience as a building department electrical inspector trainee;
2. ☑ Have been a journeyman electrician or equivalent for four years and have had three years' experience as a building department electrical inspector trainee;
3. ☑ Have had for four years' experience as a building department electrical inspector trainee;
4. ☑ Have been a journeyman electrician or equivalent for six years;
5. ☐ Am a graduate electrical engineer and registered in the State of Ohio. Registration number: ______________
6. ☑ Applicant authorizes all testing organizations including ICC to provide test results to the BBS.

**SECTION 7: EXPERIENCE** ***(DO NOT SUBSTITUTE WITH OTHER RESUMES).***

*Refer to Experience Requirements Listed in O.A.C. 4101:7-3-01 and O.R.C. 3783*

Below, list the specific projects you worked on, and the specific work you performed, your typical duties for each project, and dates of this work. You **must** demonstrate that you have the required number of months (years) of actual, practical experience for the certification requested (see matrix).

Provide letters from certified inspectors, employers, or contractors verifying your experience. Submit copies of any certificates, diplomas, or licenses. Remove all personal information.

**SECTION 7 CONT.: EXPERIENCE**

| List Each Construction Project AND Specific Type of Work Performed | Name of Employer, Contact, Address, Telephone Number | Project Time: From_ To _ (MM/YY) |
|---|---|---|
| *Example:*<br>*Children's Hospital, Toledo*<br>*Structural steel work on addition* | *Homer Steel and Trade*<br>*125 Anytown Street*<br>*My City, OH, 45454*<br>*(419)555-1212* | *July 2013-May 2014*<br>*(10 months)* |
| Electrical History<br>Preventative maintenance<br>Service & installation on electric service distribution panels<br>480 volt<br>277 volt<br>208 volt<br>120 volt | Cuyahoga Comm. College<br>11000 West Pleasant Valley<br>Parma, OHIO 44130<br>216-987-6000 | April 1996 - April 2022 |
| **Total Experience on This Page (In Months):** | | |

Gelsomino | Michael | 
*Last Name* | *First Name* | *BBS Certification ID*

| List Each Construction Project AND Specific Type of Work Performed | Name of Employer, Contact, Address, Telephone Number | Project Time: From_ To _ (MM/YY) |
|---|---|---|
| Service & Preventative Maintenance<br>4160 volt switch gear substations - 8 total<br>Main Campus | Cuyahoga Comm. College<br>11000 W. Pleasant Valley Rd<br>Parma OH 44130<br>216-987-6000 | April 1996 - April 2022 |
| Service Installation, Preventative maintenance<br>208V Service distribution panels & switch gears<br>Public Safety & Training Center | Cuyahoga Comm. College<br>11000 W. Pleasant Valley Rd.<br>Parma, Ohio 44130<br>216-987-6000 | April 1996 - April 2022 |
| Plumbing<br>• Service<br>• Installation<br>• Water closets<br>• Lav. sinks<br>• Commercial kitchen<br>• Sanitary lines<br>• Domestic Water Supply<br>• BackFlows<br>• Grease traps<br>• etc. | Cuyahoga Comm. College<br>11000 W. Pleasant Valley Rd.<br>Parma Ohio 44130<br>216-987-6000 | April 1996 - April 2022 |
| | **Total Experience on This Page (In Months):** | |

Gelsomino | Michael | 
Last Name | First Name | BBS Certification ID

**SECTION 8: PERSONAL HISTORY**

1. Have you ever been convicted of any felony, or any crime involving moral turpitude?
   ☐ Yes ☒ No

   If you answered "Yes" please explain below:
2. Have you served in the U.S. armed services? (If No, skip question 3) ☐ Yes ☒ No
3. If YES, were you discharged under honorable conditions? ☐ Yes ☐ No

   If you answered "No" please explain below:

**SECTION 9: CERTIFICATION**

*I certify the information contained in this application is true and complete, and I understand that providing false information may be grounds for not granting certification or for immediate termination of certification at any point in the future, if granted. I authorize the investigation of all statements contained herein and release all parties from all liability for any damage that may result from furnishing the same to Ohio Board of Building Standards.* Falsification is a violation of section 2921.13 of the Ohio Revised Code and is punishable as a misdemeanor of the first degree.

Signature of Applicant: ____________

Subscribed and duly sworn before me according to law, by the above named applicant this day 10 of December in the year 2022 at Fifth Third Bank, County of Cuyahoga and State of Ohio.

Notary Public: Karen Lynn Heabler

SEAL

NOTARY PUBLIC ★ STATE OF OHIO ★

KAREN LYNN HEABLER
Notary Public, State of Ohio
My Commission Expires
August 23, 2025
COMMISSION: 2020-RE-818804

Tony DiGiandomenico
400 Charles Ave.
Amherst, Ohio 44001
January 4, 2023

Ohio Department of Commerce -Board of Building Standards
77 South High St.
Columbus, Ohio 43215

To whom it may Concern:

Mike Gelsomino worked at Cuyahoga Community College for over 20 years as a Maintenance Technician and Building Maintenance Supervisor. He reported to me at Cuyahoga Community College's Parma Campus from early 2015 until 2021. His position at that time was Buildings and Utilities Maintenance Supervisor.

Mike's duties as the Building and Utilities Supervisor included coordinating and directing work activities of Building Maintenance personnel, ensuring work was performed as required by the College, State and local governments of Parma and Parma Heights. Mike's duties included performing work as an electrical and plumbing journeyman responsible for maintenance, troubleshooting, repair of the physical condition of the campus and equipment, including hvac, plumbing and electrical systems.

Mike's journeyman electrical and plumbing skills were utilized for the planning, overseeing and performing the renovations of restrooms, classrooms, offices, locker rooms and conference room on Campus. The work included removing and replacing electrical circuits of 110V, 208V and 440v. He also was responsible to make repairs and perform new installations of water, sanitary and steam lines throughout the Campus.

Mike as part of his duties met with Electrical and Mechanical Engineers in review meetings for major campus renovation projects to review design criteria and routing of both electrical and plumbing installation. He offered his insight of the current situation and made recommendations for improvement. He was responsible during the projects for inspecting the work of journeymen electricians and plumbers as one of the campus representatives. He identified issues with installations and follow up on required corrective actions.

This letter is meant to highlight Mike's experience and qualifications as an electrical and plumbing journeyman while he worked as my direct report.

Tony DiGiandomenico

**File Attachments for Item:**

ER-1 Electric Vehicle Power Transfer Systems and the 2020 NEC Part 1 (Matthews Electrical Services)

All certifications (4 hours)

Staff Notes: Matthews plans to present it at least once per quarter. It is not a multisession course.

ESIAC Recommendation:

Committee Recommendation:

## APPLICATION FOR CONTINUING EDUCATION APPROVAL
## COURSE CONDITIONS AND GUIDELINES

The Ohio Board of Building Standards is committed to the ongoing education and professional development of board-certified personnel through the delivery of high-quality, accurate and engaging professional continuing education content. To this end, the Board reviews and approves Continuing Education Courses for building department personnel.

Board approval is granted for course instruction on current codes and standards, including the OBC, OMC, OPC, and RCO, and any other content areas directly related to the responsibilities of the certification for which credit is being requested.

**Promotion**: Any person or organization promoting an approved course is required to make full and accurate disclosure regarding course title, course approval number, number of credit hours, categories for which the BBS has approved the class, and fees in promotion materials and advertising. ***The Board does not grant retroactive approval. It is recommended that courses be submitted for approval well in advance of any scheduling of classes and advertising***. Advertising may not falsely state BBS approval before approval is granted. Course providers may state that BBS approval is pending.

**Application Submission:** All Applications and associated materials shall be submitted by email in .pdf format. Instructions for completing the application are attached.

**Certificate of Completion:** Course providers shall provide participants a certificate of completion containing the following information:

- Name of participant
- Title of approved courses
- BBS approval #
- BBS approved certifications
- Date of the continuing education program
- Number of approved credit hours awarded, and
- Signature of authorized sponsor or instructor.

Any person or organization administering an approved course shall return a completed BBS Course Attendance form by email.

**Participants**: Participants must attend the complete course as presented by the instructor to receive credit hours approved by the Board. The organization or instructor of online courses shall plan and execute methods to verify the individual's attendance and completion of the course. No partial credit will be given to any participant who failed to complete the entire course as approved.

**Board approval**: All courses are approved for the calendar year in which application is made. Courses may be renewed so long as the referenced code is in effect, and the CEUs, certification and content remain unchanged. When the referenced code is updated, courses must be updated, and new approvals obtained.

**Facility/training area**: BBS Course may be delivered in person or online, or both, at the sponsor's option.
Course facilities shall include the following:

**In Person Classes:**

- Sufficient seating capacity
- ADA accessible facilities
- Appropriate Audio/Visual devices for delivery
- Writing surfaces for participants

**Online Classes:**

- Web-accessible
- ADA accessible delivery
- Tech support available
- Live and recorded courses permitted

In-person facilities shall comfortably and safely seat at least the number of attendees present in the room and shall be climate controlled, non-smoking, and sound controlled so that outside noise will not interfere with the training.

Ohio | Department of Commerce

Mike DeWine, Governor
Jon Husted, Lt. Governor

Sheryl Maxfield, Director

Board of Building Standards

# Application for Continuing Education Course Approval

**Provider Information:**

Name: Henry P. Matthews

Organization: Matthews Electrical Services

Address: 1203 McKinley Place; Fostoria, Ohio 4830

E-mail: hpmatthews@matthewselectrical.net Telephone: 419-575-3488

Website: www.matthewselectrical.net

Conference Sponsor (if applicable)________ Conference Email:________

**Check here if Course Renewal:**______ Prior course number ________ (*i.e. BBS2018-429*)

*Renewals will only be granted for identical content and certifications, within the current code cycle.*
*Attach a copy of prior course approval letter for confirmation. No further information is required.*

**New Course Information:**

Course title: Electric Vehicle Power Transfer Systems and the NEC Part 1

Course instructor: Henry P. Matthews

Course description: This course will cover article 625 in the NEC for electric vehicle power transfer systems. This course will also cover the history of electric vehicles and discuss projected growth and the electrical infrastructure requirements. This course will focus on installations for one and two family dwelling units and the other relevant NEC sections required for a code-compliant electric vehicle installation.

Instructional hours per session: 4 Number of Sessions: at least one per quarter

Course Date(s) and Location: January 7, 2023 via Zoom. Registration at www.matthewselectrical.net

**Special Content:**

Code Administration:______

Existing Buildings: ______

Electrical Instruction: ______

Plumbing Instruction:______

Conference Course: ______

Conference Name: ______

Conference location:______

Course to be offered online? ✓ **On Demand**_____ **Webinar** ✓

Course Website: www.matthewselectrical.net

Detail online course participation confirmation method (*i.e. test, quizlets, participant activity confirmation*):
Surveys, polls, and roll call after each break will be conducted.

**Course applicable for the following certifications**

Residential Certifications Only: ✓ Commercial Certifications: ✓

Administrative Course, All Certifications: ______

**Application materials included:**

✓ Course Outline or Course Learning Objectives
✓ Presentation Materials/Slides (not required for roundtable courses)
✓ Assessment Materials (for online courses)
✓ Presenter Bio

**Please submit application and materials in .pdf format to: michael.lane@com.ohio.gov or BBS@com.ohio.gov**

# Instructions for new Continuing Education Approval form

Provider Information

1. Please include all contact information.
2. If course is not part of a conference, leave conference sponsor and email blank.

Course Renewal

1. Indicate if the course is being submitted for renewal. Include prior approval letter and write in prior course number.
2. Certification approval for courses has now changed: all existing courses being renewed will be approved within the new classification system.
    a. Courses previously approved for only residential certifications will be approved for all residential certifications.
    b. Courses previously approved for at least on commercial certification will now be approved for all commercial certifications and all residential certifications.
    c. Courses on required instruction topics, Ohio Ethics, Code Administration and Existing Buildings, will be noted as Administrative Courses and be approved for all certifications.
3. Courses being renewed should skip the New Course information section and are not required to submit outline, agenda, slides or other instructional materials for review. Skip to Special Content, and mark any item that applies to the course.

New Course Information

1. Enter course title, name of instructor, and a brief description of the course content. Learning objectives may be substituted for course description, if desired.
2. Number of instructional hours per session is the length of instructional time.
3. Number of sessions: can be 1 or the number of sessions planned.
4. Course date(s) and location: not necessary at this time, enter if known.

Special Content

1. Indicate if the course will meet instructional time in Code Administration or Existing Buildings.
2. Indicate if the course is a plumbing or electrical course, for ESIAC review and trainee course tracking.
3. If the course is associated with a conference, indicate the conference name and location, as this will allow BBS to coordinate approvals with the conference provider.
4. If the course will be offered online, specify whether it will be on demand or offered as a virtual webinar, or both. Include website where the course will be provided.

Course applicable for the following certifications

***This section represents a major change from previous BBS course approval forms.***

1. If the course is only for residential certifications, check 'Residential Certifications Only'. The course, if approved, will be approved for all residential certifications.
2. If the course is appropriate for any commercial certifications, check Commercial Certifications. The course, if approved, will be approved for all commercial certification **AND** all residential certifications.
3. If the course is intended to meet required instruction in Code Administration (Chapter 1) or Existing Buildings (commercial or residential) check 'Administrative Course, All Certifications'.

Application Materials Included

This is a checklist for the course submitter's use, to be sure all materials necessary for review are included with the application. All materials should be submitted in .pdf format, along with the application, via email to Michael.Lane@com.ohio.gov or BBS@com.ohio.gov

BIOGRAPHY
Henry P. Matthews PE, CPE, CESCP, PVA

Henry has over 31 years of experience in the electrical design, construction, engineering and safety fields. He has a passion for teaching and mentoring.

Henry obtained his Bachelor of Science degree in Electrical Engineering from Penn State University in 1989.

He also earned a Master of Business Administration from Bowling Green State University in 2003.

In addition, Henry earned several certificates including:

- Plumbing and Electrician from Penn Foster Career School
- Welding from Owens Community College in Findlay, Ohio
- Residential Solar PV Systems from Solar Engineering International

Henry currently holds the following licenses, and memberships:

- Licensed Electrical Contractor in Ohio
- Licensed Training Agency in Ohio
- Licensed Professional Engineer in Ohio, Michigan, Kentucky, Indiana, Illinois, Wisconsin
- Certified Plant Engineer (CPE)
- Certified Building Operator (CBO)
- Certified Electrical Compliance Safety Professional (CESCP) by NFPA
- Solar PV Associate by the North American Board of Certified Energy Practitioners
- Electric Vehicle Infrastructure Training Program (EVITP) certification
- Senior Member of the Institute of Electrical and Electronic Engineers (IEEE)
- Member of the International Association of Electrical Inspectors (IAEI)
- Member of the National Fire Protection Association (NFPA)

Henry is currently employed as an Advanced Senior Engineer for Marathon Petroleum Company in Findlay, Ohio. During his 16 years at Marathon, Henry has worked as an Electrical Design Engineer, Project Engineer, Engineering Supervisor and currently as a Reliability Engineer.

Henry is also the owner of Matthews Electrical Services, a small, but full-service electrical contractor company.

Prior to this, he worked 13 years as an Electrical Engineer and a Plant Engineering Manager in at Cooper Standard Automotive, a major automotive parts supplier in Bowling Green, Ohio

Henry is the past co-chair of American Petroleum Institute Recommended Practice 545 Lightning Protection for Above Ground Storage Tanks.

He was also past president of the Fostoria Toastmaster club.

**Electrical Vehicle Power Transfer Equipment and the NEC**
Outline

Relevant NEC Chapters and Articles (Based on the 2020 NEC)

- Article 625 Electric Vehicle Power Transfer Systems
- Article 100 Key Definitions
- Article 110 Requirements for Electrical Installations
- Article 210 Branch Feeders
- Article 215 Feeders
- Article 220 Branch-circuit, Feeder and Service Load Calculations
- Article 230 Services
- Article 240 Overcurrent Protection
- Article 242 Overvoltage Protection
- Article 250 Grounding and Bonding
- Chapter 3 Wiring Methods and Materials
- Article 685 Integrated Electrical Systems
- Article 690 Solar Photovoltaic Systems
- Article 702 Optional Standby Systems
- Article 705 Interconnected Electric Power Production
- Article 706 Energy Storage Systems
- Chapter 9 Tables

Other Resources:

- NFPA 70E (2021) Electrical Safety in the Workplace
- NECA 413 Standard for Installing and Maintaining Electrical Vehicle Supply Equipment (EVSE)
- OSHA 1910 Subpart S Electrical Safety

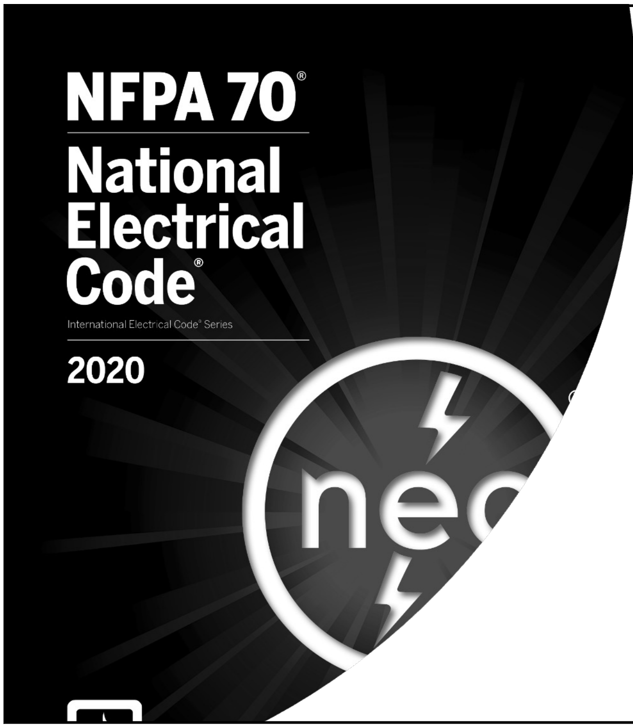
Referenced Websites:

- www.NFPA.org
- NREL – National Renewable Energy Laboratories
- www.IAEI.org (International Association of Electrical Inspectors)
- www.mikeholt.com
- www.esfi.org Electrical Safety Foundation International)
- Multiple automobile and Class 2/DC Fast charger manufacturer websites

Course Content:

- History of Electric Vehicles
- Electrical Safety review with emphasis on DC systems
- NEC definitions
- Charger site evaluation and considerations
- Types of charger connectors and their functions

- Other requirements
    - Grounding and bonding
    - GFCI and ground fault protection
    - Overcurrent protection’
    - Bi-directional current flow considerations
        - Article 705 Interconnected Electric Power Production
    - EVPE considerations
        - Article 702 optional standby systems
        - Article 705
- Types of EV chargers: Class I, Class 2 and DC Fast chargers
- Types of chargers: connected and wireless (induction)
- Installation requirements
- Electrical calculations for charger installation




1

Electric Vehicles
NEC Article: 625

OCILB Course # 4871434

The 2020 NEC has not been adopted in Ohio. PRESENTED FOR INFORMATIONAL PURPOSES ONLY

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# Notice!

**This course is based on the 2020 NEC.**

**The 2020 NEC has not been adopted in Ohio**

**Presented for**
**INFORMATIONAL PURPOSES ONLY.**

The 2020 NEC has not been adopted in Ohio. PRESENTED FOR INFORMATIONAL PURPOSES ONLY

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## Webinar Rules

- Attendee must be present the entire time (except breaks)
- Mute microphone at all times
  - Prevents distraction during webinar
  - Instructor may activate participant microphone if verbal response is needed

The 2020 NEC has not been adopted in Ohio. PRESENTED FOR INFORMATIONAL PURPOSES ONLY

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## Webinar Rules (Continued)

- 5 minute breaks every hour
  - Return promptly after breaks
  - The instructor will check attendance after each break
- Emergencies
- Contingency Plans: Ohio Weather
- Unexpected interruption
  - Re-joining webinar
  - Problems:
    - send me a text message: 419-575-3488
    - Or email: hpmatthews66@att.net

The 2020 NEC has not been adopted in Ohio. PRESENTED FOR INFORMATIONAL PURPOSES ONLY

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# WELCOME!

- Goals
  - Promote learning
  - Make session engaging
    - Discussion
    - Videos
    - Case Studies
    - Polls
  - Make 4 hours as productive as possible!

The 2020 NEC has not been adopted in Ohio. PRESENTED FOR INFORMATIONAL PURPOSES ONLY

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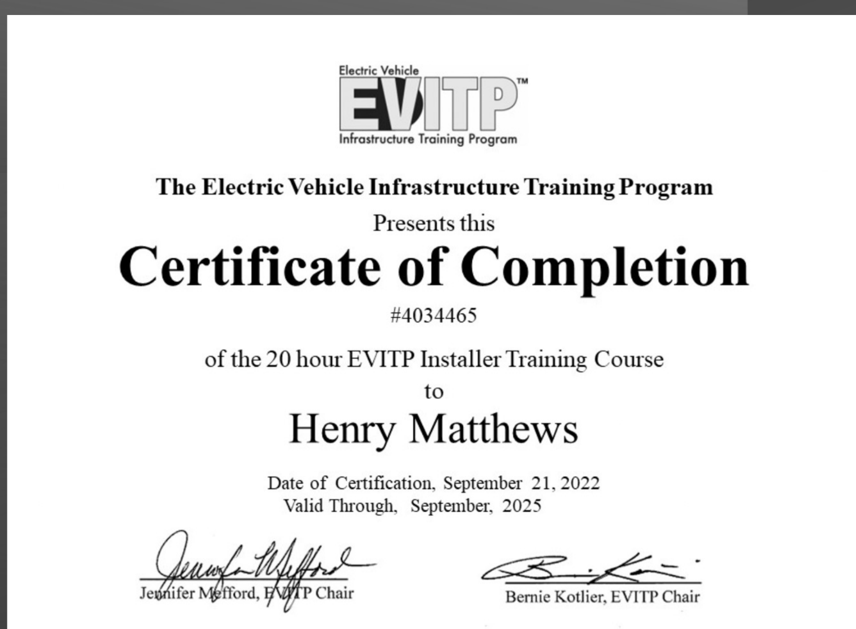

Electric Vehicle EVITP™ Infrastructure Training Program

**The Electric Vehicle Infrastructure Training Program**

Presents this

**Certificate of Completion**

#4034465

of the 20 hour EVITP Installer Training Course

to

Henry Matthews

Date of Certification, September 21, 2022

Valid Through, September, 2025

Jennifer Mefford, EVITP Chair

Bernie Kotlier, EVITP Chair

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Roll Call!

Turn on your cameras!

The 2020 NEC has not been adopted in Ohio. PRESENTED FOR INFORMATIONAL PURPOSES ONLY

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# Agenda

- Relevant EV NEC Articles and other sources of information
- History of Electric Vehicles
- Electrical Safety review with emphasis on DC systems
- NEC definitions
- Charger site evaluation and considerations
- Types of charger connectors and their functions

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## Relevant NEC Chapters and Articles (Based on the 2020 NEC)

- Article 625 Electric Vehicle Power Transfer Systems
- Article 100 Key Definitions
- Article 110 Requirements for Electrical Installations
- Article 210 Branch Feeders
- Article 215 Feeders
- Article 220 Branch-circuit, Feeder and Service Load Calculations
- Article 230 Services

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## Relevant NEC Chapters and Articles (Based on the 2020 NEC)

- Article 240 Overcurrent Protection
- Article 242 Overvoltage Protection
- Article 250 Grounding and Bonding
- Chapter 3 Wiring Methods and Materials
- Article 685 Integrated Electrical Systems
- Article 690 Solar Photovoltaic Systems

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## Relevant NEC Chapters and Articles (Based on the 2020 NEC)

- Article 702 Optional Standby Systems
- Article 705 Interconnected Electric Power Production
- Article 706 Energy Storage Systems
- Chapter 9 Tables

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## Other Resources

- NFPA 70E (2021) Electrical Safety in the Workplace
- NECA 413 Standard for Installing and Maintaining Electrical Vehicle Supply Equipment (EVSE)
- OSHA 1910 Subpart S Electrical Safety

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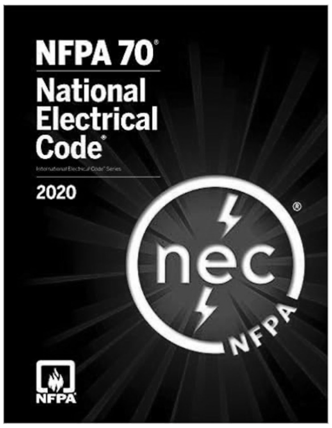
# Resources





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# Websites

- www.NFPA.org
- www.evassociation.org  Electric Vehicle Charging Association
- www.chargedevs.com.  Charged Electric Vehicles Magazine
- www.IAEI.org  (International Association of Electrical Inspectors)
- www.mikeholt.com
- www.esfi.org Electrical Safety Foundation International)
- NREL – National Renewable Energy Laboratories
- Multiple  automobile and Class 2/DC Fast charger manufacturer websites

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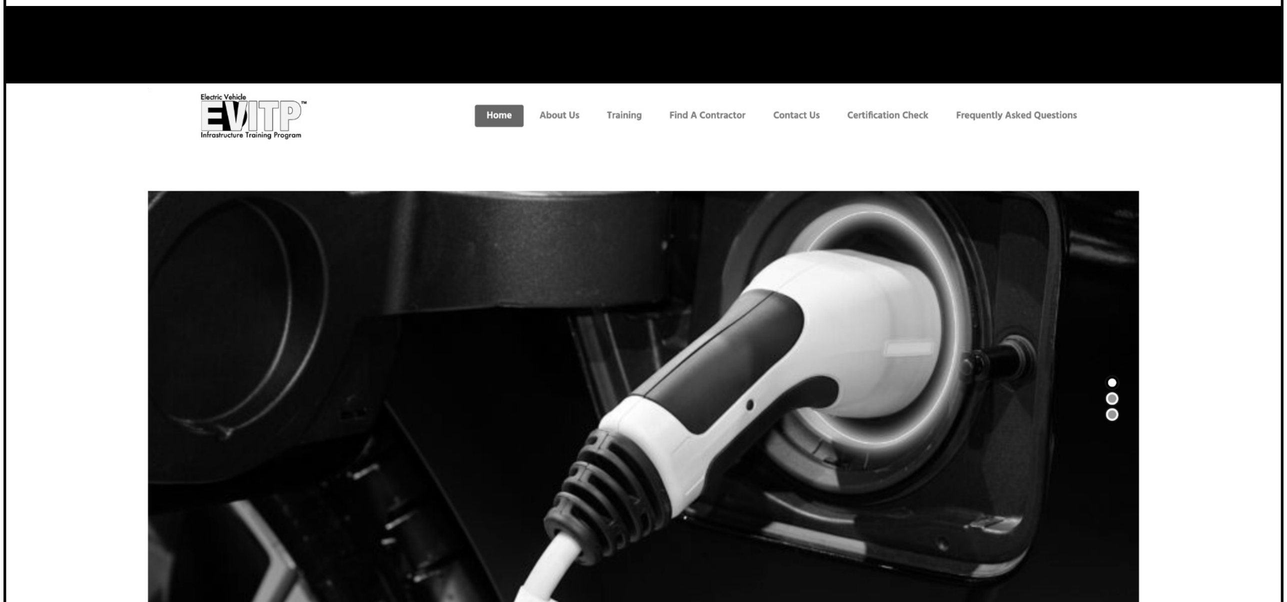


https://evitp.org/

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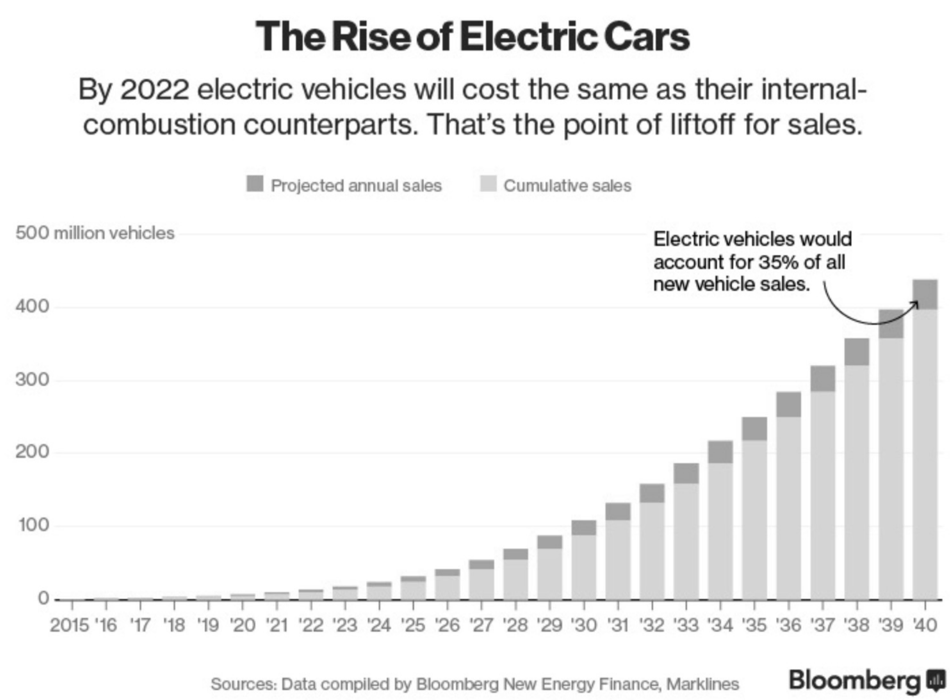


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## Electric Vehicle Growth Challenges

- Existing infrastructure
- Cost of electric vehicles
- Range Anxiety
- Availability of resources, battery materials for example
- Contractor skill level: AC to DC adaptability
- Lithium-Ion battery safety
- Comfort level with new technology

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## Origins of the Electric Vehicle (EV)

- Inventor of the first EV is not known
- 1829, Anyos Jedlik (Hungary) developed small-scale model car powered by an electric motor
- 1834, the first American built battery-electric car by Thomas Davenport, a blacksmith from Vermont. Batteries were not rechargeable
  - Davenport was also the inventor of the first American-build DC electric motor
- 1886, Karl Benz (Germany) applied for patent for his gas-powered vehicle
- 1893, Charles and Frank Duryeas, (Springfield, Mass), credited with first America gas-powered vehicle

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## Origins of the Electric Vehicles

- Designs improved, but distance limited by batteries. Most were not rechargeable
- Gaston Plante (France) invented a better rechargeable lead-acid battery in 1859
- Electric vehicles gained popularity due to easier starting, less vibration, less odor, less noise and easier to change gears
- From 1899 to 1900, EVs outsold gasoline cars 10 to 1

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## Origins of the Electric Vehicles

- By 1900, there were gas, steam and electric powered vehicles available
- Mix was about even with 33% gas, 33% steam and 33% electric
- The best roads were in cities and towns, which was ideal for the limited range of electric vehicles

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## The Decline of Electric Vehicles

- By 1910, the popularity of EVs started to decline:
- Improved roads increased demand for longer range vehicles
- Discovery of Texas crude oil made gas more affordable
- Invention of the electric starter by Charles Kettering in 1912 made it easier to start gas power cars vs the traditional hand crank
- Mass production of Internal Combustion Engine (ICE) cars by Henry Ford made gas cars more affordable to consumer
- Electric vehicles virtually disappeared by 1935

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## Reappearance of Electric Vehicles

- Began to see rebirth in 1960s and 1970s due to concerns about air pollution and the OPEC Oil Embargo
- A few car makers resumed production of EVs in limited quantities
- Spearheaded by California's Zero Emission Vehicle (ZEV) mandate
  - Required 2% of vehicles to be ZEV by 1998 and 10% by 2003
- The global economic recession in late 2000s led to more interest in alternative fueled vehicles.
- Tesla (California), led by Elon Musk, launched the Tesla Roadster in 2008
  - First highway capable all-electric vehicle in serial production in 2008

22

## Reappearance of Electric Vehicles

- 1995, GM announced prototype EV called Impact, later renamed EV-1

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## Reappearance of Electric Vehicles

- Tesla Roadster, 2008

24

# Types of Electric Vehicles

There are several types of Electric Vehicles:

- Hybrid Electric Vehicles (HEV)
- Plug-In Hybrid (PHEV)
- Plug-In Electric Vehicle (PEV)
- Battery Electric Vehicle (BEV)

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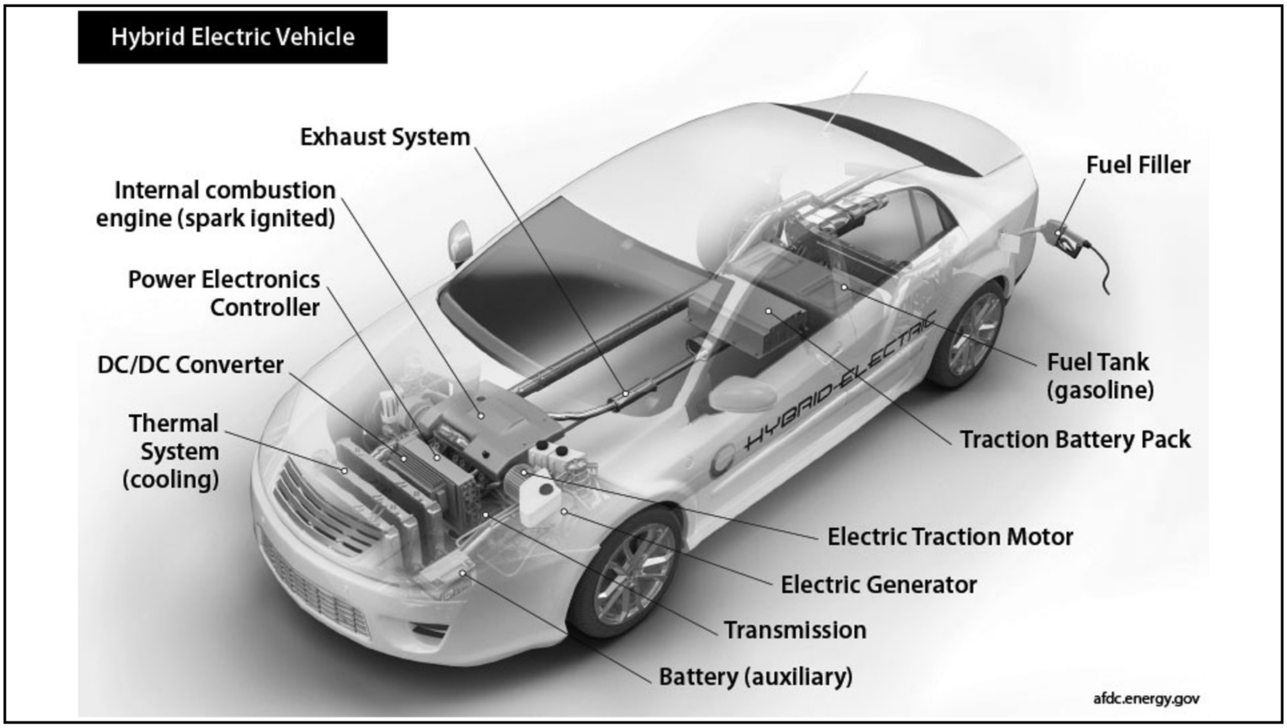
## Hybrid Electric Vehicle (HEV)

- Combines traditional ICE with and electric propulsion system
- First popular electric vehicle, ex. Toyota Prius
- Utilizes regenerative braking which converts vehicle’s kinetic (moving) energy into electric energy to charge the batter
- The internal combustion engine can generate electricity by turning an electrical generator
- Does not rely on external AC or DC charging.  Regenerative charging or charging by ICE engine keeps battery charged

26

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# Plug-In Hybrid (PHEV)

- Has internal rechargeable batteries
- Also has internal combustion engine similar to pure Hybrid EV
- Batteries recharged by external power source
- Combination of external charging and ICE eases “range anxiety” of running out of gas or power while going long distances
- ICE can power car if batteries are depleted

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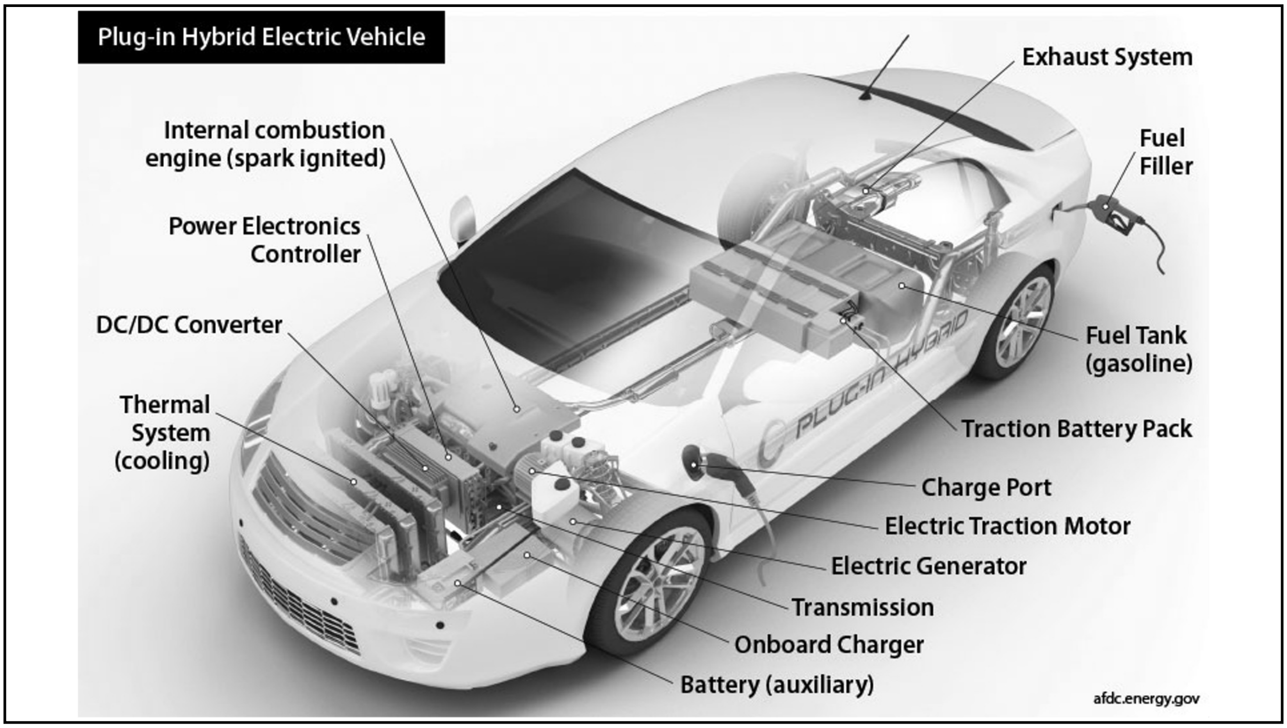


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## Plug-In Electric Vehicle (PEV)

- A superset of the electric vehicles that includes:
  - Battery Electric Vehicles
  - Plug-in Hybrid Vehicles (PHEVs)
- Slower to adopt than hybrid versions for several reasons
  - Cost
  - Battery range
  - Lack of charging infrastructure leading to range anxiety (running out of charge)

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# Battery Electric Vehicle (BEV)

- Also known as an All-Electric Vehicle
- Has internal batteries that can only be recharged from an external power source of electricity
- Does not have an internal combustion engine to help recharge batteries

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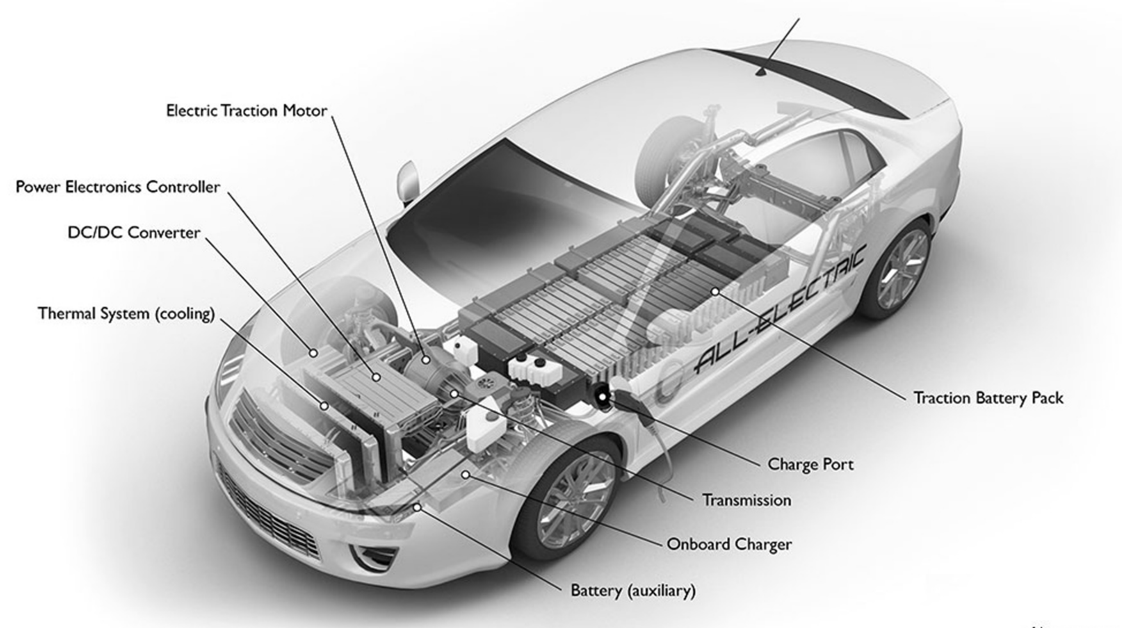
## All-Electric Vehicle




afdc.energy.gov

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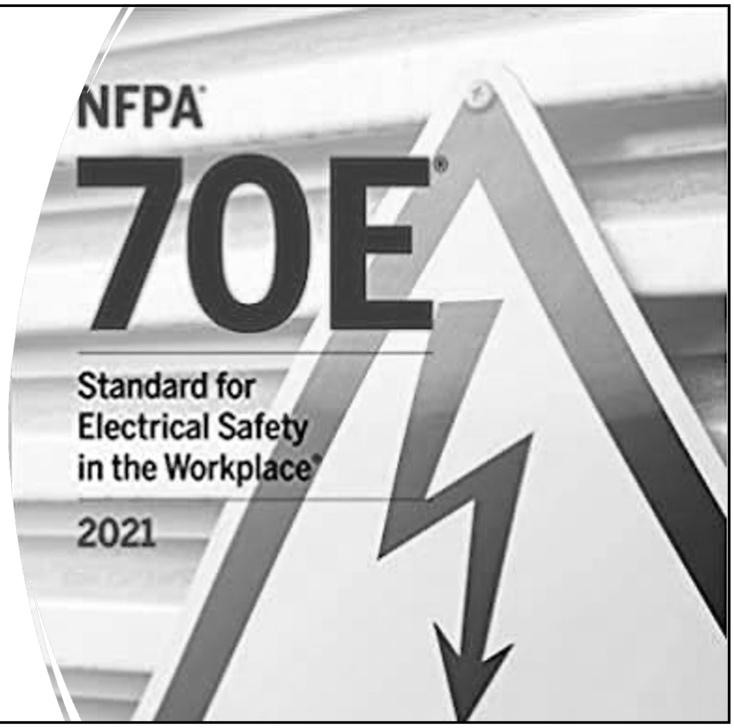
# Safety Considerations

- NFPA 70E
- Battery Safety
- Lithium-Ion batteries: thermal run-away and other issues
- AC and DC electrical work
- Bi-directional flow of electricity
- Proper PPE

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# Electric Vehicle Supply Equipment

- Three types:

- Level 1
- Level 2
- DC Fast Charging (several levels)

34

# Connector Handshake

- Plug not powered until plugged into and commanded by vehicle
- Electric Vehicle Supply Equipment (EVSE) signals presence of AC input power
- Vehicle detects plug via proximity circuit (prevents drive away while connected)

35

# Level 1 Chargers

- Usually come with the Plug-In Electric Vehicle
- Inexpensive
- Portable
- Usually plugs into standard 120V AC outlet
- Operates at 1.4 kW, 12 amps: requires 15A circuit breaker or
- Operates at 1.9 kW, 16 amps: requires 20A circuit breaker
- Long charge times, usually overnight in garage (12 - 16 hours)
- Supply AC power to the EV's on-board battery charger

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## Level 2 Chargers

- Higher capacity chargers
- Usually not portable, fixed installation
- Installed in garages, shopping parking lots, businesses (fleet charging)
- Operates at 208 or 240V AC, single-phase or 3-phase
- Higher power usually requires 3-phase circuit
- Commercial charges range from 6.6 to 19.2 kW

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## Level 2 Chargers

- Requires 30 to 60 amp circuit breaker depending on power requirements and electrical system (single phase or 3-phrase)
- Dramatically reduces time to charge batteries
- Charges batteries between 3 and 8 hours
- Delivers AC power to the EV onboard charger, same as Level 1 chargers

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## DC Fast Chargers

- Three competing technologies
- SAE J1772 Combo
- CHAdeMO
- Tesla proprietary
- Bypasses EV charging system (AC)
- Provides DC power directly to vehicle battery management system
- Some charging stations have all three technologies for efficiency

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## DC Fast Chargers

- Provide fastest way to charge batteries
- Can provide charge in 15 to 60 minutes
- Require more power, 3-phase power
- Outputs of 15kW to over 350kW
- Usually connected to a network requirement some form of payment
- Common networks: Blink, ChargePoint, Electrify America, Greenlots SKY, NRG eVgo, SemaConnect and more

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| | |
|---|---|
| 30 kW | 87 miles/hour |
| 50 kW | 145 miles/hour |
| 100 kW | 289 miles/hour |
| 120 kW | 347 miles/hour |
| 150 kW | 434 miles/hour |
| 180 kW | 520 miles/hour |
| 250 kW | 723 miles/hour |
| 350 kW | 1012 miles/hour |

41

# SAE J1772 Combo

- Has two extra large pins for DC Fast charging
- Used by GM, Ford, Chrysler, Audi, Daimler, Porsche, Volkswagen and BMW

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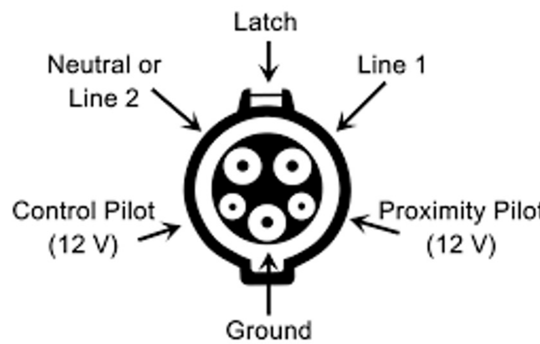
# SAE J1772 Connector for Level 1 and Level 2 Chargers

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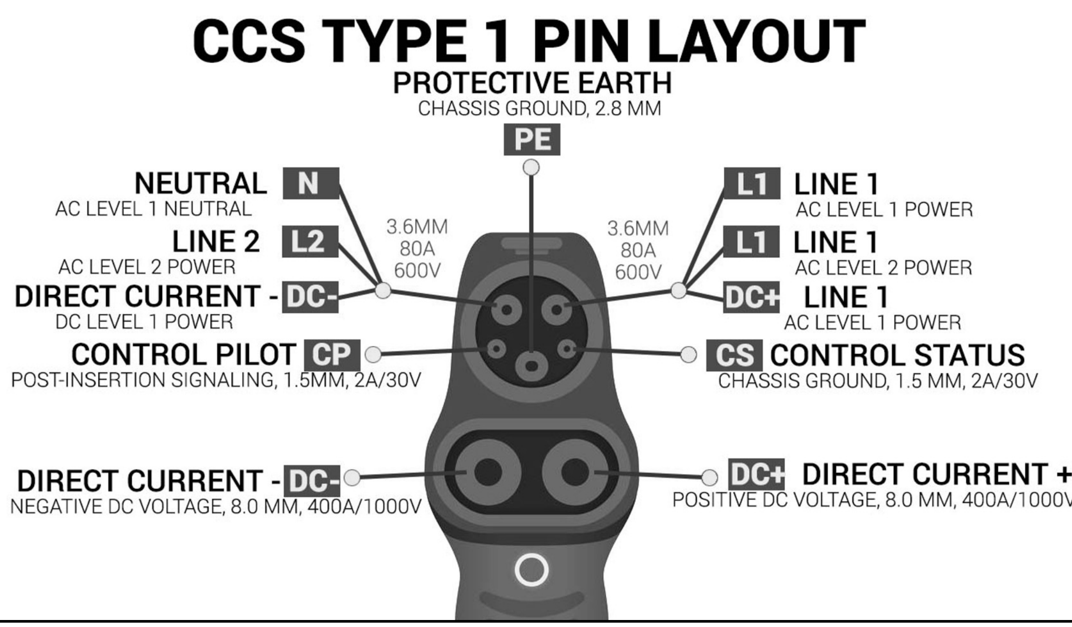
# SAE J1772 Combo for Fast Chargers

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## CHAdeMO Connector for DC Fast Charging

- Developed by the Tokyo Electric Power Company in Japan
- Used by Nissan, Mitsubishi, Toyota
- Abbreviatedfor **CHArge de Move**
- Meaning “Let's have a cup of tea while charging” in Japanese

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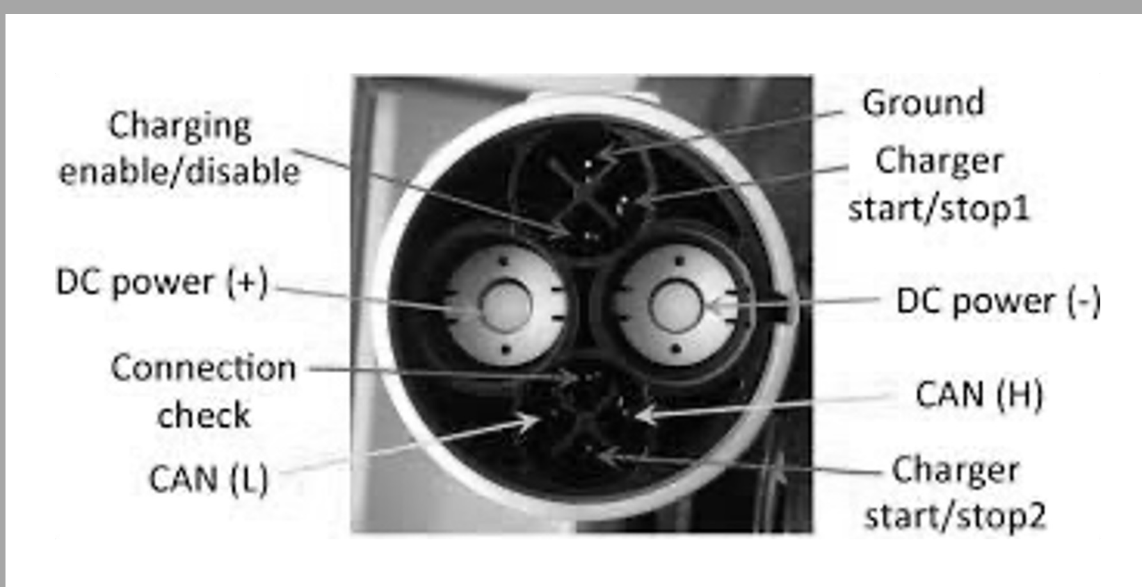


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# Contractor Basic Steps

- Electrical contractor must perform a site assessment for EVSE installation
- Obtain electrical wiring permit(s) and coordination of the inspection and approval processes.
- Coordinate with local utility company for time-of-use (TOU) meters, off- peak metering, etc.)
- Facilitate the installation of the EVSE and associated branch circuit wiring
- Inspection, startup, and commissioning completed EVSE installation

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# EVSE Installation Considerations

- Use EVSE nameplate data to calculate the full load current of equipment.
- EVSE is considered to be a continuous load
- Size ampacity of conductors and overcurrent protective devices at not less than 125% of the calculated load current.
- Verify the conductor material and size of the existing service conductors (copper vs. aluminum)

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## Scope: Section 625.1

- This article covers the electrical conductors and equipment connecting an electric vehicle to the premises wiring for the purposes of charging, power export or bidirectional current flow.

49

## Scope: Section 625.1

- Informational notes:

1. NFPA 505-2018 Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance and Operations

2. UL 2594-2013, Standard for Electric Vehicle Supply Equipment
   UL 2202-2009, Standard for Electric Vehicle Charging System Equipment

50

## Definitions: Section 625.2

- Cable Management System

- An apparatus designed to control and organize the output cable to the electric vehicle or to the primary pad

51

## Definitions: Section 625.2

- Charger Power Converter

- The device used to convert energy from the power grid to a high-frequency output for wireless power transfer

52

## Definitions: Section 625.2

- Electric Vehicle Connector (2020)

- A device that, when electrically coupled to an electric vehicle inlet, establishes and electrical connection to the electric vehicle for the purpose of power transfer and information exchange.

53

## Definitions: Section 625.2

- Electric Vehicle Power Export Equipment, EVPE (New for 2020)

- The equipment, including the outlet on the vehicle, that is used to provide electrical power at voltages greater than or equal to 30 VAC or 60 VDC to loads external to the vehicle, using the vehicle as the source of supply

54

## Definitions: Section 625.2

- Electric Vehicle Power Export Equipment, EVPE (New for 2020)

Informational note: EVPE and EVSE are sometimes contained in one piece of equipment, sometimes referred to as bidirectional EVSE

55

## Definitions: Section 625.2

- Electric Vehicle Supply Equipment, EVSE (Revised for 2020)

- The conductors including the ungrounded, grounded, and equipment grounding conductors, and the EV connectors, attachment plugs, personnel protection system, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the electric vehicle

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# WARNING!

- Pay close attention to definitions for:
  - **FASTENED IN PLACE**
  - **FIXED IN PLACE**
  - **PORTABLE**


Specific requirements for each, including GFCI requirements!

57

# Definitions: Section 625.2

- Fastened in Place (Revised for 2020)
- Mounting means of equipment in which the fastening means are specifically designed to permit periodic removal, without the use of a tool, for relocation interchangeability, maintenance or repair.

58

## Definitions: Section 625.2

- Fixed in Place

- Mounting means of an EVSE attached to a wall or surface with fasteners that require a tool to be removed.

59

## Definitions: Section 625.2

- Output Cable to the Electric Vehicle

- An assembly consisting of a length of flexible EV cable and an electric vehicle connector (supplying power to the electric vehicle).

60

## Definitions: Section 625.2

- Output Cable to the Primary Pad

- A multi-conductor, shielded cable assembly consisting of conductors to carry the high-frequency energy and any status signals between the charger power converter and the primary pad.

61

## Definitions: Section 625.2

- Personnel Protection System

- A system of personnel protection devices and constructional features that when used together provide protection against electric shock of personnel

62

## Definitions: Section 625.2

- Power Supply Cord

- As assembly consisting of an attachment plug and length of flexible cord that connects equipment to a receptacle.

63

## Definitions: Section 625.2

- Primary Pad (revised for 2020)

- A device external to the EV that transfers power via the contactless coupling as part of a wireless power transfer system

64

# Definitions: Section 625.2

- Wireless Power Transfer (WPT)

- The transfer of electrical energy from a power source to an external load via electric and magnetic fields or waves by a contactless inductive means between a primary and secondary device.

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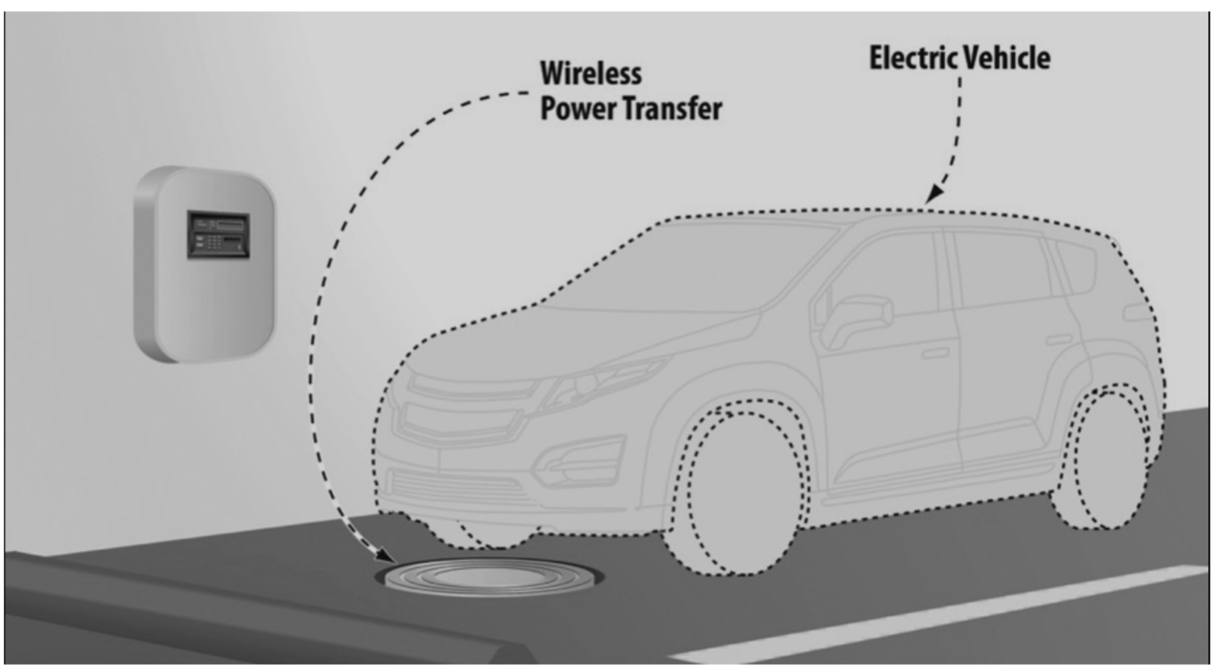


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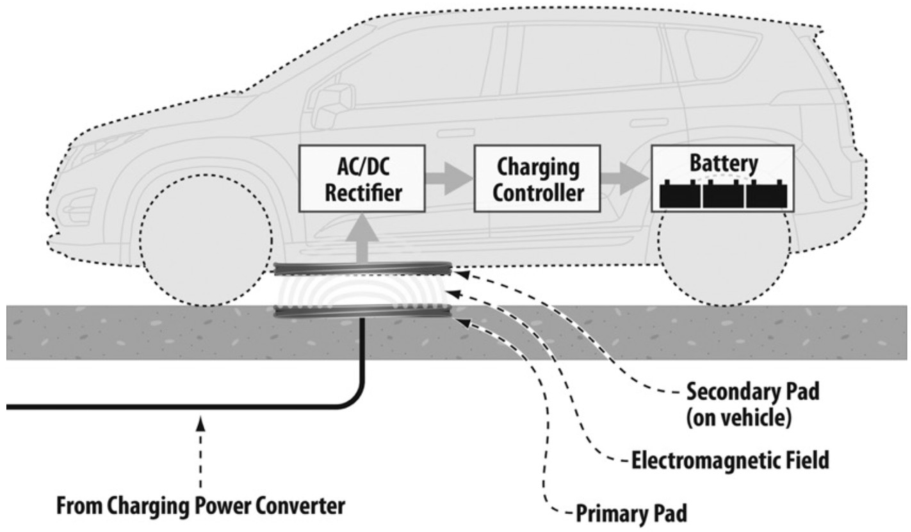


67

# Definitions: Section 625.2

- Wireless Power Transfer Equipment (WPTE)

- Equipment consisting of a charger power converter and a primary pad. The two devices are either separate units or contained within the enclosure

68

# 625.4 Voltages

- Unless other voltages are specified, the nominal AC system voltages used to supply equipment in Article 625 are…
- 120
- 120/240
- 208Y/120
- 240
- 480Y/277
- 480
- 600Y/347
- 600 and
- 1000 volts
- and DC system voltages of up to 1000

69

# 625.5 Listed

- All equipment covered by the scope of this article shall be listed

70

# 625.17 Cords and Cables

- Shall be Listed Type EV, EVJ, EVE, EVJE, EVT, or EVJT flexible cable or
- An integral part of listed electric vehicle supply equipment
- Overall cord length shall not exceed 25 feet in length unless it is equipped with a cable management system that is part of a listed electric vehicle supply equipment
- Note: damage to cables are one of the biggest maintenance issues with EV power supply equipment. A cable management system may help keep cables neat, orderly and off of the ground

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**SPEC 70859**

## Southwire Electric Vehicle EVE/EVJE and EV/EVJ Cables

90° or 105°C Dry/60°C Wet. 300, 600/1000 Volts. Class K, Bare Copper Conductors. TPE or EPDM Insulation and TPE or CPE oil, sunlight and flame resistant jacket.


Image not to scale & for reference only. See Table 1 for Dimensions

**CONSTRUCTION:**

| | |
|---|---|
| **Conductors:** | Class K, Flexible stranded bare copper per ASTM B3 and ASTM B174 |
| **Insulation:** | Thermoplastic Elastomer (TPE) with Optional Nylon Covering or Ethylene Propylene Diene Monomer (EPDM) |
| **Filler:** | Paper or Polypropylene filler |
| **Separator:** | Paper or Talc |
| **Jacket:** | Black; Thermoplastic Elastomer (TPE) or Thermoset Chlorinated Polyethylene (CPE) |

**APPLICATIONS:**

EV Charging Cables, designed for residential or commercial charging applications. Flexible construction, cabled with fillers, with wet rated, oil resistant, crush and impact resistant, low temperature materials. These cables meet Underwriters Laboratories and the Canadian Standard Association requirements as well as the National Electrical Code articles 400 (Flexible Cords & Flexible Cables) and 625 (Electric Vehicle Power Transfer System).

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**SPECIFICATIONS:**

- ASTM B3 and ASTM B174
- UL 62 - Type EVE/EVJE or EV/EVJ
- CSA C22.2 No. 49 - Type EVT(TPE)/EVJE(TPE) or EV/EVJ
- NFPA 70, NEC Articles: 400, 625
- RoHS-3 – The CE Marking has been applied solely to express the conformance to the material restrictions identified in the European Directive (EU) 2015/863

**SAMPLE PRINT LEGEND:** (Marker Tape)

SOUTHWIRE® 3/C XX AWG (X.XXmm2) & 1/C XX AWG (X.XXmm2) EVE E312819 c(UL)us 1000V 105C DRY 60C WET -- EVT(TPE) 1000V 105C DRY 60C WET FT2 WATER RESISTANT -- FOR USE WITH ELECTRIC VEHICLES

**PROPERTIES:**

Voltage: 300V EVJE, EVJ; 600V or 1000V EVE or EV.
Temperature Range: -40°C to 105°C Dry, 60°C Wet

## Other EV Offerings:

**Custom EV Cable Design/Engineered Solutions**

- DC Fast Charging Cable
- DC Fast Liquid-Cooled Charging Cable
- Coiled EV Cable
- Portable Charger, Charging Cable
- Custom Designs & 3 Phase Cables are Available
- Shielded Options
- Sizes up to 500 kcmil for listed products

**EV Infrastructure**

- Utility, Transmission & Distribution Cables
- Cable in Conduit (CIC)
- Armorlite Type MC Cable
- SimPull THHN/XHHW
- SimPull Medium Voltage Cable
- Low Smoke/Zero-Halogen Cable for confined space installations
- DLO Cable

73

# 625.22 Personnel Protection System

- The equipment shall have a listed system of protection against electric shock of personnel.
- A personnel protection system shall not be required for supplies less than 60 volts dc.

74

## 625.40 EV Branch Circuit

- Each outlet installed for the purpose of charging electric vehicles shall be supplied by an individual branch circuit. Each circuit shall have no other outlets.


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## 625.41 Overcurrent Protection

- Overcurrent protection for EVSE and WPTE equipment shall be sized for continuous duty (125%)
- Shall have a rating of not less than 125% of the maximum load of the equipment.
- Use nameplate data to determine maximum rating
- Where noncontinuous loads are supplied from the same feeder, the overcurrent device shall have a rating of not less than the sum of the noncontinuous loads plus 125 percent of the continuous loads.

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# 625.43 Disconnecting Means

- Disconnecting means required for equipment rated more than 60 amps or more than 150V to ground
- Shall be lockable in the open position

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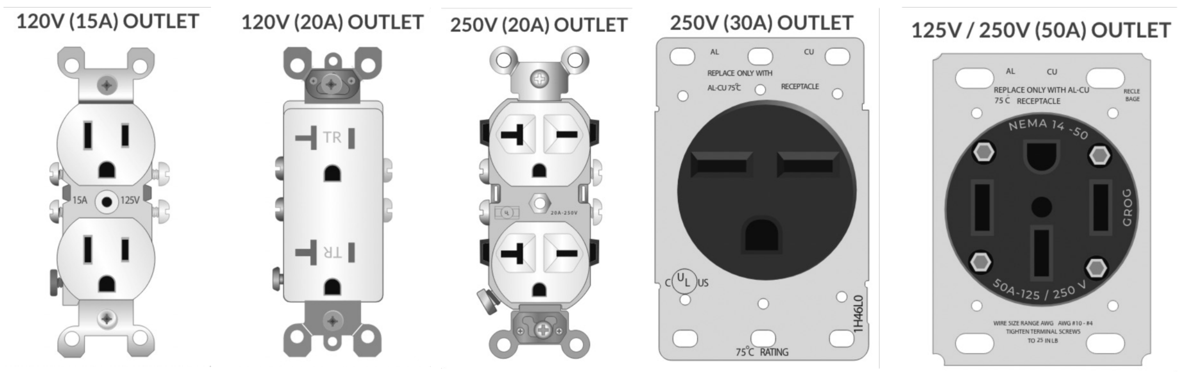
78

# 625.43(A) Portable Equipment

- Portable equipment shall be connected to the premises wiring by one or more of the following methods:

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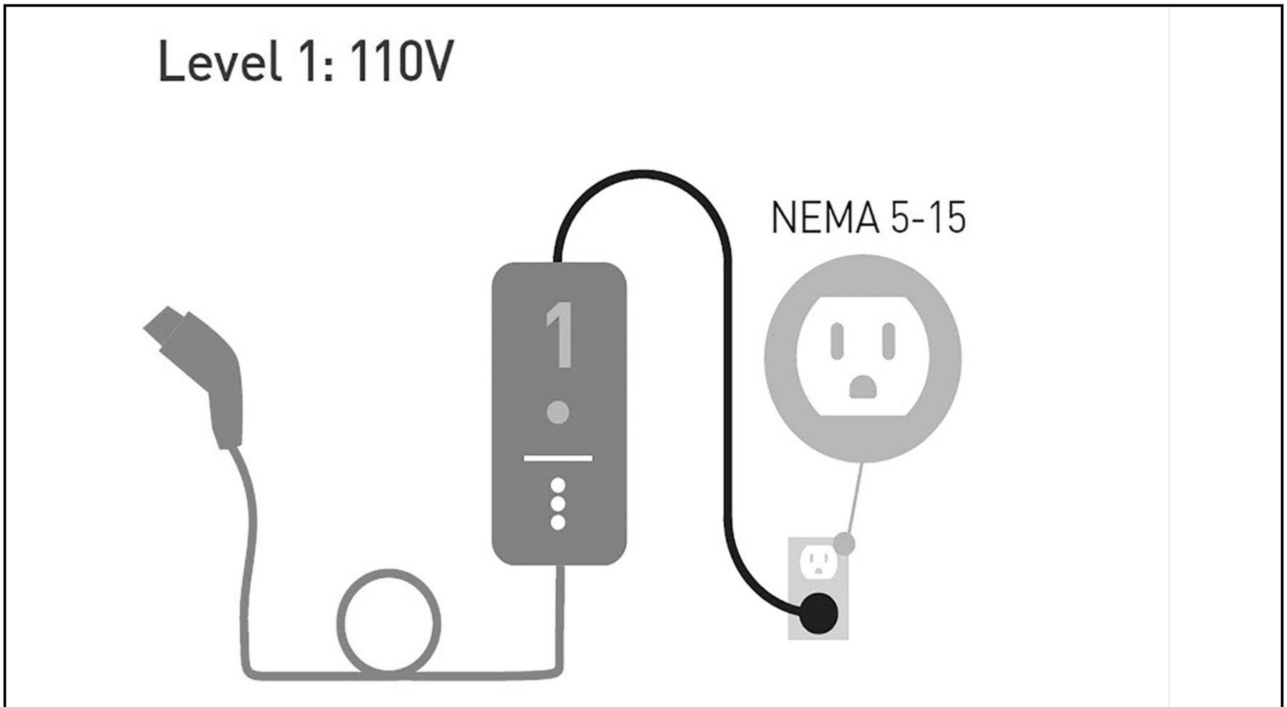


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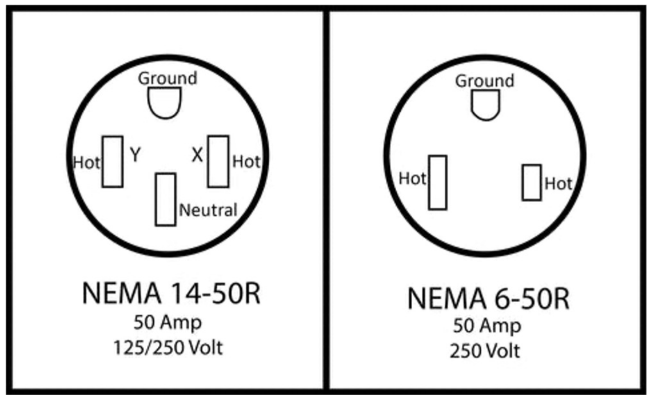
# 625.43(B) Fastened In-Place Equipment

- Equipment fastened in place shall be connected to the premises wiring by one or more of the following methods: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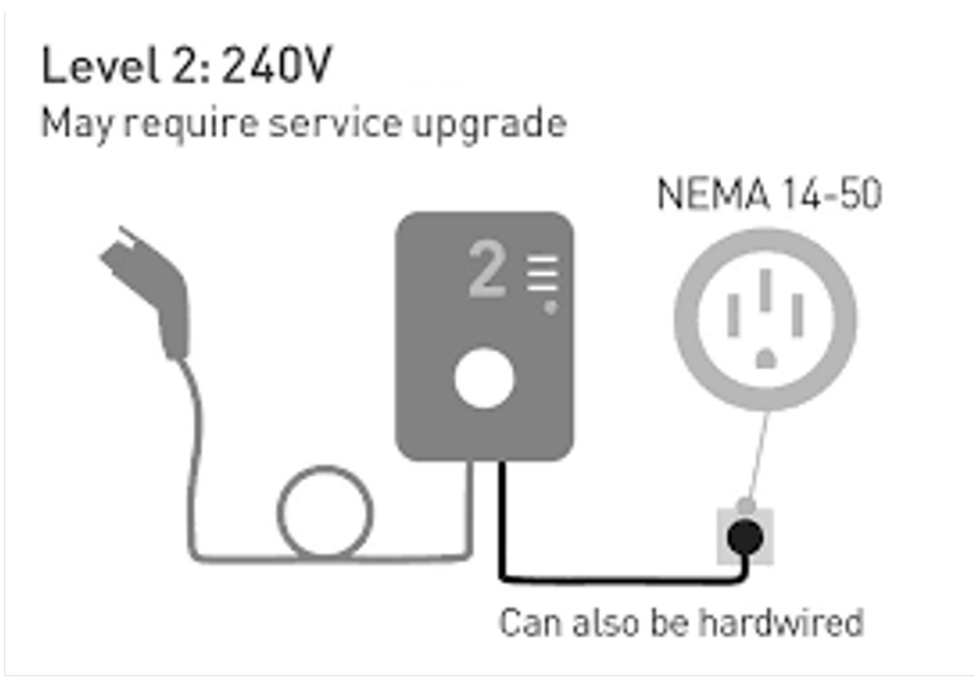


82

## 625.43(C) Fixed Equipment

- All other EVSE and WPTE shall be permanently wired and fixed in place to the supporting surface

83

## 625.46 Loss of Primary Source

- Means shall be provided to prevent the backfeed of power to the EV, EVSE or premises wiring system if power is lost.
- Exception is if a listed interactive system is installed

CAUTION!

DO NOT BACKFEED!

84

## 625.48 Interactive Systems

EVSE that incorporates a power export function and that is part of an interactive system that serves as an optional standby system, an electric power production source, or a bidirectional power feed shall be listed and marked as suitable for that purpose.

When used as an optional standby system, the requirements of Article 702 shall apply (Example: generartors)

When used as an electric power production source, the requirements of Article 705 shall apply (Example: Solar PV, Wind Turbine etc.)

EVPE that consists of a receptacle outlet only shall be in accordance with 625.60 (AC Receptacle Outlets Used for EVPE)

85

## 625.48 Interactive Systems

Informational Note:

- For further information on supply equipment, see ANSI/UL 1741, *Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources*, and ANSI/UL 9741, *Bidirectional Electric Vehicle (EV) Charging System Equipment*; for vehicle interactive systems, see SAE J3072, *Standard for Interconnection Requirements for Onboard, Utility-Interactive Inverter Systems*.

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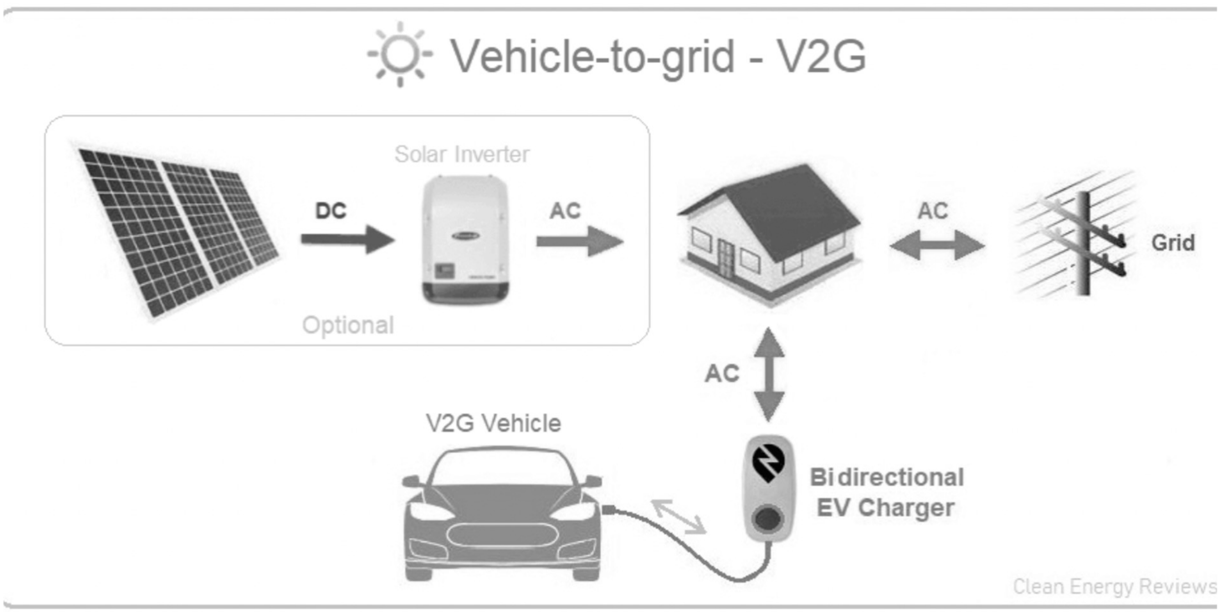


87

# 625.50 Location

- Minimum mounting height for fixed or fastened-in-place EVSE coupling connectors (cabling and connectors)
- Not less than 18 inches above the floor for indoor locations
- Not less than 24 inches above the grade for outdoor locations

- https://www.youtube.com/watch?v=vda14KgqaKg

88

# 625.25 Ventilation


- Some batteries can emit flammable vapors
- Most batteries used for electric vehicles do not emit vapors, but
- It is imperative to understand the types of batteries used and whether or not they require mechanical ventilation!

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# 625.25 Ventilation

- There are ventilation requirements for charging an electric vehicle in an enclosed location
- Mechanical ventilation is not required when
  - Electric vehicle storage batteries are used, or
  - Where the equipment used for charging electric vehicles is listed for use without ventilation

90

# 625.25 Ventilation

- Mechanical ventilation is required when…
- Where the equipment used for charging electric vehicles is listed for use with ventilation
- Requirements:
  - Include both supply and exhaust equipment
  - be permanently installed
  - Located to intake outside air
  - Location to exhaust to outside air
- See Tables 625.25(B)(2)(a) and 625.25(B)(2)(b) for required ventilation in cubic feet per meter (CFM)

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**Table 625.52(B)(1)(a) Minimum Ventilation Required in Cubic Meters per Minute ($m^3$/min) for Each of the Total Number of Electric Vehicles That Can Be Charged at One Time**

| | Branch-Circuit Voltage | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Single Phase | | | 3 Phase | | |
| Branch-Circuit Ampere Rating | DC ≥ 50 V | 120 V | 208 V | 240 V or 120/240 V | 208 V or 208Y/120 V | 240 V | 480 V or 480Y/277 V |
| 15 | 0.5 | 1.1 | 1.8 | 2.1 | — | — | — |
| 20 | 0.6 | 1.4 | 2.4 | 2.8 | 4.2 | 4.8 | 9.7 |
| 30 | 0.9 | 2.1 | 3.6 | 4.2 | 6.3 | 7.2 | 15 |
| 40 | 1.2 | 2.8 | 4.8 | 5.6 | 8.4 | 9.7 | 19 |
| 50 | 1.5 | 3.5 | 6.1 | 7.0 | 10 | 12 | 24 |
| 60 | 1.8 | 4.2 | 7.3 | 8.4 | 13 | 15 | 29 |
| 100 | 2.9 | 7.0 | 12 | 14 | 21 | 24 | 48 |
| 150 | — | — | — | — | 31 | 36 | 73 |
| 200 | — | — | — | — | 42 | 48 | 97 |
| 250 | — | — | — | — | 52 | 60 | 120 |
| 300 | — | — | — | — | 63 | 73 | 145 |
| 350 | — | — | — | — | 73 | 85 | 170 |
| 400 | — | — | — | — | 84 | 97 | 195 |

92

## 625.54 Ground-Fault Circuit-Interrupter Protection for Personnel

- Portable and fastened-in-place EVSE that is permitted to be cord-and plug-connected must be supplied through a GFCI-protected receptacle.
- The outlet supplying direct-connected EVSE is not required to be GFCI protected unless specified in the manufacturer's instructions.

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## 625.56 Receptacle Enclosures

- Receptacles for EV charging in a wet location shall be installed in a weatherproof enclosure
- Outlet box hood for the WP enclosure shall be listed and identified for Extra Duty
- If the the enclosure or assembly does not include a hood, it is not required to be marked as Extra Duty

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95

# 625.60 AC Receptacle Outlets Used for EVPE

- EVPE refers to receptacles <u>inside</u> of the electric vehicle used to supply power to external loads
- Requirements:
  - Shall be listed
  - Have maximum rating of 250 V, single phase, 50 amps
  - Shall have overcurrent protection suitable to handle available fault current
  - Have GFCI protection

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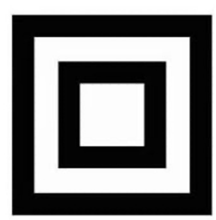
Part IV. Wireless Power Transfer Equipment

625.101 Grounding

- The primary pad base plate shall be made of a non-ferrous material (copper, aluminum e.g.)
- Shall be grounded unless it is listed as double insulated



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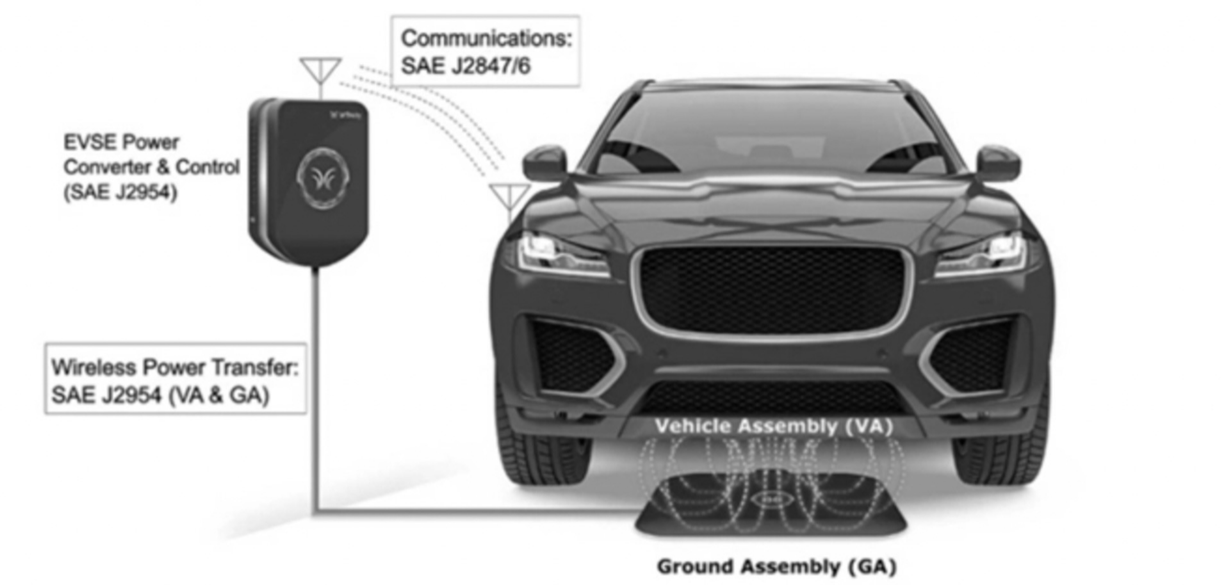


*Figure 6: Genesis car with wireless charging (Source: WiTricity)*

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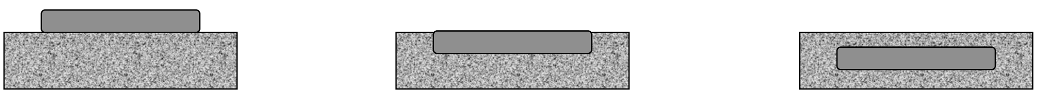
## 625.102 Installation

- The charger power converter, if not integral to the primary pad, shall be installed in a NEMA 3R enclosure
  - Mounted no less than 18 inches above the floor (indoor locations)
  - Mounted no less than 24 inches above grade (outdoor locations)
- The converter shall be mounted in one of the following ways:
  - Pedestal
  - Wall or pole
  - Building or structure
  - Raised concrete pad

100

## 625.102 Installation

- If the charger power converter is a part of the primary pad, it shall comply with the following:
- The primary pad shall be mounted by one of the following methods:
  - On the surface
  - Embedded in the surface of the floor with its top flush with the surface
  - Embedded in the surface of the floor with its top below the surface



101

## 625.102 Installation

- If the primary pad is located in an area requiring snow removal, it shall not be located on or above the surface.
- The enclosure shall be provided with a suitable enclosure rating, minimum Type 3.
- If the primary pad is located in an area subject to severe climatic conditions (e.g., flooding), it shall be suitably rated for those conditions or be provided with a suitably rated enclosure.

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# 625.102 Installation: Protection of Output Cable

- The output cable to the primary pad shall be secured in place over its entire length for the purpose of restricting its movement and to prevent strain at the connection points
- If installed in conditions where drive-over could occur, the cable shall be provided with supplemental protection
- Where the charger power converter is a part of the primary pad assembly, the power supply cord to the primary pad shall also be protected.

103

# 625.102 Installation: Other Wiring Systems

- Other wiring systems and fittings specifically listed for use on the WPTE shall be permitted.

UL LISTED

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## Maintenance

- Cord Management is single biggest issue with chargers
- Damage to cord
  - Insulation damage
  - Theft
  - Getting run over
  - Ice-clearing equipment

105

## Example Calculations: Single Phase

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# Sample Calculations: 3-Phase

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**File Attachments for Item:**

ER-2 Conduit and Box Fill Calculations Based on the 2020 NEC (Master Electrical Contractors Association)

All certifications (5 hours)

Staff Notes:

ESIAC Recommendation:

Committee Recommendation:

**Ohio** | **Department of Commerce**

Mike DeWine, Governor
Jon Husted, Lt. Governor

Sheryl Maxfield, Director

Board of Building Standards

# Application for Continuing Education Course Approval

**Provider Information:**

Name: Laura Bachman

Organization: Master Electrical Contractors Association

Address: 1555 Stanley Avenue Dayton Ohio 45404

E-mail: Laurameca@aol.com Telephone: 937-264-0418

Website: ____________

Conference Sponsor (if applicable)____________Conference Email:____________

**Check here if Course Renewal:**________Prior course number ____________ (*i.e. BBS2018-429*)

*Renewals will only be granted for identical content and certifications, within the current code cycle.*
*Attach a copy of prior course approval letter for confirmation. No further information is required.*

**New Course Information:**

Course title: Conduit and Box fill calculations Based on the 2020 NEC

Course instructor: D.Dewayne Jenkins and Robert Barnett

Course description: The purpose is to provide detailed instruction on conduit and box fill calculations

Instructional hours per session: five (5) Number of Sessions:____________

Course Date(s) and Location: March 18, 2023 Presidential Banquet Center 4548 Presidential way Dayton Ohio 45429

**Special Content:**

Code Administration: ☐

Existing Buildings: ☐

Electrical Instruction: ☑

Plumbing Instruction: ☐

Conference Course: ____________

Conference Name: ____________

Conference location: ____________

Course to be offered online? ☐ **On Demand** ☐ **Webinar** ☐

Course Website: ____________

Detail online course participation confirmation method (*i.e. test, quizlets, participant activity confirmation*):

____________

**Course applicable for the following certifications**

Residential Certifications Only: ☑ Commercial Certifications: ☑

Administrative Course, All Certifications: ☑

**Application materials included:**

☑ Course Outline or Course Learning Objectives
☑ Presentation Materials/Slides (not required for roundtable courses)
☐ Assessment Materials (for online courses)
☑ Presenter Bio

**Please submit application and materials in .pdf format to:** michael.lane@com.ohio.gov or BBS@com.ohio.gov

**Daniel Dewayne Jenkins**

Dewayne started his career in the electrical field in August of 1982 in Dayton, Ohio and has over 40 years' experience in the electrical industry both as a contractor and inspector. He served 4 years in an electrical apprenticeship program and has over 8 years in the field as a journeyman electrician and he has 4 years, to his credit, as an electrical estimator and project manager.

Dewayne has been a licensed electrical contractor and a certified electrical safety inspector since 1996. He also holds Ohio certifications as building inspector (1998), electrical plans examiner (2006) and residential building official (2007) and chief building official (2008). He is currently employed by the City of Kettering in the position as the Senior Building Inspector and conducts electrical plans examinations, electrical safety inspections and building inspections for the past 23 years.

Dewayne is an adjunct lecturer II for Sinclair Community College in the electrical trades for the past 20 years. A technical presenter for the Ohio Board of Building Standards (OBBS), International Association of Electrical Inspectors (IAEI), Master Electrical Contractors Association (MECA), Adequate Wiring Committee (AWC) & Greater Cincinnati Electrical Association (GCEA). He has served as President for the Ohio Chapter IAEI (2010). Dewayne has also serves as President of the Southwest Division of IAEI, Ohio Chapter (2018-2022) and President of the Miami Valley Building Officials Council (2002 & 2003). He also serves on the Electrical Safety Inspector Advisory Committee for the Ohio Board of Building Standards.

Address: 3600 Shroyer Road, Kettering, OH 45429

# Robert L. Barnett

10696 Wengerlawn Road
Brookville, OH 45309

937.510.0424
rbarnett@tricountyelectricalservices.com

## Small Business Owner

**Strategic Planning • Project Management • Construction • Team Leadership • Customer Service • Value Engineering • Project Coordination • Highly Detailed • Organizational Effectiveness • Design-Build • Quality Control • Materials Management • Educational Leadership**

A multi-skilled professional with a solid career history in the electrical industry. Able to manage complex projects in various environments. Able to lead projects in under budget by managing and supervising an effective team in the installation of a quality product. Making a professional appearance to customers and other employees.

## Technical Proficiencies

| | | | |
|---|---|---|---|
| Microsoft Office | Excel | AutoCAD | Networks |
| Internet & Research | Word | Accounting Software | Citrix |
| Database Management | PowerPoint | ExamView | PDF Software |

## Professional Experience

**Tri-County Electric, Brookville OH (License# EL48489)** **2018-Present**

**Owner (Since 2018)**

- Creating and implementing business plans and strategies based on long term visions. Implement high-level planning to measure progress, gather insight and readjust plans and goals as necessary.
- Establish and maintain business banking accounts, payment processing systems, taxes, insurance and manage day-to-day costs and business expenses.
- Procuring business and contractor licensing for compliance with state and local licensing requirements.
- Establish solid marketing strategies and maintaining working relationships with clients to ensure outstanding customer service.
- Manage day-to-day business operations by overseeing employees and projects. Addressing various issues with staffing, project and technical issues.

**Reliable Electric, Dayton OH** **2006-2017**

**Project Manager (3 years)**

- Establish and manage cost, schedules, manpower and performance of large, highly complex projects. Fully accountable for complex/diverse projects with a high degree of business risk.
- Collaborate with general contractors, design professionals, sales representatives and business owners to accomplish project objectives. Identify and resolve project issues and manage project risk.
- ***Project Examples:***
    - Managed a $1.5M energy conservation project at Wright State University. Successfully supervised a team of 10 electricians in a complex energy retrofit on an active college university. Completed the project on time and under budget.
    - Completed a $4M urban development project in Downtown Cincinnati with a two-year scope.

**Project Foreman (3 years)**

- Perform business management duties such as maintaining records and files, preparing reports and ordering supplies and materials.
- Layout and installation of lighting, power, equipment and special systems wiring, based on construction documents and local codes.
- Assign work to other employees, prioritize the work of others and organize and coordinate the work of the project.
- Direct and train workers to install, maintain, or repair electrical wiring, equipment and fixtures.

**Commercial Service Technician (2 years)**

- Created and maintained business relationships with commercial and industrial clients.
- Troubleshoot malfunctions in circuitry, equipment, motor control circuits and special systems wiring using test equipment to correctly diagnose and repair problems.
- Use a variety of tools and equipment such as power construction equipment, measuring devices, power tools and testing equipment.

**Field Electrician (3 years)**

- Assist project foreman and journeyman on large commercial construction sites.
- Install, maintain and repair of electrical wiring, equipment and fixtures.
- Perform physical demanding tasks such as digging trenches to lay conduit and moving/lifting heavy objects.
- Fire alarm system installation and troubleshooting.

**Sinclair Community College, Dayton OH** **2013-2020**

**Adjunct Instructor (7 years)**

- First year instructor for the Independent Electrical Contractors (IEC) Apprenticeship Training Program, sponsored by the Master Electrical Contractors Association Training School (MECATS) Dayton Ohio
- Responsible for creating a positive learning environment for 10-12 entry level apprentice electricians.
- Develop lesson plans, quizzes and exams for student development and evaluation. Provide support and direction for students in and out of the classroom.
- Previously an active member of the MECATS A&T Committee.

## Education

- **Electrical Engineering Technology/IEC Apprenticeship Program,** Sinclair Community College, Dayton OH, 2010 (GPA: 4.0)
  Ohio licensed Journeyman
  Ohio Fire Alarm licensed
- **Architectural /Engineering Technology,** Miami Valley Career Technology Center, Clayton OH, 2006 (GPA: 3.5)
- **Milton-Union High School,** West Milton OH, 2006 (GPA: 3.0)

# WELCOME!

# FROM THE MASTER ELECTRICAL CONTRACTORS ASSOCIATION

# CONDUIT AND BOX FILL CALCULATIONS

Presented by: Dewayne Jenkins

Based on 2020 NEC

# 300.14 LENGTH OF FREE CONDUCTORS AT OUTLETS, JUNCTIONS, AND SWITCH POINTS

- At least 150 mm (6 in.) of free conductor, measured from the point in the box where it emerges from its raceway or cable sheath, shall be left at each outlet, junction, and switch point for splices or the connection of luminaires or devices.
- Where the opening to an outlet, junction, or switch point is less than 200 mm (8 in.) in any dimension, each conductor shall be long enough to extend at least 75 mm (3 in.) outside the opening.

# 300.14 - EXCEPTION

- *Exception: Conductors that are not spliced or terminated at the outlet, junction, or switch point shall not be required to comply with 300.14.*

# 300.14 - COMMENT

- For a conductor that loops through an outlet box and that is intended for connection to a receptacle, switch, lampholder, or other such device, 300.14 specifies the length of slack (free conductor) required for the box size, The intent is to ensure enough slack for the terminal connections to be made easily.
- The exception excludes conductors running through a box, which should have sufficient slack to prevent physical damage from the insertion of devices or from the use of luminaire studs, hickeys, or other luminaire supports within the box.

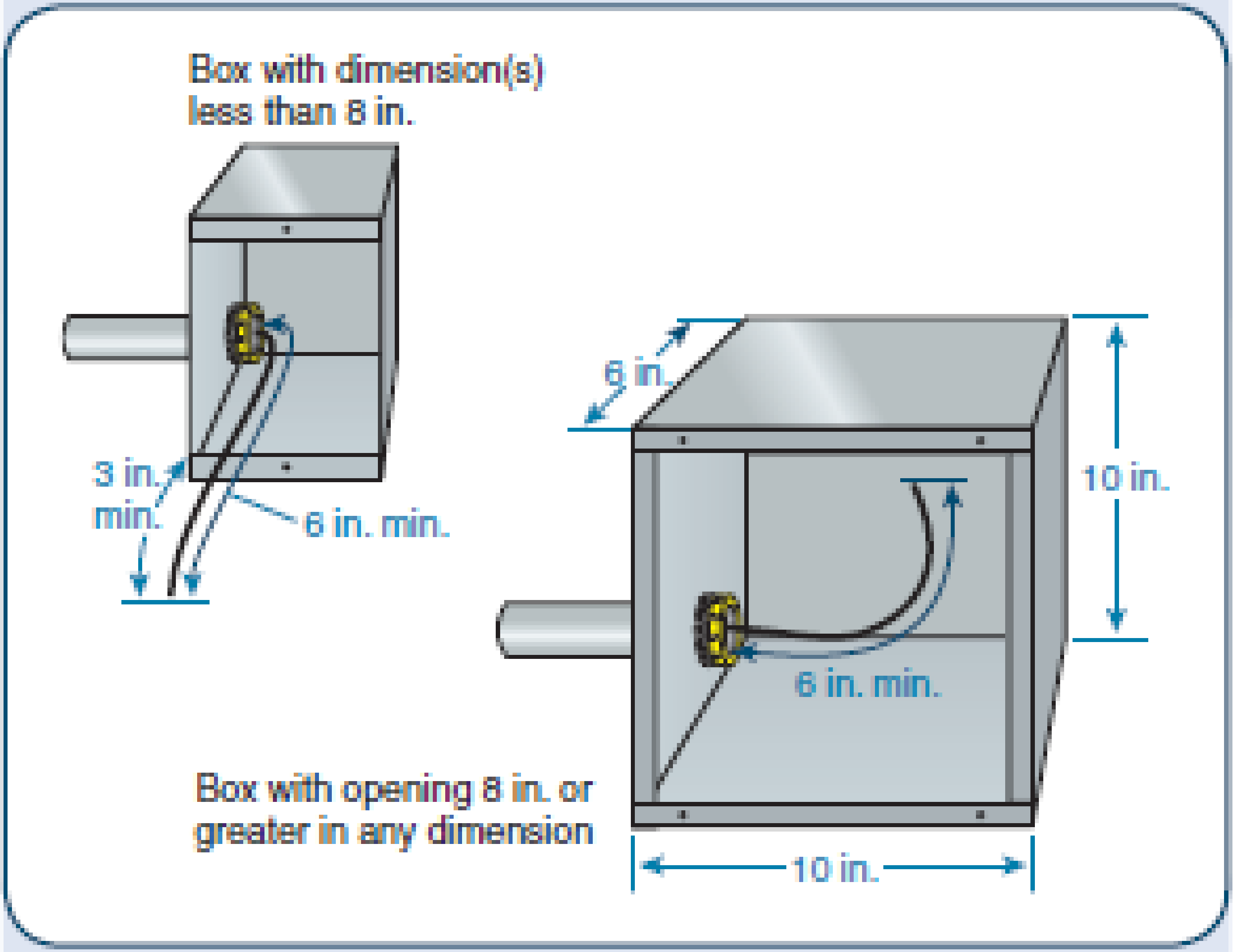



***EXHIBIT 300.13*** *Two different boxes with free conductor lengths according to 300.14.*

# 300.15 BOXES, CONDUIT BODIES, OR FITTINGS WHERE REQUIRED

- A box shall be installed at each outlet and switch point for concealed knob-and-tube wiring.
- Fittings and connectors shall be used only with the specific wiring methods for which they are designed and listed.
- Where the wiring method is conduit, tubing, Type AC cable, Type MC cable, Type MI cable, nonmetallic-sheathed cable, or other cables, a box or conduit body shall be installed at each conductor splice point, outlet point, switch point, junction point, termination point, or pull point, unless otherwise permitted in 300.15(A) through (L).

# 310.15 (A) WIRING METHODS WITH INTERIOR ACCESS.

- A box or conduit body shall not be required for each splice, junction, switch, pull, termination, or outlet points in wiring methods with removable covers, such as wireways, multioutlet assemblies, auxiliary gutters, and surface raceways.
- The covers shall be accessible after installation.

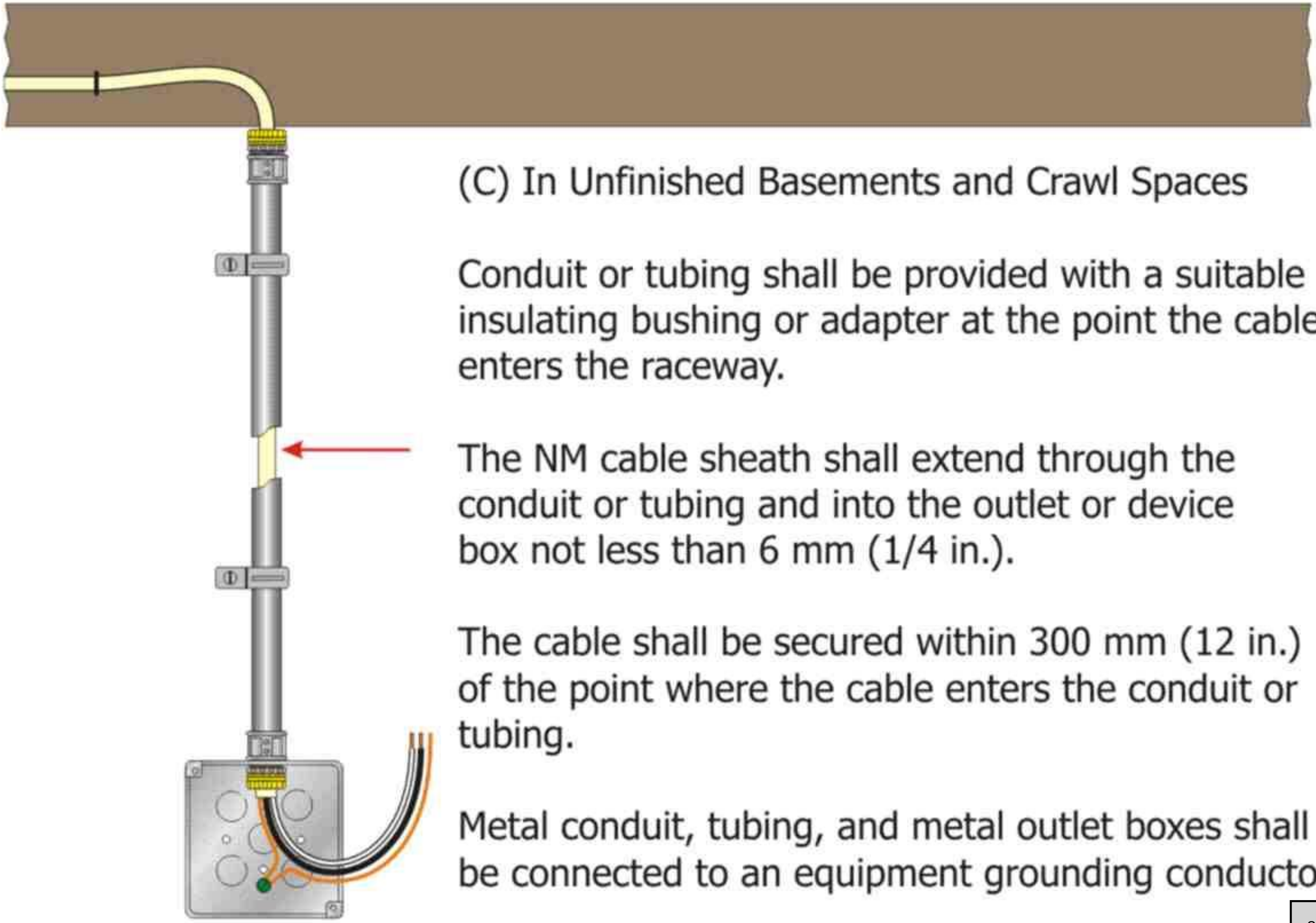
# 300.15 (B) - EQUIPMENT.

- An integral junction box or wiring compartment as part of approved equipment shall be permitted in lieu of a box.

# 300.15(C) - PROTECTION.

- A box or conduit body shall not be required where cables enter or exit from conduit or tubing that is used to provide cable support or protection against physical damage.
- A fitting shall be provided on the end(s) of the conduit or tubing to protect the cable from abrasion.

# 334.15 Exposed Work



(C) In Unfinished Basements and Crawl Spaces

Conduit or tubing shall be provided with a suitable insulating bushing or adapter at the point the cable enters the raceway.

The NM cable sheath shall extend through the conduit or tubing and into the outlet or device box not less than 6 mm (1/4 in.).

The cable shall be secured within 300 mm (12 in.) of the point where the cable enters the conduit or tubing.

Metal conduit, tubing, and metal outlet boxes shall be connected to an equipment grounding conductor.

# 314.1 SCOPE

- This article covers the installation and use of all boxes and conduit bodies used as outlet, device, junction, or pull boxes, depending on their use, and handhole enclosures.
- Cast, sheet metal, nonmetallic, and other boxes such as FS, FD, and larger boxes are not classified as conduit bodies.
- This article also includes installation requirements for fittings used to join raceways and to connect raceways and cables to boxes and conduit bodies.

# 314.16 NUMBER OF CONDUCTORS IN OUTLET, DEVICE, AND JUNCTION BOXES, AND CONDUIT BODIES

- Boxes and conduit bodies shall be of sufficient size to provide free space for all enclosed conductors. In no case shall the volume of the box, as calculated in 314.16(A), be less than the fill calculation as calculated in 314.16(B).
- The minimum volume for conduit bodies shall be as calculated in 314.16(C).
- The provisions of this section shall not apply to terminal housings supplied with motors or generators. See 430.12
- Boxes and conduit bodies enclosing conductors 4 AWG or larger shall also comply with the provisions of 314.28.

# 314.16 (A) - BOX VOLUME CALCULATIONS.

- The volume of a wiring enclosure (box) shall be the total volume of the assembled sections and, where used, the space provided by plaster rings, domed covers, extension rings, and so forth, that are marked with their volume or are made from boxes the dimensions of which are listed in Table 314.16(A).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# 314.16 (A) (1) STANDARD BOXES.

- The volumes of standard boxes that are not marked with their volume shall be as given in Table 314.16(A).

## TABLE 314.16(A) Metal Boxes

| Box Trade Size | | | Minimum Volume | | Maximum Number of Conductors* (arranged by AWG size) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | in. | | $cm^3$ | $in.^3$ | 18 | 16 | 14 | 12 | 10 | 8 | 6 |
| 100 × 32 | (4 × 1¼) | round/octagonal | 205 | 12.5 | 8 | 7 | 6 | 5 | 5 | 5 | 2 |
| 100 × 38 | (4 × 1½) | round/octagonal | 254 | 15.5 | 10 | 8 | 7 | 6 | 6 | 5 | 3 |
| 100 × 54 | (4 × 2⅛) | round/octagonal | 353 | 21.5 | 14 | 12 | 10 | 9 | 8 | 7 | 4 |
| 100 × 32 | (4 × 1¼) | square | 295 | 18.0 | 12 | 10 | 9 | 8 | 7 | 6 | 3 |
| 100 × 38 | (4 × 1½) | square | 344 | 21.0 | 14 | 12 | 10 | 9 | 8 | 7 | 4 |
| 100 × 54 | (4 × 2⅛) | square | 497 | 30.3 | 20 | 17 | 15 | 13 | 12 | 10 | 6 |
| 120 × 32 | (4¹¹⁄₁₆ × 1¼) | square | 418 | 25.5 | 17 | 14 | 12 | 11 | 10 | 8 | 5 |
| 120 × 38 | (4¹¹⁄₁₆ × 1½) | square | 484 | 29.5 | 19 | 16 | 14 | 13 | 11 | 9 | 5 |
| 120 × 54 | (4¹¹⁄₁₆ × 2⅛) | square | 689 | 42.0 | 28 | 24 | 21 | 18 | 16 | 14 | 8 |
| 75 × 50 × 38 | (3 × 2 × 1½) | device | 123 | 7.5 | 5 | 4 | 3 | 3 | 3 | 2 | 1 |
| 75 × 50 × 50 | (3 × 2 × 2) | device | 164 | 10.0 | 6 | 5 | 5 | 4 | 4 | 3 | 2 |
| 753 50 × 57 | (3 × 2 × 2¼) | device | 172 | 10.5 | 7 | 6 | 5 | 4 | 4 | 3 | 2 |
| 75 × 50 × 65 | (3 × 2 × 2½) | device | 205 | 12.5 | 8 | 7 | 6 | 5 | 5 | 4 | 2 |
| 75 × 50 × 70 | (3 × 2 × 2¾) | device | 230 | 14.0 | 9 | 8 | 7 | 6 | 5 | 4 | 2 |
| 75 × 50 × 90 | (3 × 2 × 3½) | device | 295 | 18.0 | 12 | 10 | 9 | 8 | 7 | 6 | 3 |
| 100 × 54 × 38 | (4 × 2⅛ × 1½) | device | 169 | 10.3 | 6 | 5 | 5 | 4 | 4 | 3 | 2 |
| 100 × 54 × 48 | (4 × 2⅛ × 1⅞) | device | 213 | 13.0 | 8 | 7 | 6 | 5 | 5 | 4 | 2 |
| 100 × 54 × 54 | (4 × 2⅛ × 2⅛) | device | 238 | 14.5 | 9 | 8 | 7 | 6 | 5 | 4 | 2 |
| 95 × 50 × 65 | (3¾ × 2 × 2½) | masonry box/gang | 230 | 14.0 | 9 | 8 | 7 | 6 | 5 | 4 | 2 |
| 95 × 50 × 90 | (3¾ × 2 × 3½) | masonry box/gang | 344 | 21.0 | 14 | 12 | 10 | 9 | 8 | 7 | 4 |
| min. 44.5 depth | FS — single cover/gang (1¾) | | 221 | 13.5 | 9 | 7 | 6 | 6 | 5 | 4 | 2 |
| min. 60.3 depth | FD — single cover/gang (2⅜) | | 295 | 18.0 | 12 | 10 | 9 | 8 | 7 | 6 | 3 |
| min. 44.5 depth | FS — multiple cover/gang (1¾) | | 295 | 18.0 | 12 | 10 | 9 | 8 | 7 | 6 | 3 |
| min. 60.3 depth | FD — multiple cover/gang (2⅜) | | 395 | 24.0 | 16 | 13 | 12 | 10 | 9 | 8 | [illegible] |

*Where no volume allowances are required by 314.16(B)(2) through (B)(5).

**TABLE 314.16(B) Volume Allowance Required per Conductor**

| Size of Conductor (AWG) | Free Space Within Box for Each Conductor | |
|---|---|---|
| | $cm^3$ | $in.^3$ |
| 18 | 24.6 | 1.50 |
| 16 | 28.7 | 1.75 |
| 14 | 32.8 | 2.00 |
| 12 | 36.9 | 2.25 |
| 10 | 41.0 | 2.50 |
| 8 | 49.2 | 3.00 |
| 6 | 81.9 | 5.00 |

# 314.16 (A)(2) OTHER BOXES.

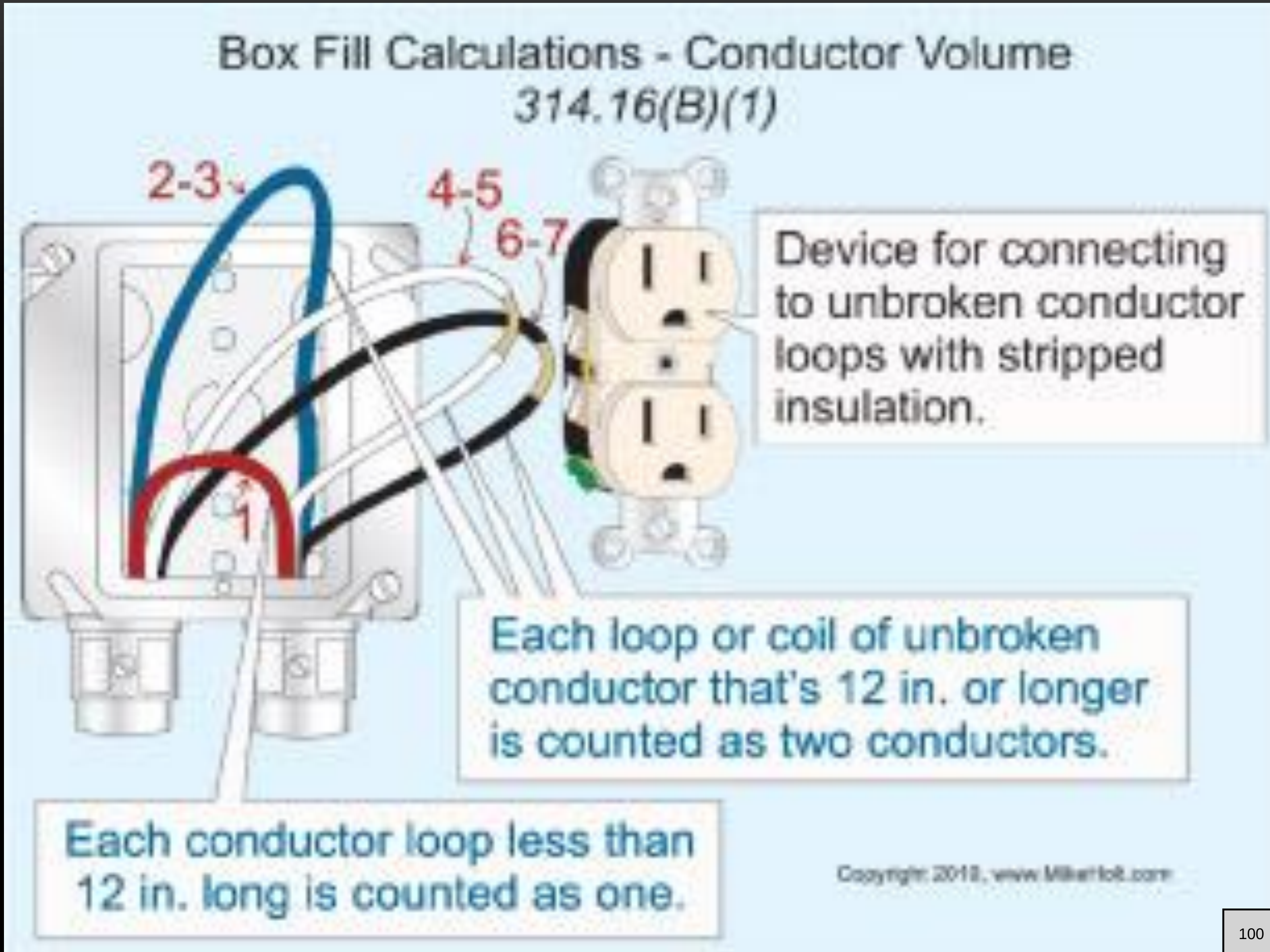
- Boxes 1650 cm3 (100 in.3) or less, other than those described in Table 314.16(A), and nonmetallic boxes shall be durably and legibly marked by the manufacturer with their volume.
- Boxes described in Table 314.16(A) that have a volume larger than is designated in the table shall be permitted to have their volume marked as required by this section.

# 314.16 (B) BOX FILL CALCULATIONS.

- The volumes in paragraphs 314.16(B)(1) through (B)(5), as applicable, shall be added together.
- No allowance shall be required for small fittings such as locknuts and bushings.

# 314.16 (B) (1) CONDUCTOR FILL.

- Each conductor that originates outside the box and terminates or is spliced within the box shall be counted once, and each conductor that passes through the box without splice or termination shall be counted once.
- Each loop or coil of unbroken conductor not less than twice the minimum length required for free conductors in 300.14 shall be counted twice.
- The conductor fill shall be calculated using Table 314.16(B). A conductor, no part of which leaves the box, shall not be counted.


Box Fill Calculations - Conductor Volume
314.16(B)(1)
2-3
4-5
6-7
1
Device for connecting to unbroken conductor loops with stripped insulation.
Each loop or coil of unbroken conductor that's 12 in. or longer is counted as two conductors.
Each conductor loop less than 12 in. long is counted as one.
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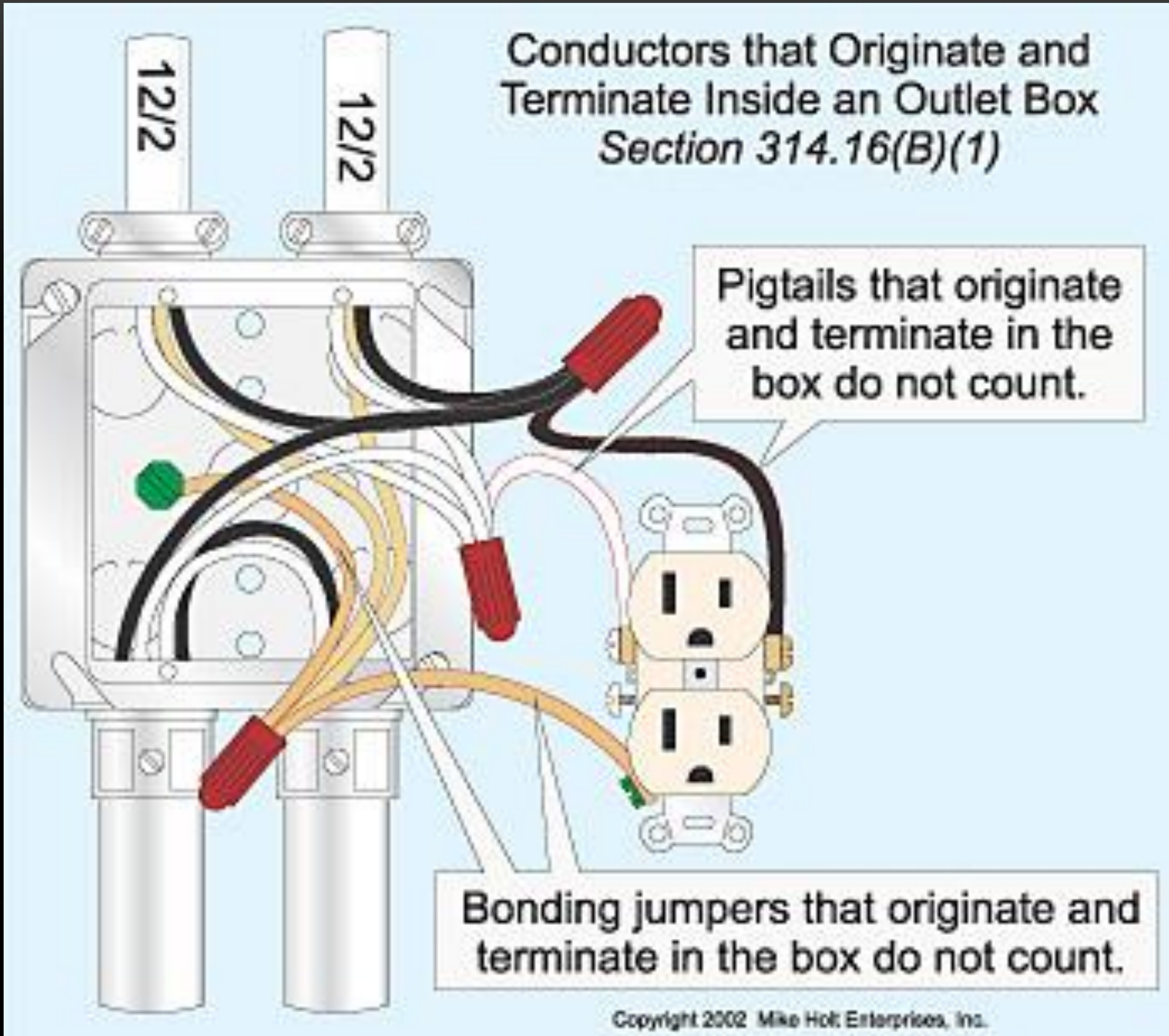
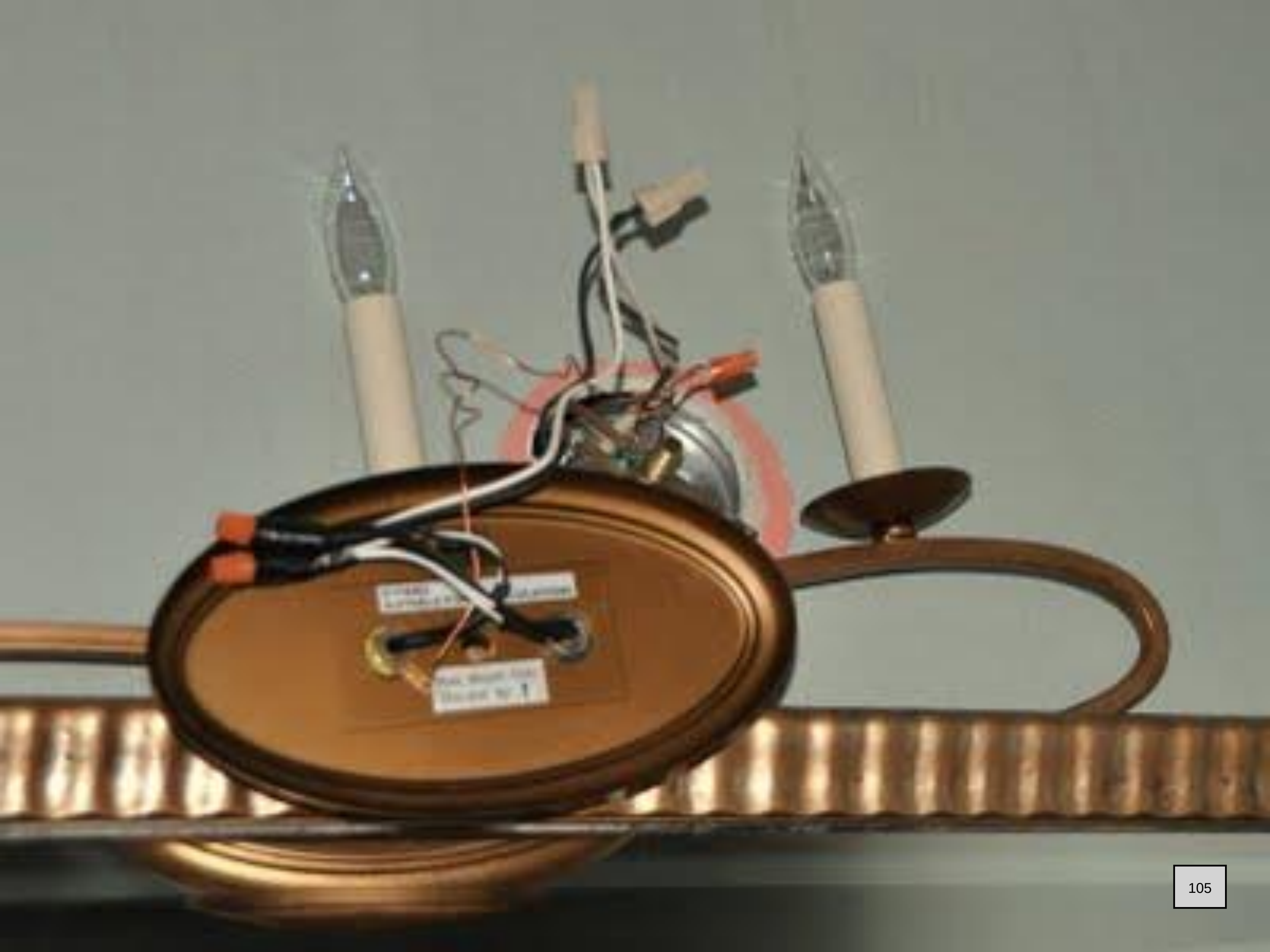

Conductors that Originate and
Terminate Inside an Outlet Box
*Section 314.16(B)(1)*
12/2
12/2
Pigtails that originate
and terminate in the
box do not count.
Bonding jumpers that originate and
terminate in the box do not count.
Copyright 2002 Mike Holt Enterprises, Inc.


OWER SUPPLY
DANGER
DANGER

# CONDUCTOR FILL EXCEPTION

- *Exception: An equipment grounding conductor or conductors or not over four fixture wires smaller than 14 AWG, or both, shall be permitted to be omitted from the calculations where they enter a box from a domed luminaire or similar canopy and terminate within that box.*



# 314.16 (B) (2) CLAMP FILL.

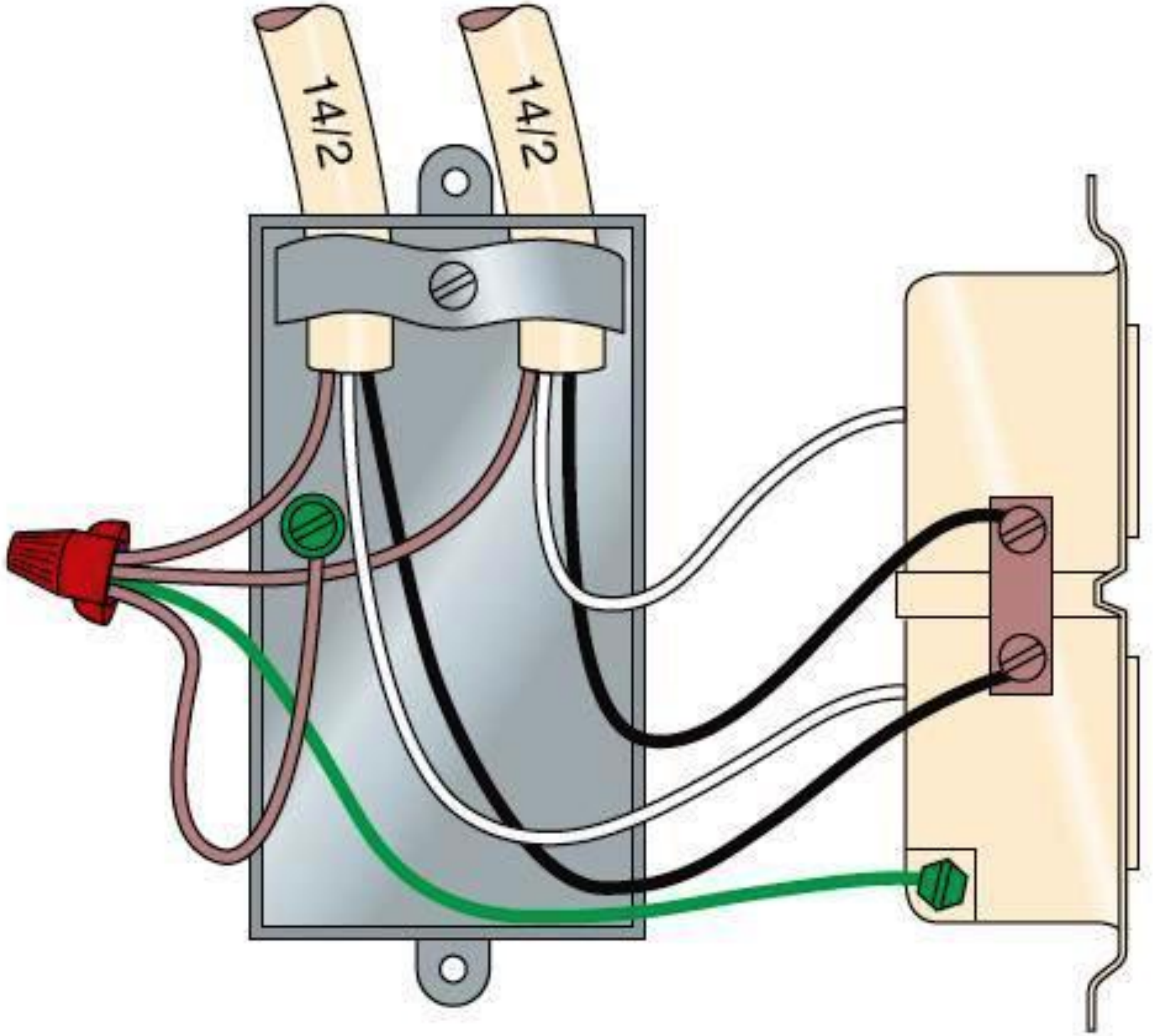
- Where one or more internal cable clamps, whether factory or field supplied, are present in the box, a single volume allowance in accordance with Table 314.16(B) shall be made based on the largest conductor present in the box.
- No allowance shall be required for a cable connector with its clamping mechanism outside the box.

# 314.16 (B) (3) SUPPORT FITTINGS FILL.

- Where one or more luminaire studs or hickeys are present in the box, a single volume allowance in accordance with Table 314.16(B) shall be made for each type of fitting based on the largest conductor present in the box.

# 314.16 (B) (4) DEVICE OR EQUIPMENT FILL.

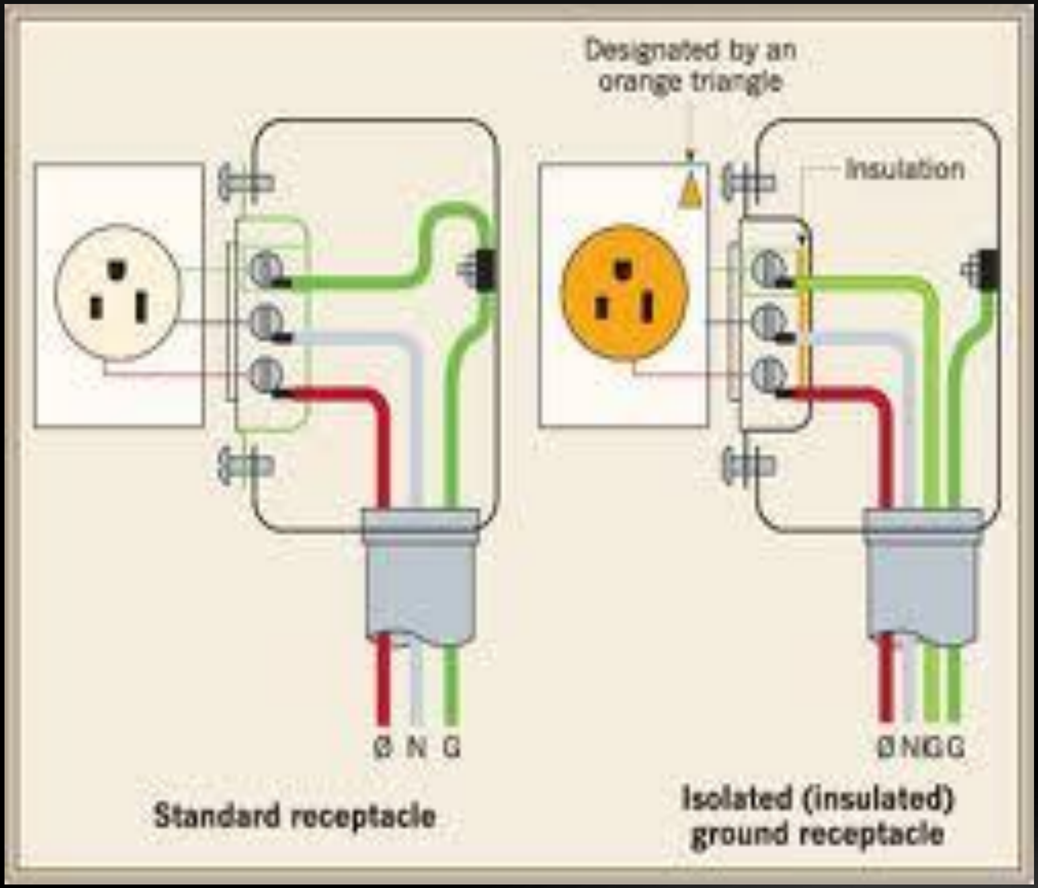
- For each yoke or strap containing one or more devices or equipment, a double volume allowance in accordance with Table 314.16(B) shall be made for each yoke or strap based on the largest conductor connected to a device(s) or equipment supported by that yoke or strap.
- A device or utilization equipment wider than a single 50 mm (2 in.) device box as described in Table 314.16(A) shall have double volume allowances provided for each gang required for mounting.




Standard 3 in. × 2 in. × 3½ in. device box (18 $in.^3$)

# 314.16 (B) (5) EQUIPMENT GROUNDING CONDUCTOR FILL

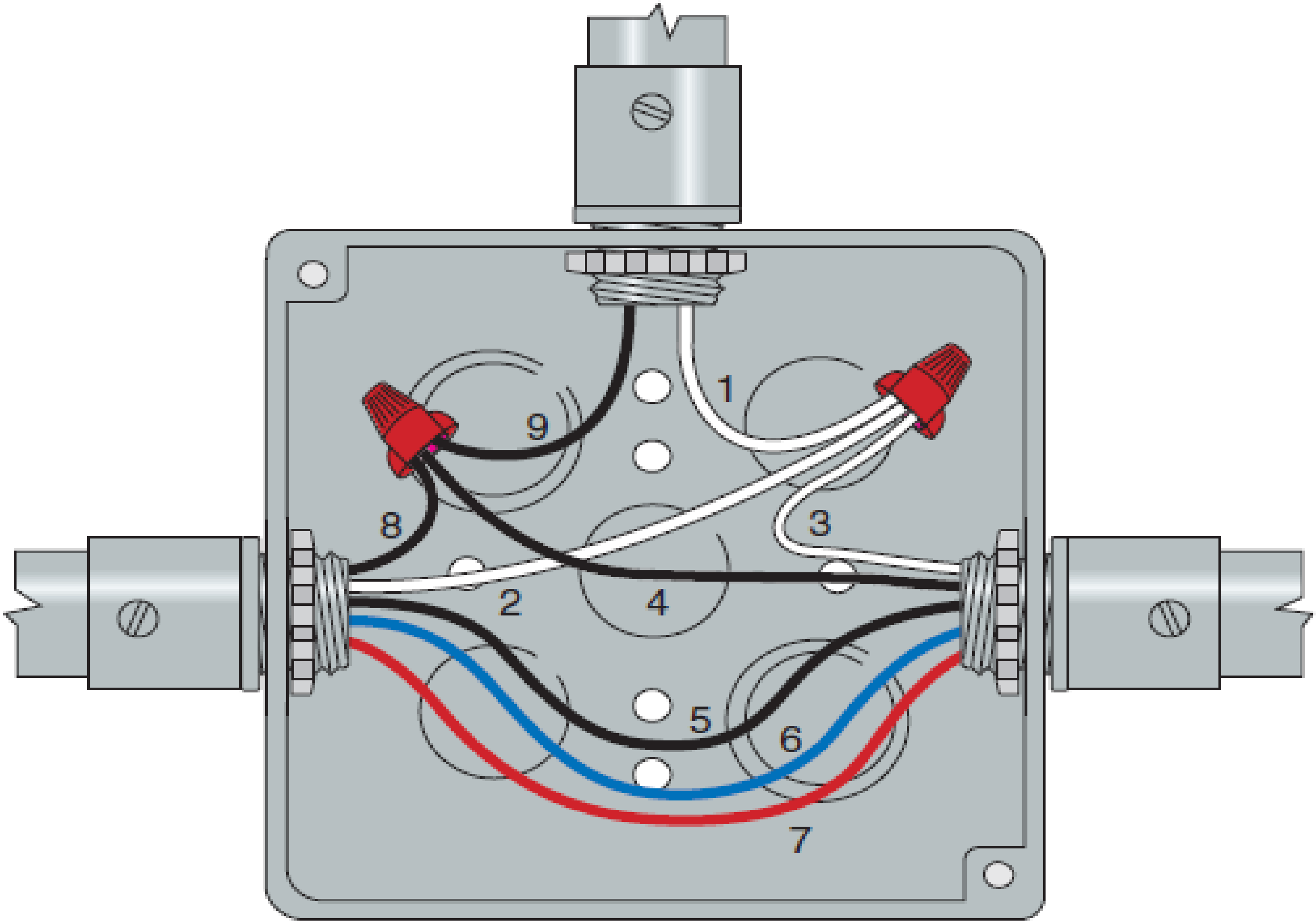
- Where one or more equipment grounding conductors or equipment bonding jumpers enter a box, a single volume allowance in accordance with Table 314.16(B) shall be made based on the largest equipment grounding conductor or equipment bonding jumper present in the box.
- Where an additional set of equipment grounding conductors, as permitted by 250.146(D), is present in the box, an additional volume allowance shall be made based on the largest equipment grounding conductor in the additional set.


Designated by an orange triangle
Insulation
Ø N G
Ø N G G
Standard receptacle
Isolated (insulated) ground receptacle

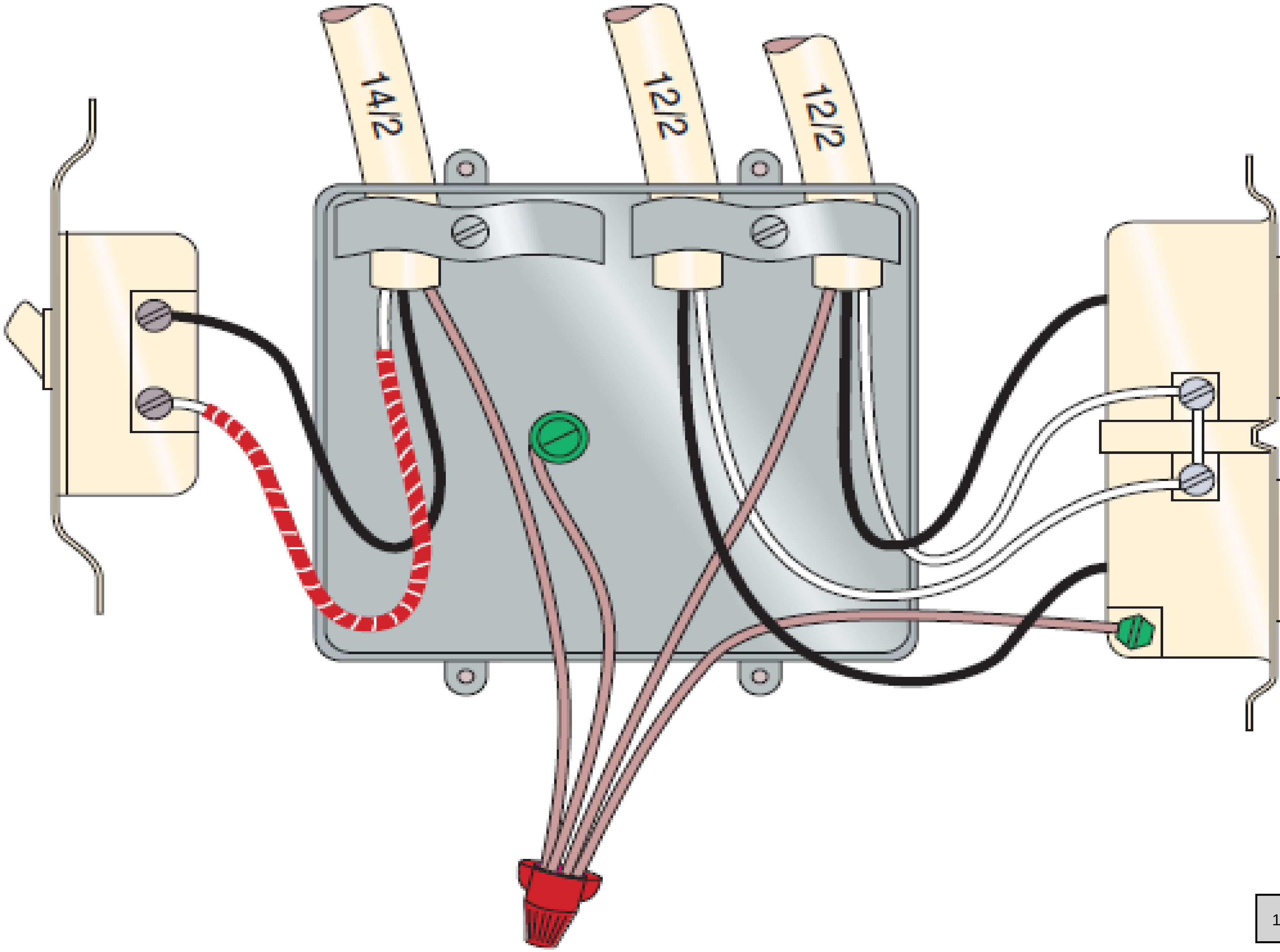
**COMMENTARY TABLE 314.1** Summary of Items Contributing to Box Fill

| Items Contained Within Box | Volume Allowance | Based on [see Table 314.16(B)] |
|---|---|---|
| Conductors that originate outside box | One for each conductor | Actual conductor size |
| Conductors that pass through box without splice or connection (less than 12 in. in total length) | One for each conductor | Actual conductor size |
| Conductors 12 in. or greater that are looped (or coiled) and unbroken (see 300.14 for exact measurement) | Two for a single (entire) unbroken conductor | Actual conductor size |
| Conductors that originate within box and do not leave box | None (these conductors not counted) | n.a. |
| Fixture wires [per 314.16(B)(1), Exception] | None (these conductors not counted) | n.a. |
| Internal cable clamps (one or more) | One only | Largest-sized conductor present |
| Support fittings (such as luminaire studs or hickeys) | One for each type of support fitting | Largest-sized conductor present |
| Devices (such as receptacles, switches) or utilization equipment (such as timers, dimmers, AFCI receptacles, GFCI receptacles, TVSS receptacles) | Two for each yoke or mounting strap | Largest-sized conductor connected to device or utilization equipment |
| Equipment grounding conductor (one or more) | One only | Largest equipment grounding conductor present |
| Isolated equipment grounding conductor (one or more) [see 250.146(D)] | One only | Largest isolated and insulated equipment grounding conductor present |

n.a.= not applicable.

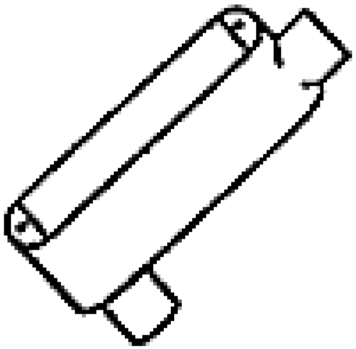



Standard 4 in. × 1½ in. square box (21.0 in.$^3$)


14/2
12/2
12/2

# 314.16 (C) CONDUIT BODIES.

- **(1) General.** Conduit bodies enclosing 6 AWG conductors or smaller, other than short-radius conduit bodies as described in 314.16(C)(3), shall have a cross-sectional area not less than twice the cross-sectional area of the largest conduit or tubing to which they can be attached.
- The maximum number of conductors permitted shall be the maximum number permitted by Table 1 of Chapter 9 for the conduit or tubing to which it is attached.



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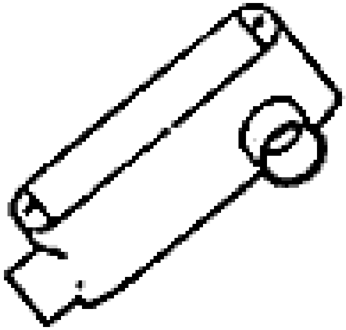

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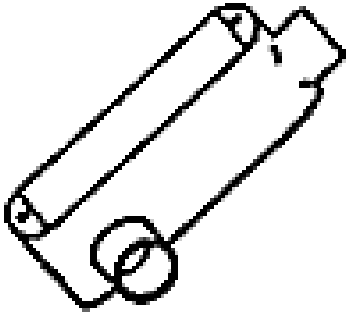
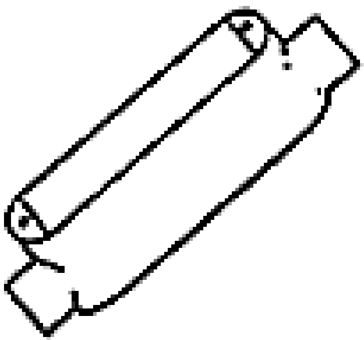


LR



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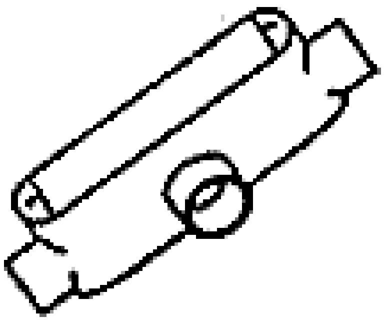

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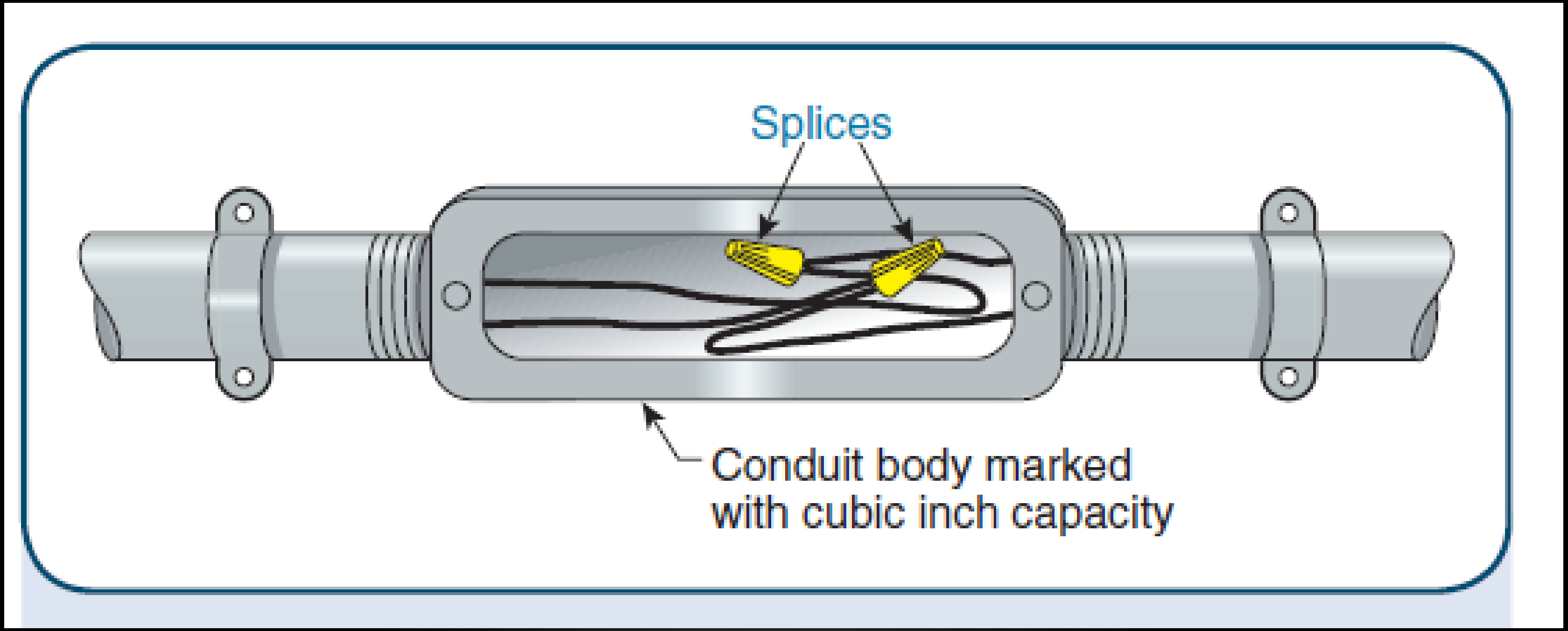
# 314.16 (C) (2) WITH SPLICES, TAPS, OR DEVICES.

- Only those conduit bodies that are durably and legibly marked by the manufacturer with their volume shall be permitted to contain splices, taps, or devices.
- The maximum number of conductors shall be calculated in accordance with 314.16(B).
- Conduit bodies shall be supported in a rigid and secure manner.

# 314.16 (C) (3) SHORT RADIUS CONDUIT BODIES.

- Conduit bodies such as capped elbows and service-entrance elbows that enclose conductors 6 AWG or smaller, and are only intended to enable the installation of the raceway and the contained conductors, shall not contain splices, taps, or devices and shall be of sufficient size to provide free space for all conductors enclosed in the conduit body.

# CONDUIT BODY



# 314.28 PULL AND JUNCTION BOXES AND CONDUIT BODIES

- Boxes and conduit bodies used as pull or junction boxes shall comply with 314.28(A) through (E).
- *Exception: Terminal housings supplied with motors shall comply with the provisions of 430.12.*

# 314.28 (A)

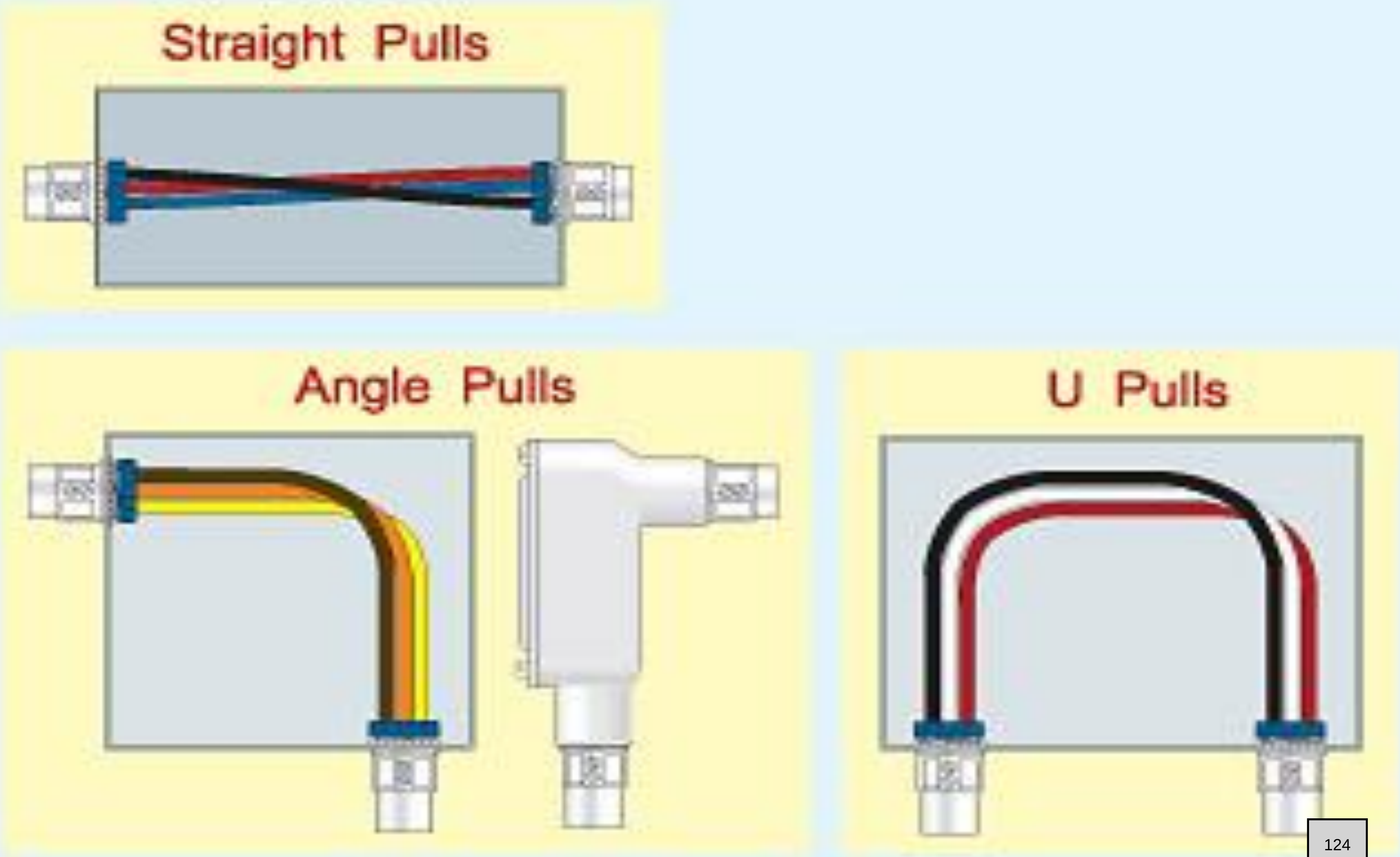
- A) Minimum Size. For raceways containing conductors of 4 AWG or larger that are required to be insulated, and for cables containing conductors of 4 AWG or larger, the minimum dimensions of pull or junction boxes installed in a raceway or cable run shall comply with (A)(1) through (A)(3).
- Where an enclosure dimension is to be calculated based on the diameter of entering raceways, the diameter shall be the metric designator (trade size) expressed in the units of measurement employed.

# 314.28 (A) (1) & (2)

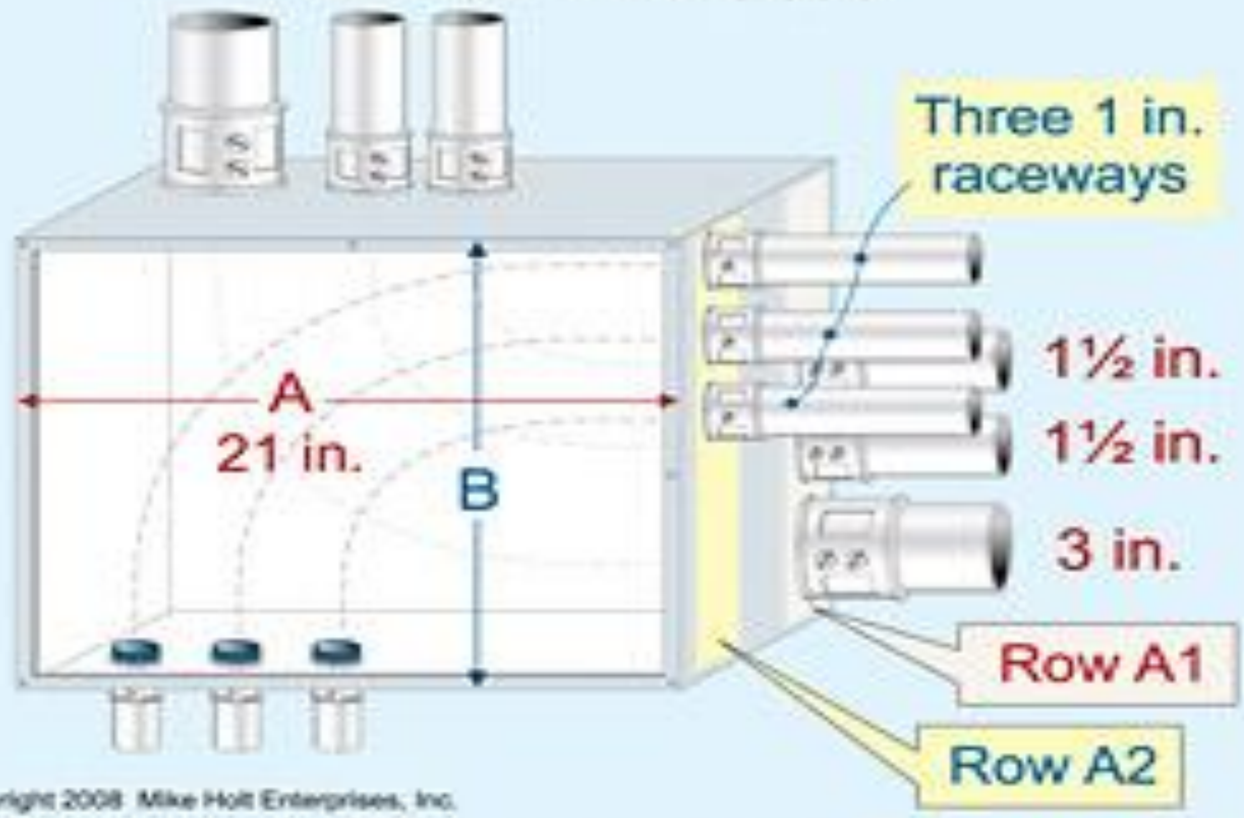
- **(1) Straight Pulls.** In straight pulls, the length of the box or conduit body shall not be less than eight times the metric designator (trade size) of the largest raceway.
- **(2) Angle or U Pulls, or Splices.** Where splices or where angle or U pulls are made, the distance between each raceway entry inside the box or conduit body and the opposite wall of the box or conduit body shall not be less than six times the metric designator (trade size) of the largest raceway in a row.
- This distance shall be increased for additional entries by the amount of the sum of the diameters of all other raceway entries in the same row on the same wall of the box.
- Each row shall be calculated individually, and the single row that provides the maximum distance shall be used.

# Pull and Junction Boxes - 4 AWG and Larger

*Section 314.28(A)*



# Sizing Junction/Pull Boxes for Angle Conductor Pulls
## Determining Largest Row
*Section 314.28(A)(2)*



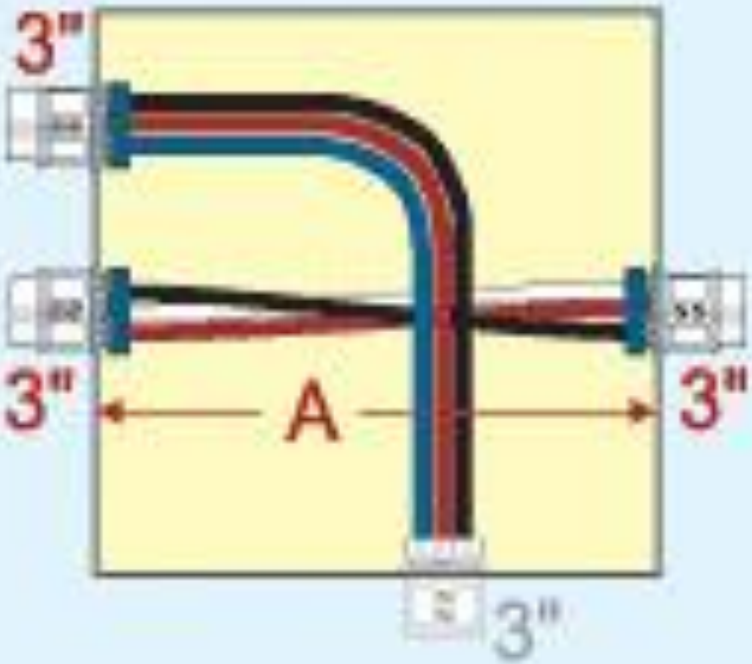



Row A1 = (6 x 3 in.) + 1½ + 1½ = 21 in.

Row A2 = (6 x 1 in.) + 1 in. + 1 in. = 8 in. (omit)

Dimension A = 21 in.

# Pull (Junction) Box Sizing
# 4 AWG and Larger
# *Section 314.28(A)*



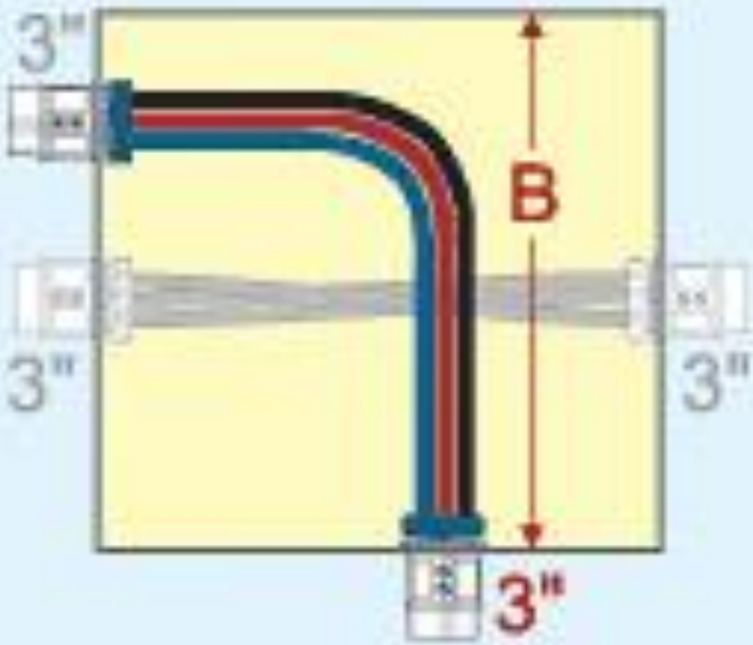

**Horizontal Dimension A**

**Straight Pull:**
Left to Right: 8 x 3 in. = 24 in.
Right to Left: 8 x 3 in. = 24 in.

**Angle Pull:**
Left to Right: (6 x 3 in.) + 3 in. = 21 in.
Right to Left: No Calculation

**Largest Calculation = 24 in.**

# Pull (Junction) Box Sizing
# 4 AWG and Larger
# *Section 314.28(A)*



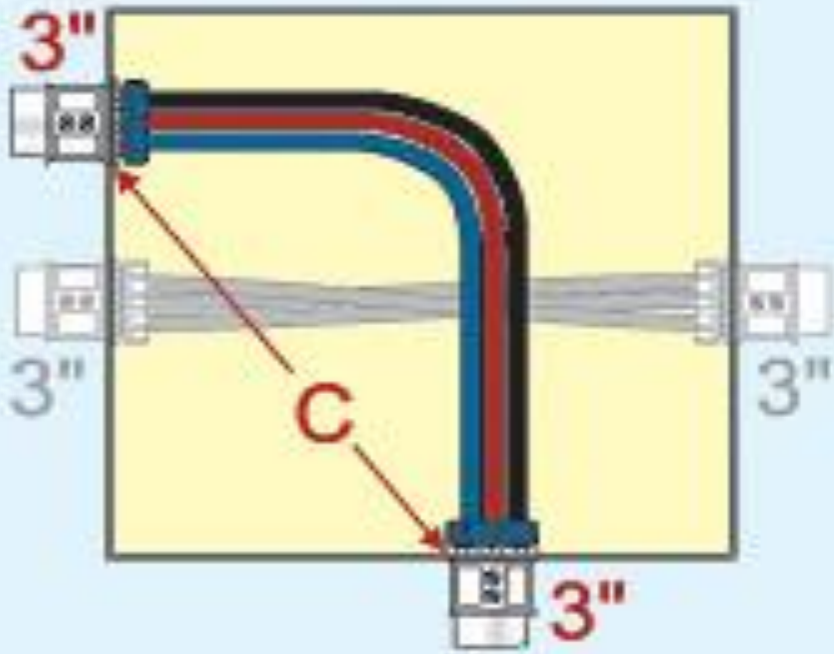

**Vertical Dimension B**

**Straight Pull:**
Top to Bottom: No Calculation
Bottom to Top: No Calculation

**Angle Pull:**
Top to Bottom: (No Calculation)
Bottom to Top: 6 x 3 in. = 18 in.

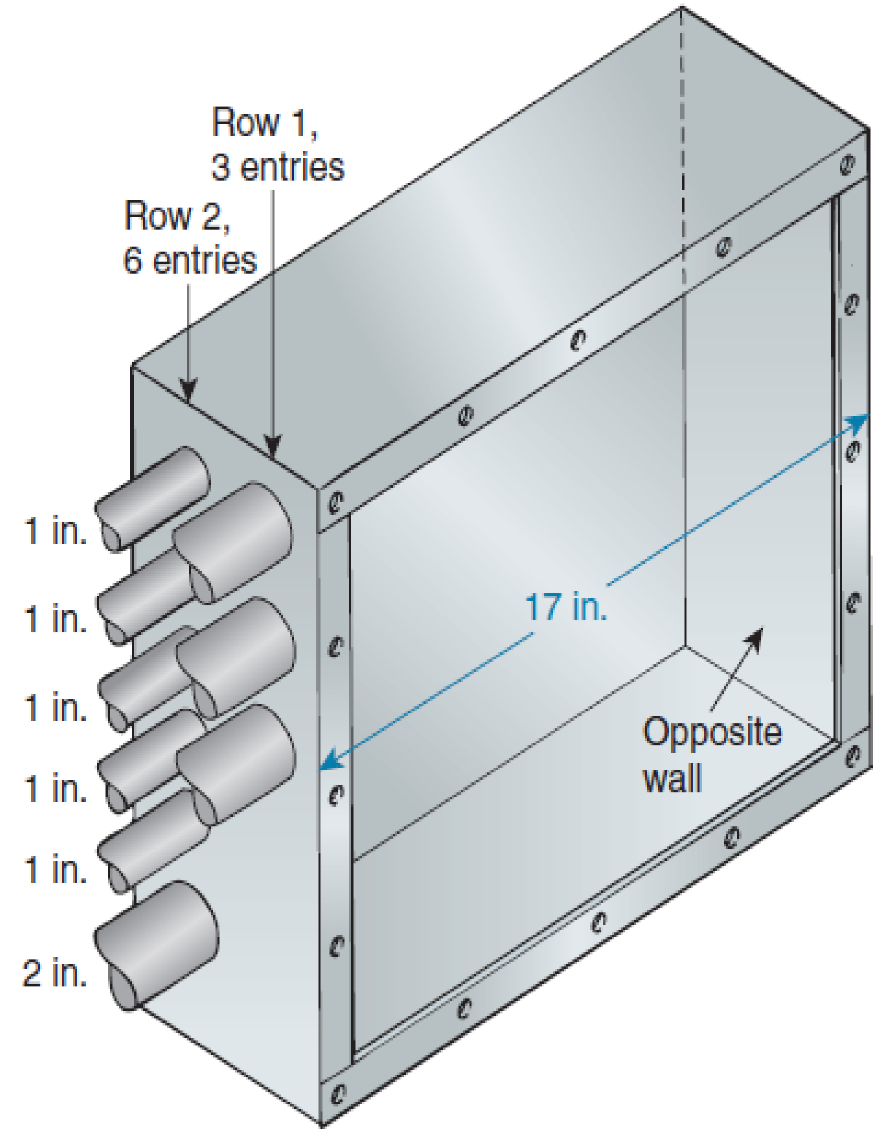
**Largest Calculation = 18 in.**

# Pull (Junction) Box Sizing
## 4 AWG and Larger
## *Section 314.28(A)(2)*

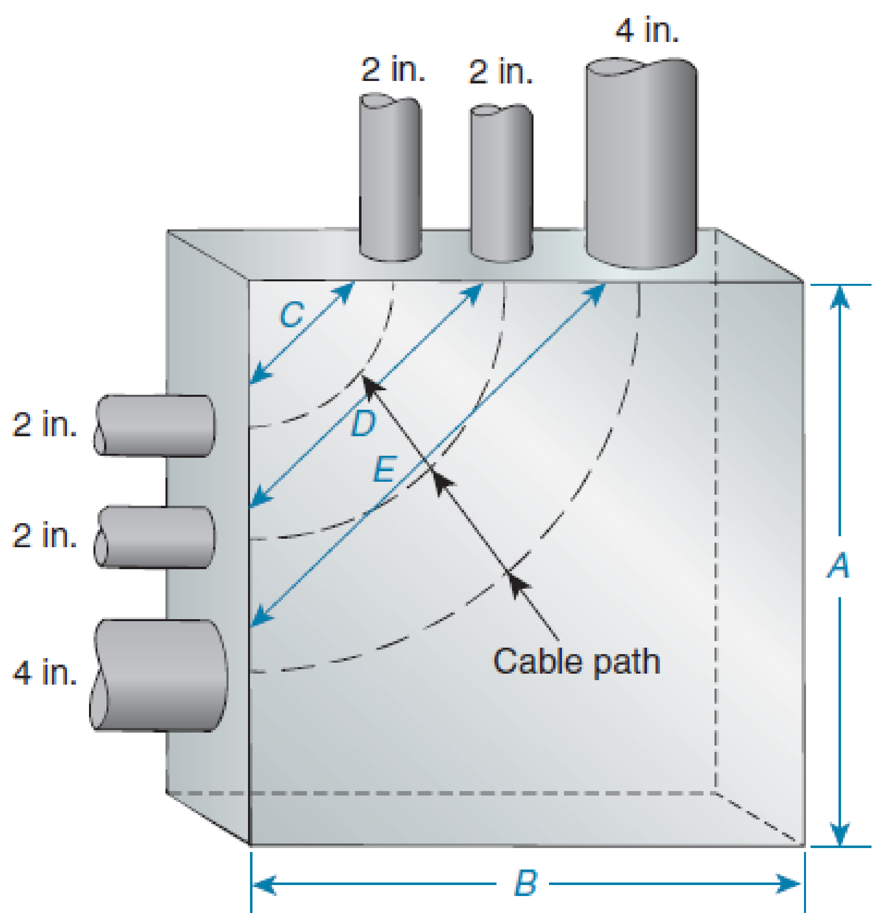



**Distance Between Raceways - "C"**

(Containing the same conductor)
Angle Pull is the only application
6 x 3 in. = 18 in.




6 × 2 in. (trade diameter of largest raceway) = 12 in.
12 in. + 5 in. (sum of diameters of other entries, row 2 only)
= 17 in. (min. required from each entry to opposite wall)




*A* = (6 × 4 in.) + 2 in. + 2 in. = 28 in. min.
*B* = (6 × 4 in.) + 2 in. + 2 in. = 28 in. min.
*C* = 6 × 2 in. = 12 in. min. required between raceways enclosing the same conductor
*D* = 6 × 2 in. = 12 in. min. required between raceways enclosing the same conductor
*E* = 6 × 4 in. = 24 in. min. required between raceways enclosing the same conductor

# 314.28 (A)(2) EXCEPTION

- *Exception: Where a raceway or cable entry is in the wall of a box or conduit body opposite a removable cover, the distance from that wall to the cover shall be permitted to comply with the distance required for one wire per terminal in Table 312.6(A).*
- TABLE 312.6(A) Minimum Wire-Bending Space at Terminals and Minimum Width of Wiring Gutters

# 314.28 (A)(2)

- The distance between raceway entries enclosing the same conductor shall not be less than six times the metric designator (trade size) of the larger raceway.
- When transposing cable size into raceway size in 314.28(A)(1) and (A)(2), the minimum metric designator (trade size) raceway required for the number and size of conductors in the cable shall be used.

# 314.28 (A) (3) SMALLER DIMENSIONS.

- Boxes or conduit bodies of dimensions less than those required in 314.28(A)(1) and (A)(2) shall be permitted for installations of combinations of conductors that are less than the maximum conduit or tubing fill (of conduits or tubing being used) permitted by Table 1 of Chapter 9, provided the box or conduit body has been listed for, and is permanently marked with, the maximum number and maximum size of conductors permitted.

# 314.28 (B), (C) & (D)

- **(B) Conductors in Pull or Junction Boxes.** In pull boxes or junction boxes having any dimension over 1.8 m (6 ft), all conductors shall be cabled or racked up in an approved manner.
- **(C) Covers.** All pull boxes, junction boxes, and conduit bodies shall be provided with covers compatible with the box or conduit body construction and suitable for the conditions of use. Where used, metal covers shall comply with the grounding requirements of 250.110.
- **(D) Permanent Barriers.** Where permanent barriers are installed in a box, each section shall be considered as a separate box.

# 314.28 (E)

- **(E) Power Distribution Blocks.** Power distribution blocks shall be permitted in pull and junction boxes over 1650 cm3 (100 in.3) for connections of conductors where installed in boxes and where the installation complies with (1) through (5).
- *Exception: Equipment grounding terminal bars shall be permitted in smaller enclosures.*
- **(1) Installation**. Power distribution blocks installed in boxes shall be listed.

# POWER DISTRIBUTION BLOCKS

# 314.28 (E) 2 & 3

- **(2) Size.** In addition to the overall size requirement in the first sentence of 314.28(A)(2), the power distribution block shall be installed in a box with dimensions not smaller than specified in the installation instructions of the power distribution block.
- **(3) Wire Bending Space.** Wire bending space at the terminals of power distribution blocks shall comply with 312.6.

# 314.28 (E) 4 & 5

- **(4) Live Parts.** Power distribution blocks shall not have uninsulated live parts exposed within a box, whether or not the box cover is installed.
- **(5) Through Conductors.** Where the pull or junction boxes are used for conductors that do not terminate on the power distribution block(s), the through conductors shall be arranged so the power distribution block terminals are unobstructed following installation.

# CALCULATIONS

- A metal device box with internal cable clamp contains a 3-way switch and one 14/3 with ground romex.
- How many conductors will this installation have?
- Wires – 3 (one for each conductor)
- Clamps – 1
- Ground – 1
- Device – 2 (double volume)
- Total – 7 wires
- 7 @ 2.0 cu. In.  = 14 cubic Inches box minimum

# CALCULATIONS

- A 18 cubic inch plastic device box has (3) 12/2 with ground nm cables with a GFI receptacle.
- Permitted or not permitted?
- Wires – 6
- Grounds – 1
- Devices – 2
- Total = 9
- @ 2.25 cubic inches = 20.25 cu in. min.
- Not Permitted! 22 cu. or 4" square w/ring

# CALCULATIONS

- What is the minimum size metal box needed for (2) 12/2 w/ground and (2) 14/2 w/ground nm-cables with internal clamps?

- The receptacle is connected to a 20 amp circuit, while a switch is connected to a 15 amp circuit

# CALCULATIONS CONTINUED

- (4) # 12 AWG wires @ 2.25 Cu. inches
- (4) # 14 AWG wires @ 2.0 Cu. inches
- Grounds @ 2.25 Cu. inches
- Internal clamp @ 2.25 Cu. Inches
- Receptacle @ 2 x 2.25 (double volume)
- Switch @ 2 x 2.0
- 9 + 8 + 2.25 + 2.25 + 4.5 + 4 = 30 cubic in.
- What size box? See Table 314.16 (A)
- 4" sq. box by 2-1/8" deep = 30.3 cubic in.

# QUESTION 1

- A 10” x 10” x 4” deep box would only require 6” of free conductor measured from the point in the box where the conductors enter the enclosure. The 3” outside the box rule does or does not apply?
- Does Not!  - 300.14 States boxes larger than 8” in any dimension does not require the 3” requirement.

# QUESTION 2

- FS, FD, and larger cast or sheet metal boxes are or are not classified as conduit bodies?

- Are not! – 314.1

# QUESTION 3

- Each yoke or strap containing one or more devices or equipment in a device box counts as ______ conductor (s)?
- A) one
- B) two
- C) three
- D) four

- B) two – 314.16 (B)(4)

# QUESTION 4

- A 6 AWG copper conductor requires _____ cubic inches of free space within a box?
- A) 3”
- B) 4”
- C) 5”
- D) 6”

- 5” - Table 314.16 (B)

# QUESTION 5

- All of the following shall be counted when calculating box conductor fill, except for _____?
- A) conductors that pass through the box without splice or termination.
- B) fixtures, hickeys, and clamps.
- C) looped or unbroken conductors
- D) four fixture wires smaller than 14 AWG

- D)  - 314.16 (B) (1) exception

# QUESTION 6

- A raised plaster ring is permitted to increase the maximum number of conductors permitted in an outlet box when it is_____?
- A) listed as a box extension
- B) by the same manufacturer as the box
- C) marked with its cubic inches
- D) metallic and capable of being grounded

- C) marked with its cubic inches 314.16 (A)

# CONDUIT FILL

- 300.17 – The number and size of conductors in any raceway shall not be more than will permit dissipation of the heat and ready installation or withdrawal of the conductors without damage to the conductors or to their insulation.

# ANNEX C

- Conduit and Tubing Fill for Conductors and Fixture Wires of the same size.
- Tables C.1 through C.12
- This table not part of the requirements of the NEC but is included for informational purposes only.

# CHAPTER 9 – TABLE 1

- Percent of Cross Section of Conduit and Tubing for Conductors

- One Conductor = 53%
- Two Conductors = 31%
- Over 2 Conductors = 40%
- Based on common conditions of proper cabling, alignment of conductors, length of pull and number of bends.

# INFORMATIONAL NOTE NO. 2

- When pulling three conductors or cables into a raceway, if the ratio of the raceway (inside diameter) to the conductor or cable (outside diameter) is between 2.8 and 3.2 jamming can occur.
- The probability of four or more conductors or cables jamming in a raceway is very low.

# NOTES TO TABLES

- 1.) See Annex C for the maximum number of conductors and fixture wires, all of the same size permitted in raceways or tubing of a specific size.
- 2.) Table one only applies to complete conduit or tubing systems and does not apply to sections of raceways or tubing used for physical protection.
- 3.) Equipment grounding or bonding conductors must be included when calculating conduit or tubing fill.

# NOTES TO TABLES

- 4.) Where conduit or tubing nipples are 24" or less and installed between boxes, cabinets and similar enclosures the wire fill is permitted to be increased to 60% and adjustment factors do not apply to this condition.
- 5.) Conductors not included in Chapter 9, the actual dimension shall be used.

# NOTES TO TABLES

- 6.) For combinations of conductors of different sizes, use Table 5 & 5A for conductor dimensions and Table 4 for conduit or tubing dimensions.
- 7.) When calculating the maximum number of conductors in a conduit or tubing, all of the same size (CSA including insulation) the next higher whole number may be used to determine the maximum conductors permitted when the calculation results in a decimal of 0.8 or larger.

# NOTES TO TABLES

- 8.) Where the bare conductors are permitted by other sections of this code. The dimension for bare conductors in Table 8 shall be permitted.
- 9.) A multiconductor cable of two or more conductors shall be treated as a single conductor for calculating percentage conduit fill area. For cables having elliptical cross sections, the cross-sectional area shall be based on the major diameter of the ellipse as the circle diameter.

# EXAMPLES

- How many 10 AWG THHN copper conductors can fit into an 1-1/4" EMT conduit? See Table C.1 - 28 # 10 AWG
- RMC? Table C.8 - 29 # 10 AWG
- PVC Conduit SCH-80 T. C.9 - 23 # 10 AWG

# MIXED WIRE SIZE EXAMPLE

- What is the minimum size EMT conduit needed for (3) 6 AWG, (4) 10 AWG & (3) 12 AWG THHN copper conductors? (See Table 5)
- 6 AWG is 0.0507 x 3 = .15 in sq area
- 10 AWG is 0.0211 x 4 = .08 in sq area
- 12 AWG is 0.0133 x 3 = .0399 in sq area
- Total of all conductors is 0.2699 in sq area
- (See Table 4) EMT – 1” is 0.346 @ 40%

TABLE 5 *continued*

| Type | Size (AWG or kcmil) | Approximate Diameter | | Approximate Area | |
|---|---|---|---|---|---|
| | | mm | in. | mm² | in.² |
| **Type: RHH*, RHW*, RHW-2*, THHN, THHW, THW, THW-2, TFN, TFFN, THWN, THWN-2, XF, XFF** | | | | | |
| RHH,* RHW,* RHW-2,* XF, XFF | 10 | 5.232 | 0.206 | 21.48 | 0.0333 |
| RHH*, RHW*, RHW-2* | 8 | 6.756 | 0.266 | 35.87 | 0.0556 |
| TW, THW, THHW, THW-2, RHH*, RHW*, RHW-2* | 6 | 7.722 | 0.304 | 46.84 | 0.0726 |
| | 4 | 8.941 | 0.352 | 62.77 | 0.0973 |
| | 3 | 9.652 | 0.380 | 73.16 | 0.1134 |
| | 2 | 10.46 | 0.412 | 86.00 | 0.1333 |
| | 1 | 12.50 | 0.492 | 122.6 | 0.1901 |
| | 1/0 | 13.51 | 0.532 | 143.4 | 0.2223 |
| | 2/0 | 14.68 | 0.578 | 169.3 | 0.2624 |
| | 3/0 | 16.00 | 0.630 | 201.1 | 0.3117 |
| | 4/0 | 17.48 | 0.688 | 239.9 | 0.3718 |
| | 250 | 19.43 | 0.765 | 296.5 | 0.4596 |
| | 300 | 20.83 | 0.820 | 340.7 | 0.5281 |
| | 350 | 22.12 | 0.871 | 384.4 | 0.5958 |
| | 400 | 23.32 | 0.918 | 427.0 | 0.6619 |
| | 500 | 25.48 | 1.003 | 509.7 | 0.7901 |
| | 600 | 28.27 | 1.113 | 627.7 | 0.9729 |
| | 700 | 30.07 | 1.184 | 710.3 | 1.1010 |
| | 750 | 30.94 | 1.218 | 751.7 | 1.1652 |
| | 800 | 31.75 | 1.250 | 791.7 | 1.2272 |
| | 900 | 33.38 | 1.314 | 874.9 | 1.3561 |
| | 1000 | 34.85 | 1.372 | 953.8 | 1.4784 |
| | 1250 | 39.09 | 1.539 | 1200 | 1.8602 |
| | 1500 | 42.21 | 1.662 | 1400 | 2.1695 |
| | 1750 | 45.11 | 1.776 | 1598 | 2.4773 |
| | 2000 | 47.80 | 1.882 | 1795 | 2.7818 |
| TFN, TFFN | 18 | 2.134 | 0.084 | 3.548 | 0.0055 |
| | 16 | 2.438 | 0.096 | 4.645 | 0.0072 |
| THHN, THWN, THWN-2 | 14 | 2.819 | 0.111 | 6.258 | 0.0097 |
| | 12 | 3.302 | 0.130 | 8.581 | 0.0133 |
| | 10 | 4.166 | 0.164 | 13.61 | 0.0211 |
| | 8 | 5.486 | 0.216 | 23.61 | 0.0366 |
| | 6 | 6.452 | 0.254 | 32.71 | 0.0507 |
| | 4 | 8.230 | 0.324 | 53.16 | 0.0824 |
| | 3 | 8.941 | 0.352 | 62.77 | 0.0973 |
| | 2 | 9.754 | 0.384 | 74.71 | 0.1158 |
| | 1 | 11.33 | 0.446 | 100.8 | 0.1562 |
| | 1/0 | 12.34 | 0.486 | 119.7 | 0.1855 |
| | 2/0 | 13.51 | 0.532 | 143.4 | 0.2223 |
| | 3/0 | 14.83 | 0.584 | 172.8 | 0.2679 |
| | 4/0 | 16.31 | 0.642 | 208.8 | 0.3237 |
| | 250 | 18.06 | 0.711 | 256.1 | 0.3970 |
| | 300 | 19.46 | 0.766 | 297.3 | 0.4608 |

# DERATING

- Adjustments – More than 3 current-carrying conductors in a conduit or tubing or bundling of cable assemblies longer than 24” without maintaining spacing.
- See 310.15 (B)(3)(a) for percentage of deration.
- Remember 334.80 for 2 or more NM Cables that are ran through holes that will be fire or draft-stopped also requires consideration of 310.15 (B)(3)(a)

## TABLE 310.15(B)(3)(a) Adjustment Factors for More Than Three Current-Carrying Conductors in a Raceway or Cable

| Number of Conductors[1] | Percent of Values in Table 310.15(B)(16) through Table 310.15(B)(19) as Adjusted for Ambient Temperature if Necessary |
|---|---|
| 4–6 | 80 |
| 7–9 | 70 |
| 10–20 | 50 |
| 21–30 | 45 |
| 31–40 | 40 |
| 41 and above | 35 |

[1]Number of conductors is the total number of conductors in the raceway or cable adjusted in accordance with 310.15(B)(5) and (6).

# QUESTION

- If there are 7 current carrying conductors in a conduit, the adjustment factor to be used to determine the ampacity of the conductors is:
- A.) 80%
- B.) 70%
- C.) 50%
- D.) 45%
- B.) 70%

# QUESTION

- I have a ¾" EMT conduit with (9) 12 AWG copper Type THHN conductors installed. What is the allowable ampacity rating of the 12 AWG conductors?
- T. 310.16 - 12 AWG THHN is 30 Amps
- T. 310.15(B)(3)(a) indicates 70%
- 30 x .70 = 21 Amps
- See T.310.15(B)16 * 12 AWG , refer to 240.4(D)
- Select 20 Amp OCD.

# QUESTION

- I have dual listed copper wire like THHN/THWN, what temperature can I use when determining the allowable ampacity?
- THHN = 90 degree C. in dry locations
- THWN = 75 degree C. in wet locations

# ADJUSTMENT FACTOR FIXES

- Lower OCD to adjusted allowable ampacity.
- Separate the amount of current carrying conductors in one raceway.
- Increase wire size to allow greater adjusted ampacity.
- Separate bundled cable assemblies
- Nipples 24” or less do not apply.
- Increase distance above roof.

# DERATING

- Correction Factors – When conductors are ran through areas where an ambient temperature is greater than 30 degree C. or 86 degree F.
- Correction Table  T. 310.15(B)(2)(a)

## TABLE 310.15(B)(2)(A) Ambient Temperature Correction Factors Based on 30°C (86°F)

**For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.**

| Ambient Temperature (°C) | Temperature Rating of Conductor | | | Ambient Temperature (°F) |
|---|---|---|---|---|
| | 60°C | 75°C | 90°C | |
| 10 or less | 1.29 | 1.20 | 1.15 | 50 or less |
| 11–15 | 1.22 | 1.15 | 1.12 | 51–59 |
| 16–20 | 1.15 | 1.11 | 1.08 | 60–68 |
| 21–25 | 1.08 | 1.05 | 1.04 | 69–77 |
| 26–30 | 1.00 | 1.00 | 1.00 | 78–86 |
| 31–35 | 0.91 | 0.94 | 0.96 | 87–95 |
| 36–40 | 0.82 | 0.88 | 0.91 | 96–104 |
| 41–45 | 0.71 | 0.82 | 0.87 | 105–113 |
| 46–50 | 0.58 | 0.75 | 0.82 | 114–122 |
| 51–55 | 0.41 | 0.67 | 0.76 | 123–131 |
| 56–60 | — | 0.58 | 0.71 | 132–140 |
| 61–65 | — | 0.47 | 0.65 | 141–149 |
| 66–70 | — | 0.33 | 0.58 | 150–158 |
| 71–75 | — | — | 0.50 | 159–167 |
| 76–80 | — | — | 0.41 | 168–176 |
| 81–85 | — | — | 0.29 | 177–185 |

# QUESTION

- A size 2 AWG copper, Type THHN conductors is run through a room with an ambient temperature of 110 degree F. (43.3 degree C.) and there are no conductor termination in this area. The ampacity of the conductor is:
- T. 310.16 – 2 AWG = 130 Amps at 90 degree C.
- 130 x 0.87 = 113 Amps

# ADJUSTMENT & CORRECTION

- A raceway contains two 3-phase circuits that supply a 38 amp continuous load. The circuit will be supplied by THHN copper conductors and circuit terminations are 75 degree C. In route to supply the load, the circuits run through a boiler room with the design temperature of 120 degree F. The minimum size conductors is:

# QUESTION CONTINUED

- 38 Amp continuous load x 125% = 47.5 A.
- 6 – current carrying conductors x 80%
- 120 degree F. ambient temperature of THHN wires terminated @ 75 Degree C. = 82%
- 4 AWG @ 75 degree C = 85 Amps
- 85 x .80 x .82 = 55.76 Amps

# THANK YOU!

- From the Master Electrical Contractors Association!

**File Attachments for Item:**

ER-3 Understanding the National Electric Code Based on the 2017 NEC (Master Electrical Contractors Association)

All certifications (5 hours)

Staff Notes:

ESIAC Recommendation:

Committee Recommendation:

Ohio | Department of Commerce

Mike DeWine, Governor
Jon Husted, Lt. Governor

Sheryl Maxfield, Director

Board of Building Standards

# Application for Continuing Education Course Approval

**Provider Information:**

Name: Laura Bachman

Organization: Master Electrical Contractors Association

Address: 1555 Stanley Avenue Dayton Ohio 45404

E-mail: Laurameca@aol.com Telephone: 937-264-0418

Website: ______

Conference Sponsor (if applicable) ______ Conference Email: ______

**Check here if Course Renewal:** ______ Prior course number ______ (*i.e. BBS2018-429*)

*Renewals will only be granted for identical content and certifications, within the current code cycle. Attach a copy of prior course approval letter for confirmation. No further information is required.*

**New Course Information:**

Course title: Understanding the NEC - Based on the 2017 National Electric Code

Course instructor: D.Dewayne Jenkins and Robert Barnett

Course description: The discuss and learn the purpose and intent of NEC, understand who it's written for and where it fits into your work.

Instructional hours per session: five (5) Number of Sessions: ______

Course Date(s) and Location: March 11, 2023 Presidential Banquet Center 4548 Presidential way Dayton Ohio 45429

**Special Content:**

Code Administration: ☐

Existing Buildings: ☐

Electrical Instruction: ☑

Plumbing Instruction: ☐

Conference Course: ______

Conference Name: ______

Conference location: ______

Course to be offered online? ☐ **On Demand** ☐ **Webinar** ☐

Course Website: ______

Detail online course participation confirmation method (*i.e. test, quizlets, participant activity confirmation*):

______

**Course applicable for the following certifications**

Residential Certifications Only: ☑ Commercial Certifications: ☑

Administrative Course, All Certifications: ☑

**Application materials included:**

☑ Course Outline or Course Learning Objectives

☑ Presentation Materials/Slides (not required for roundtable courses)

☐ Assessment Materials (for online courses)

☑ Presenter Bio

**Please submit application and materials in .pdf format to:** michael.lane@com.ohio.gov or BBS@com.ohio.gov

# CODE CLASSES - CONTINUING EDUCATION PROGRAM

LOCATION: **PRESIDENTIAL BANQUET CENTER**
**4548 PRESIDENTIAL WAY DAYTON OHIO 45429**

DATES: **MARCH 11 AND MARCH 18, 2023**

TIME: 7:00 AM – 7:30 AM – BREAKFAST
7:30 AM - 1:00 PM – CLASS

## INTRODUCTION:

THESE CLASSES WILL BE DIRECTED TO THE MEN IN THE FIELD, CONTRACTORS AND ELECTRICAL INSPECTORS.

THE CLASSES ARE APPROVED BY THE STATE OF OHIO FOR RECERTIFICATION CREDITS WHICH ARE REQUIRED FOR THE STATE REGISTRATION AND RECERTIFICATION.

CONTRACTORS CAN RECEIVE A TOTAL OF TEN (10) CREDIT HOURS APPROVED BY THE OCILB.
(PENDING ACCEPTACE OF OBBS) INSPECTORS CAN RECEIVE TEN (10) CREDIT HOURS APPROVED BY OBBS.
THIS COURSE IS APPROVED FOR CONTINUING EDUCATION CREDIT IN KENTUCKY FOR ME/EE.

## TOPICS TO BE COVERED:

THESE SESSIONS WILL CONSIST OF THE UNDERSTANDING THE NEC – BASED ON THE 2017 NEC

## THE INSTRUCTORS:

DEWAYNE JENKINS - ESI & EPE for the City of Kettering Ohio
ROBERT BARNETT – Tri-County Electric Owner/Operator

## ENROLLMENT –

OPEN TO MEMBERS AND NON-MEMBERS. CLASS SIZE – FIRST PAID 125 PERSONS. IF YOU ARE NOT NOTIFIED, PLEASE PLAN ON ATTENDING. (LAURA BACHMAN 937-264-0418)

## FOR MORE INFORMATION:

LAURA BACHMAN - 937 264-0418 OR MECAIECDAYTON@GMAIL.COM

ATTENDEES SHOULD BRING A COPY OF THE 2017 NEC BOOK

(OVER)

**Daniel Dewayne Jenkins**

Dewayne started his career in the electrical field in August of 1982 in Dayton, Ohio and has over 40 years' experience in the electrical industry both as a contractor and inspector. He served 4 years in an electrical apprenticeship program and has over 8 years in the field as a journeyman electrician and he has 4 years, to his credit, as an electrical estimator and project manager.

Dewayne has been a licensed electrical contractor and a certified electrical safety inspector since 1996. He also holds Ohio certifications as building inspector (1998), electrical plans examiner (2006) and residential building official (2007) and chief building official (2008). He is currently employed by the City of Kettering in the position as the Senior Building Inspector and conducts electrical plans examinations, electrical safety inspections and building inspections for the past 23 years.

Dewayne is an adjunct lecturer II for Sinclair Community College in the electrical trades for the past 20 years. A technical presenter for the Ohio Board of Building Standards (OBBS), International Association of Electrical Inspectors (IAEI), Master Electrical Contractors Association (MECA), Adequate Wiring Committee (AWC) & Greater Cincinnati Electrical Association (GCEA). He has served as President for the Ohio Chapter IAEI (2010). Dewayne has also serves as President of the Southwest Division of IAEI, Ohio Chapter (2018-2022) and President of the Miami Valley Building Officials Council (2002 & 2003). He also serves on the Electrical Safety Inspector Advisory Committee for the Ohio Board of Building Standards.

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# Robert L. Barnett

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## Small Business Owner

**Strategic Planning • Project Management • Construction • Team Leadership • Customer Service • Value Engineering • Project Coordination • Highly Detailed • Organizational Effectiveness • Design-Build • Quality Control • Materials Management • Educational Leadership**

A multi-skilled professional with a solid career history in the electrical industry. Able to manage complex projects in various environments. Able to lead projects in under budget by managing and supervising an effective team in the installation of a quality product. Making a professional appearance to customers and other employees.

## Technical Proficiencies

| | | | |
|---|---|---|---|
| Microsoft Office | Excel | AutoCAD | Networks |
| Internet & Research | Word | Accounting Software | Citrix |
| Database Management | PowerPoint | ExamView | PDF Software |

## Professional Experience

**Tri-County Electric, Brookville OH (License# EL48489)** **2018-Present**

**Owner (Since 2018)**

- Creating and implementing business plans and strategies based on long term visions. Implement high-level planning to measure progress, gather insight and readjust plans and goals as necessary.
- Establish and maintain business banking accounts, payment processing systems, taxes, insurance and manage day-to-day costs and business expenses.
- Procuring business and contractor licensing for compliance with state and local licensing requirements.
- Establish solid marketing strategies and maintaining working relationships with clients to ensure outstanding customer service.
- Manage day-to-day business operations by overseeing employees and projects. Addressing various issues with staffing, project and technical issues.

**Reliable Electric, Dayton OH** **2006-2017**

**Project Manager (3 years)**

- Establish and manage cost, schedules, manpower and performance of large, highly complex projects. Fully accountable for complex/diverse projects with a high degree of business risk.
- Collaborate with general contractors, design professionals, sales representatives and business owners to accomplish project objectives. Identify and resolve project issues and manage project risk.
- ***Project Examples:***
  - Managed a $1.5M energy conservation project at Wright State University. Successfully supervised a team of 10 electricians in a complex energy retrofit on an active college university. Completed the project on time and under budget.
  - Completed a $4M urban development project in Downtown Cincinnati with a two-year scope.

**Project Foreman (3 years)**

- Perform business management duties such as maintaining records and files, preparing reports and ordering supplies and materials.
- Layout and installation of lighting, power, equipment and special systems wiring, based on construction documents and local codes.
- Assign work to other employees, prioritize the work of others and organize and coordinate the work of the project.
- Direct and train workers to install, maintain, or repair electrical wiring, equipment and fixtures.

**Commercial Service Technician (2 years)**

- Created and maintained business relationships with commercial and industrial clients.
- Troubleshoot malfunctions in circuitry, equipment, motor control circuits and special systems wiring using test equipment to correctly diagnose and repair problems.
- Use a variety of tools and equipment such as power construction equipment, measuring devices, power tools and testing equipment.

**Field Electrician (3 years)**

- Assist project foreman and journeyman on large commercial construction sites.
- Install, maintain and repair of electrical wiring, equipment and fixtures.
- Perform physical demanding tasks such as digging trenches to lay conduit and moving/lifting heavy objects.
- Fire alarm system installation and troubleshooting.

**Sinclair Community College, Dayton OH** **2013-2020**

**Adjunct Instructor (7 years)**

- First year instructor for the Independent Electrical Contractors (IEC) Apprenticeship Training Program, sponsored by the Master Electrical Contractors Association Training School (MECATS) Dayton Ohio
- Responsible for creating a positive learning environment for 10-12 entry level apprentice electricians.
- Develop lesson plans, quizzes and exams for student development and evaluation. Provide support and direction for students in and out of the classroom.
- Previously an active member of the MECATS A&T Committee.

## Education

- **Electrical Engineering Technology/IEC Apprenticeship Program,** Sinclair Community College, Dayton OH, 2010 (GPA: 4.0)
  Ohio licensed Journeyman
  Ohio Fire Alarm licensed
- **Architectural /Engineering Technology,** Miami Valley Career Technology Center, Clayton OH, 2006 (GPA: 3.5)
- **Milton-Union High School,** West Milton OH, 2006 (GPA: 3.0)

NATIONAL ELECTRICAL CODE

# UNDERSTANDING THE NEC:

*Based on the 2017 National Electrical Code*

By:

Robert Barnett

# Course Objectives:

- Discuss the purpose and intent of NEC, understand who it's written for and where it fits into your work.
- Understand the concepts, terms, punctuation and grammar in order to understand the complex structure of the rules and their intended purposes
- Identify key words and identifiers in the code and their meanings
- Understand the style and layout of the Code in order to use it effectively. Identify chapters, articles, tables, annexes, etc.
- Locating specific requirements using the specific tools inside and outside of the NEC (Indexes, tabs, electronic word searches)
- Use the NEC to work through practice questions based on common scenarios in the field

# The Purpose of the NEC

- What is the purpose of the National Electrical Code?

**90.1 Purpose.**

**(A) Practical Safeguarding.** The purpose of this *Code* is the practical safeguarding of persons and property from hazards arising from the use of electricity. This *Code* is not intended as a design specification or an instruction manual for untrained persons.

**(B) Adequacy.** This *Code* contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance result in an installation that is essentially free from hazard but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use.

***Article 90 is the introduction. It lays the foundation for understanding the National Electrical Code's scope and purpose, and where it fits into your work.***

# What's Covered By The NEC & What's Not??

**90.2 Scope.**

**(A) Covered.** This *Code* covers the installation and removal of electrical conductors, equipment, and raceways; signaling and communications conductors, equipment, and raceways; and optical fiber cables and raceways for the following:

(1) Public and private premises, including buildings, structures, mobile homes, recreational vehicles, and floating buildings
(2) Yards, lots, parking lots, carnivals, and industrial substations
(3) Installations of conductors and equipment that connect to the supply of electricity
(4) Installations used by the electric utility, such as office buildings, warehouses, garages, machine shops, and recreational buildings, that are not an integral part of a generating plant, substation, or control center

**(B) Not Covered.** This *Code* does not cover the following:

(1) Installations in ships, watercraft other than floating buildings, railway rolling stock, aircraft, or automotive vehicles other than mobile homes and recreational vehicles

Informational Note: Although the scope of this *Code* indicates that the *Code* does not cover installations in ships, portions of this *Code* are incorporated by reference into Title 46, Code of Federal Regulations, Parts 110–113.

(2) Installations underground in mines and self-propelled mobile surface mining machinery and its attendant electrical trailing cable
(3) Installations of railways for generation, transformation, transmission, energy storage, or distribution of power used exclusively for operation of rolling stock or installations used exclusively for signaling and communications purposes
(4) Installations of communications equipment under the exclusive control of communications utilities located outdoors or in building spaces used exclusively for such installations
(5) Installations under the exclusive control of an electric utility where such installations

a. Consist of service drops or service laterals, and associated metering, or
b. Are on property owned or leased by the electric utility for the purpose of communications, metering, generation, control, transformation, transmission, energy storage, or distribution of electric energy, or
c. Are located in legally established easements or rights-of-way, or

**(C) Special Permission.** The authority having jurisdiction for enforcing this *Code* may grant exception for the installation of conductors and equipment that are not under the exclusive control of the electric utilities and are used to connect the electric utility supply system to the service conductors of the premises served, provided such installations are outside a building or structure, or terminate inside at a readily accessible location nearest the point of entrance of the service conductors.

# The Intent of the NEC

- 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 electrical installations.
- Learning to understand and use the Code is critical to you working safely, whether you're training to become an electrician, or are already an electrician, electrical contractor, inspector, engineer, designer, or instructor.
- The NEC was written for 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.
- You must also understand the concepts and terms, and know grammar and punctuation in order to understand the complex structure of the rules and their intended purpose(s). Our goal during this course is to give you some guidelines and suggestions on using your Code book to help you understand what you're trying to accomplish, and how to get there.

# Language Considerations for the NEC

**Terms and Concepts:**

- The NEC contains many technical terms, so it's crucial for Code users to understand their meanings and applications. If you don't understand a term used in a rule, it will be impossible to properly apply the NEC requirement.

- Article 100 defines the terms that are used in two or more Code articles; 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 the Code requirements for it. Chapter 1, Article 100 covers definitions.

  - Did you know code experts often resolve National Electrical Code misunderstandings by simply using excerpts from Article 100? Become familiar with this Chapter, and you'll be ahead of the game. Try it!

  - What is the true definition of a dwelling unit? Let's take a look to see what qualifies…

**Dwelling Unit.** A single unit, providing complete and independent living facilities for one or more persons, including permanent provisions for living, sleeping, cooking, and sanitation. (CMP-2)

***Here are some NEC requirements that apply to dwelling units***

**210.12 Arc-Fault Circuit-Interrupter Protection.** Arc-fault circuit-interrupter protection shall be provided as required in 210.12(A), (B), and (C). The arc-fault circuit interrupter shall be installed in a readily accessible location.

**(A) Dwelling Units.** All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

**210.52 Dwelling Unit Receptacle Outlets.** This section provides requirements for 125-volt, 15- and 20-ampere receptacle outlets. The receptacles required by this section shall be in addition to any receptacle that is:

## DWELLING UNIT
## 120 volt AFCI Protected Receptacle Outlets - REQUIRED LOCATIONS

| DATE OF NEC EDITION | BEDROOMS | FAMILY ROOMS | DINING ROOMS | LIVING ROOMS | PARLORS | LIBRARIES | DENS | SUNROOMS | RECREATION ROOMS | CLOSETS | HALLWAYS | SIMILAR AREAS OR ROOMS | KITCHENS | LAUNDRY AREAS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | $X_{1a}$ | | | | | | | | | | | | | |
| 2002 | $X_{2a}$ | | | | | | | | | | | | | |
| 2005 | $X_{2a}$ | | | | | | | | | | | | | |
| 2008 | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | $X_{2b}$ | | |
| 2011 | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | | |
| 2014 * | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2c}$ | $X_{2d}$ | $X_{2d}$ |

04-04-2015 update



Compiled by Jerry Peck

1a. All 120-volt 15 and 20 amp branch circuits supplying RECEPTACLE OUTLETS in all bedrooms, i.e., AFCI is at breaker panel - Effective Date is January 1, 2002.

2a. All 120-volt 15 and 20 amp branch circuits supplying all OUTLETS in all bedrooms, i.e., AFCI is at breaker panel.

2b. All 120-volt 15 and 20 amp branch circuits supplying all OUTLETS in family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, or similar rooms or area, i.e., AFCI is at breaker panel - EXCEPT:

- Exception 1 Where rigid conduit, intermediate conduit, EMT, or Type AC steel armored cable using metal outlet and junction boxes is used between the breaker and the first receptacle of a circuit, the AFCI device is permitted to be installed at the first outlet in the circuit.
- Exception 2 Power limited fire alarm circuits provided those circuits are installed in rigid conduit, intermediate conduit, EMT, or Type AC steel armored cable using metal outlet and junction boxes - no AFCI protection is required. This exception will rarely be applicable for dwelling units.

2c. All 120-volt 15 and 20 amp branch circuits supplying all OUTLETS in family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, or similar rooms or area, i.e., AFCI is at breaker panel - EXCEPT:

- Exception 1 Where rigid conduit, intermediate conduit, EMT, Type MC, or Type AC steel armored cable using metal outlet and junction boxes is used between the breaker and the first receptacle of a circuit, the AFCI device is permitted to be installed at the first outlet in the circuit.
- Exception 2 Where metal or nonmetallic conduit or tubing is encased in not less than 2 inches of concrete between the breaker and the first receptacle of a circuit, the AFCI device is permitted to be installed at the first outlet in the circuit.
- Exception 3 Power limited fire alarm circuits provided those circuits are installed in rigid conduit, intermediate conduit, EMT, or Type AC steel armored cable using metal outlet and junction boxes - no AFCI protection is required. This exception will rarely be applicable for dwelling units.

2d Added kitchen and Laundry areas.

* NOTE: With the 2014 NEC, Kitchen and Laundry Areas REQUIRE both AFCI and GFCI protection

## DWELLING UNIT
## 120 volt GFCI Protected Receptacle Outlets - REQUIRED LOCATIONS

| DATE OF NEC EDITION | SWIMMING POOLS | SPAS & HOT TUBS | EXTERIOR | BATHROOMS | GARAGE & ACCESSORY | HYDRO MASSAGE TUBS | BOATHOUSES | KITCHENS | UNFINISHED BASEMENTS | CRAWLSPACES | ALL SINKS (formerly WET BARS) | LAUNDRY UTILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1971* | $X_{1a}$ | | $X_{3a}$ | | | | | | | | | |
| *1975* | $X_{1a}$ | | X | X | | | | | | | | |
| *1978* | $X_{1a}$ | | $X_{3b}$ | X | $X_{5a}$ | | | | | | | |
| *1981* | $X_{1a}$ | $X_{2a}$ | $X_{3b}$ | X | $X_{5a}$ | | | | | | | |
| *1984* | $X_{1b}$ | $X_{2a}$ | $X_{3b}$ | X | $X_{5a}$ | | | | | | | |
| *1987* | $X_{1b}$ | $X_{2a,b}$ | $X_{3b}$ | X | $X_{5a}$ | $X_{6a}$ | X | $X_{8a}$ | $X_{9a}$ | | | |
| *1990* | $X_{1b}$ | $X_{2a,b}$ | $X_{3b}$ | X | $X_{5a}$ | $X_{6a}$ | X | $X_{8a}$ | $X_{9b}$ | $X_{10}$ | | |
| *1993*[a] | $X_{1b}$ | $X_{2a,b}$ | $X_{3b}$ | X | $X_{5a}$ | $X_{6b}$ | X | $X_{8a}$ | $X_{9b}$ | $X_{10}$ | $X_{11a}$ | |
| *1996*[a] | $X_{1c}$ | $X_{2a,b}$ | $X_{3c}$ | X | $X_{5a,b}$ | $X_{6b,c}$ | X | $X_{8b}$ | $X_{9b,c}$ | $X_{10}$ | $X_{11a}$ | |
| *1999*[a] | $X_{1c}$ | $X_{2a,b}$ | $X_{3c}$ | X | $X_{5b,c}$ | $X_{6b,c}$ | X | $X_{8b}$ | $X_{9b,c}$ | $X_{10}$ | $X_{11a}$ | |
| *2002*[a] | $X_{1c}$ | $X_{2a,b}$ | $X_{3c}$ | X | $X_{5b,c}$ | $X_{6b,c}$ | X | $X_{8b}$ | $X_{9b,c}$ | $X_{10}$ | $X_{11a}$ | |
| *2005*[a] | $X_{1c}$ | $X_{2a,b}$ | $X_{3c}$ | X | $X_{5b,c}$ | $X_{6b,c}$ | X | $X_{8b}$ | $X_{9c,d}$ | $X_{10}$ | $X_{11a}$ | $X_{12a}$ |
| *2008*[a,b] | $X_{1d}$ | $X_{2a,c}$ | $X_{3c}$ | X | X | $X_{6b,d}$ | X | $X_{8c}$ | $X_{9e}$ | $X_{10}$ | $X_{11a}$ | $X_{12a}$ |
| *2011*[a,b] | $X_{1d}$ | $X_{2a,c}$ | $X_{3c}$ | X | X | $X_{6b,d}$ | X | $X_{8c}$ | $X_{9e}$ | $X_{10}$ | $X_{11a}$ | $X_{12a}$ |
| *2014*[a,b,c] | $X_{1d}$ | $X_{2a,c}$ | $X_{3c}$ | $X_{4}$ | X | $X_{6b,d}$ | X | $X_{8c,d}$ | $X_{9e}$ | $X_{10}$ | $X_{11b}$ | $X_{12b}$ |

1a. All receptacle outlets within 15 feet of the water, in any direction (also see EXTERIOR), NO receptacle outlets within 10 feet of inside of pool walls.
1b. All receptacle outlets within 20 feet of the water, in any direction (also see EXTERIOR), NO receptacle outlets within 10 feet of inside of pool walls.
1c. All receptacle outlets within 20 feet of the water, in any direction (also see EXTERIOR), NO receptacle outlets within 10 feet of inside of pool walls, except receptacle outlets for pump which must be at least 5 feet from of inside of pool walls.
1d. All receptacle outlets within 20 feet of the water, in any direction (also see EXTERIOR), NO receptacle outlets within 6 feet of inside of pool walls, receptacle outlets for pumps at least 10 feet, except not less than 6 feet if meet special requirements (single, twist-lock, GFCI protected, grounded receptacle)
2a. Outdoor spa or hot tub – see Swimming Pools.
2b. Indoor spa or hot tub, receptacle outlets within 10 feet, receptacle outlets must be at least 5 feet from inside wall of spa.
2c. Indoor spa or hot tub, receptacle outlets within 10 feet, NO receptacle outlets within 6 feet of inside of spa or hot tub walls.
3a. Effective January 1, 1973.
3b. Changed to 'with direct grade access to dwelling and receptacle outlets' in 1978. Direct grade access was defined in 1987 as 6 feet 6 inches or less above grade.
3c. Changed back to ALL dwelling unit exterior receptacle outlets in 1996; except an outlet for snow melting equipment IF on a dedicated circuit and NOT readily accessible.
4. Receptacle outlets within 6 feet of outside edge of bathtubs and shower stalls – EVEN IF NOT IN A BATHROOM.
5a. All, except receptacle outlets not readily accessible (6 feet 8 inches or higher) and receptacle outlets for dedicated appliances which are not easily movable (freezer/refrigerator/etc.).
5b. Unfinished accessory buildings are treated like garage.
5c. Accessory buildings that have a floor located at or below grade and not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use.
6a. *CIRCUITS* serving hydromassage tub. All CIRCUITS (not receptacle outlets) supplying a hydromassage tub are required to be GFCI protected.
6b. Hydromassage tub and associate electric components shall be GFCI protected – by GFCI protected circuit or by GFCI receptacle outlet.
6c. Receptacle outlets serving hydromassage tub. All 125-volt receptacle outlets within 5 feet horizontally from inside walls of hydromassage tub.
6d. Receptacle outlets serving hydromassage tub. All 125-volt 30 amp and less outlets within 6 feet horizontally from inside walls of hydromassage tub.
7. (No notes for column 7 – Boathouses)
8a. Receptacle outlets within 6 feet of kitchen sink to serve as counter top outlets, outlets not to be installed face up in work surfaces and counter tops.
8b. All receptacle outlets which serve as counter top receptacle outlets, except outlets for refrigerator or freezer.
8c. All receptacle outlets which serve as counter top receptacle outlets.
8d. All receptacle outlets provided for DISHWASHERS – receptacles are no longer permitted installed behind the dishwasher as the GFCI receptacle would not be readily accessible.
9a. At least one receptacle outlet and which must be identified as being GFCI protected.
9b. Changed to all receptacle outlets in unfinished basements and crawl spaces, except: laundry, sump pump, refrigerator or freezer.
9c. Except where not readily accessible.
9d. Changed to all receptacle outlets in unfinished basements, except: laundry appliances, refrigerator or freezer, or permanently installed burglar or fire alarm.
9e. Changed to all receptacle outlets in unfinished basements, except permanently installed fire alarm or burglar alarm system.
10. At or below grade level.
11a. Receptacle outlets within 6 feet of wet bar sink to serve as counter top receptacle outlets, outlets not to be installed face up in work surfaces and counter tops.
11b. Receptacle outlets within 6 feet of *ANY* sink - bathroom sinks are covered under bathrooms, kitchen sinks under kitchens; additionally, ALL sinks are covered by this.
12a. Receptacle outlets within 6 feet of sink.
12b. All receptacle outlets in laundry area.
a. Beginning in 1993 ALL receptacle outlets which are replaced and which are in locations which require GFCI protection in the code applicable at the time of replacement require the replacement receptacle outlets to be GFCI protected.
b. Beginning in 2008 ALL receptacle outlets installed in damp and/or wet locations are required to be listed as weather-resistant, INCLUDING GFCI receptacle outlets, these are typically identified by the abbreviations 'WR' on the face of the receptacle outlet with the 'WR' visible after installation.
c. NOTE: With the 2014 NEC, Kitchen and Laundry Areas REQUIRE both GFCI and AFCI protection

05-04-2015 update



Compiled by Jerry Peck, Construction Litigation Consultants, LLC.
Special thanks to:
The late Tarry Baker, Chief Electrical Code Compliance Officer, Broward County Board of Rules and Appeals, Florida for help with the early years

# Language Considerations for the NEC (Cont'd)

**Terms and Concepts:**

- Articles have terms unique to that specific article, and the definitions of those terms are only applicable to that given article. These definitions are usually found in the beginning of the article.
  - For example, Section 250.2 contains the definitions of terms that only apply to Article 250—Grounding and Bonding.

**250.2 Definition.**

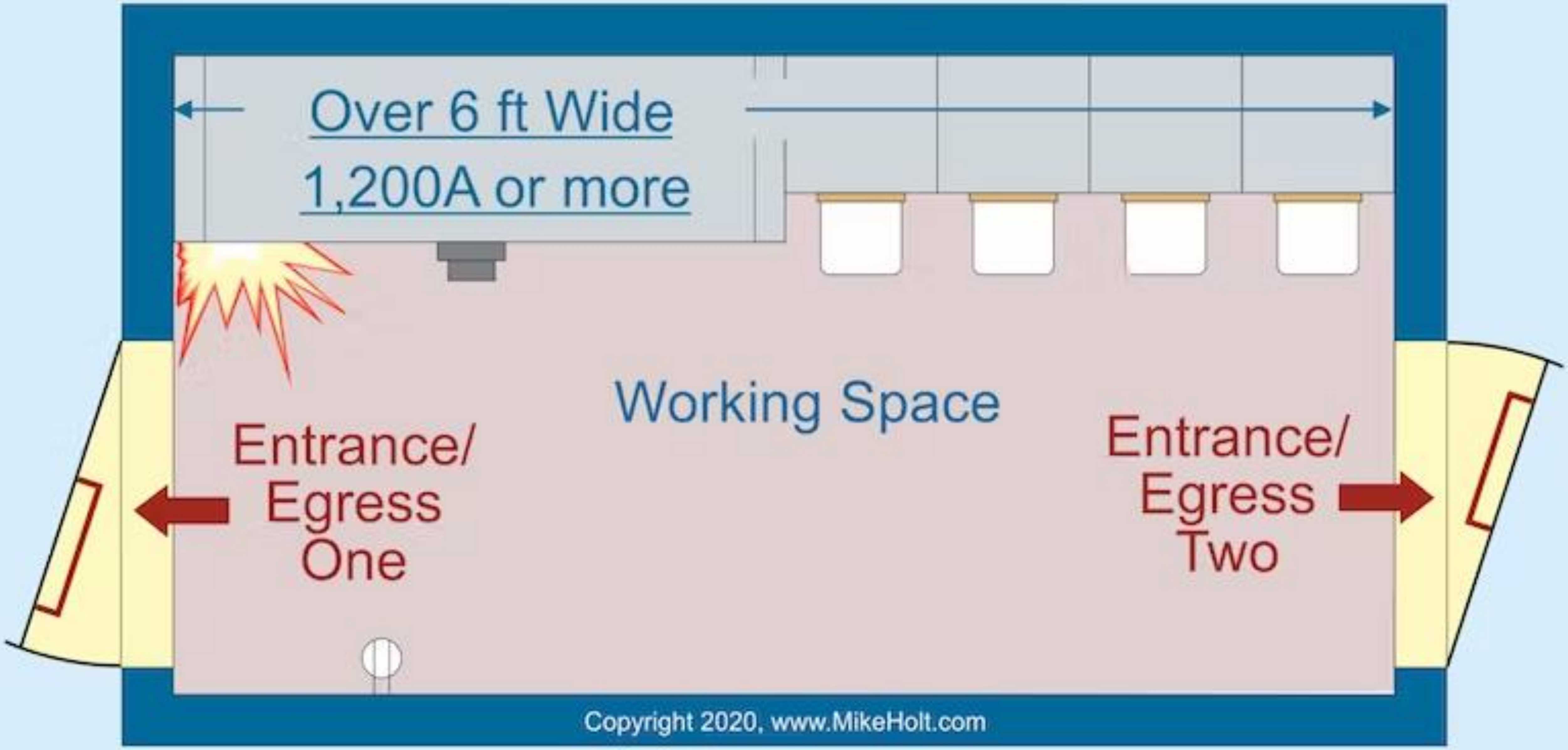
**Bonding Jumper, Supply-Side.** A conductor installed on the supply side of a service or within a service equipment enclosure(s), or for a separately derived system, that ensures the required electrical conductivity between metal parts required to be electrically connected.

# Language Considerations for the NEC (Cont'd)

**<u>Small Words, Grammar, and Punctuation</u>**

- It's not only the technical words that require close attention since simple words can make a big difference to the application of a rule.
  - Was there a comma; was it "or," "and," "other than," "greater than," or "smaller than"? The word "or" can imply alternate choices for wiring methods. A word like "or" gives us choices while the word "and" can mean an additional requirement must be met.
  - An example of these words being used 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 that 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.

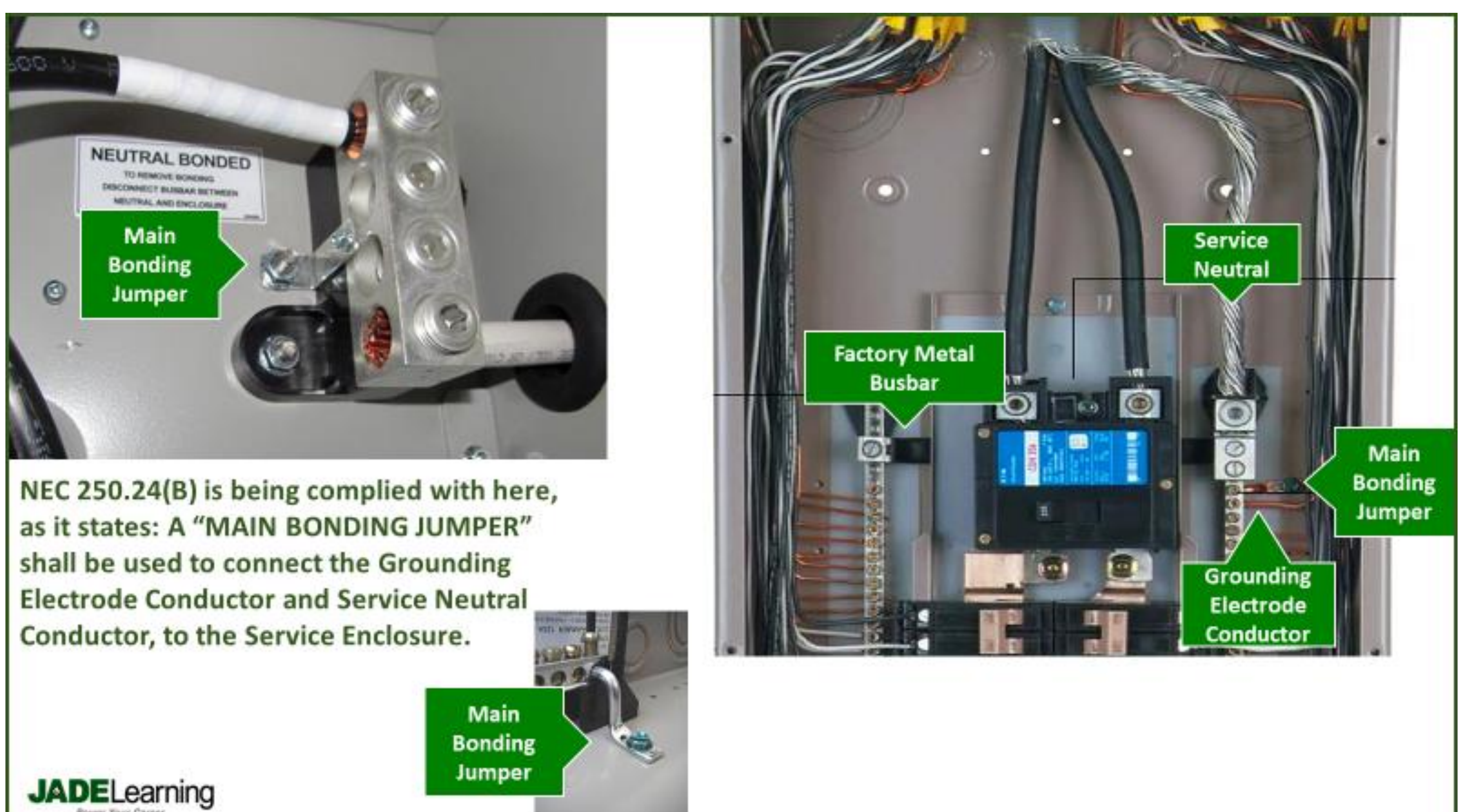
# Access to and Egress from Working Space
## Large Equipment
## *110.26(C)(2)(1)*




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

# Language Considerations for the NEC (Cont'd)

- Grammar and punctuation play an important role in establishing the meaning of a rule.
- The location of a comma can dramatically change the requirement of a rule such as in 250.28(A), where it says a main bonding jumper must be a wire, bus, screw, or similar suitable conductor. If the comma between "bus" and "screw" was removed, only a "bus screw" could be used. That comma makes a big change in the requirements of the rule…



# Language Considerations for the NEC (Cont'd)

**Slang Terms or Technical Jargon**

- Trade-related professionals in different areas of the country often use local "slang" terms that aren't shared by all. This can make it difficult to communicate if it isn't clear what the meaning of those slang terms are.

- Use the proper terms by finding out what their definitions and applications are before you use them.

  - For example, the term "pigtail" is often used to describe the short piece of conductor used to connect a device to a splice, but a "pigtail" is also a term used for a rubberized light socket with pre-terminated conductors. Although the term is the same, the meaning is very different and could cause confusion.

# Identifying Key Words Used in the NEC

***See NEC 90.5 Mandatory Rules, Permissive Rules, and Explanatory Material.***

- **Mandatory Rules.** Mandatory rules of this *Code* are those that identify actions that are specifically required or prohibited and are characterized by the use of the terms *shall* or *shall not*.

- **Permissive Rules.** Permissive rules of this Code are those that identify actions that are allowed but not required, are normally used to describe options or alternative methods, and are characterized by the use of the terms shall be permitted or shall not be required.

- **Explanatory Material.** Explanatory material, such as references to other standards, references to related sections of this Code, or information related to a Code rule, is included in this Code in the form of informational notes. Such notes are informational only and are not enforceable as requirements of this Code.

- **Informative Annexes.** Non-mandatory information relative to the use of the NEC is provided in informative annexes.

# NEC Style & Layout

- It's important to understand the structure and writing style of the Code if you want to use it effectively. The National Electrical Code is organized using eleven 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

# NEC Style & Layout (Cont'd)

**<u>Table of Contents</u>**

- The Table of Contents displays the layout of the chapters, articles, and parts as well as the page numbers. It's an excellent resource and should be referred to periodically to observe the interrelationship of the various NEC components.
- When attempting to locate the rules for a particular situation, knowledgeable Code users often go first to the Table of Contents to quickly find the specific NEC rule that applies.

# NEC Style & Layout (Cont'd)

**Chapters**

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

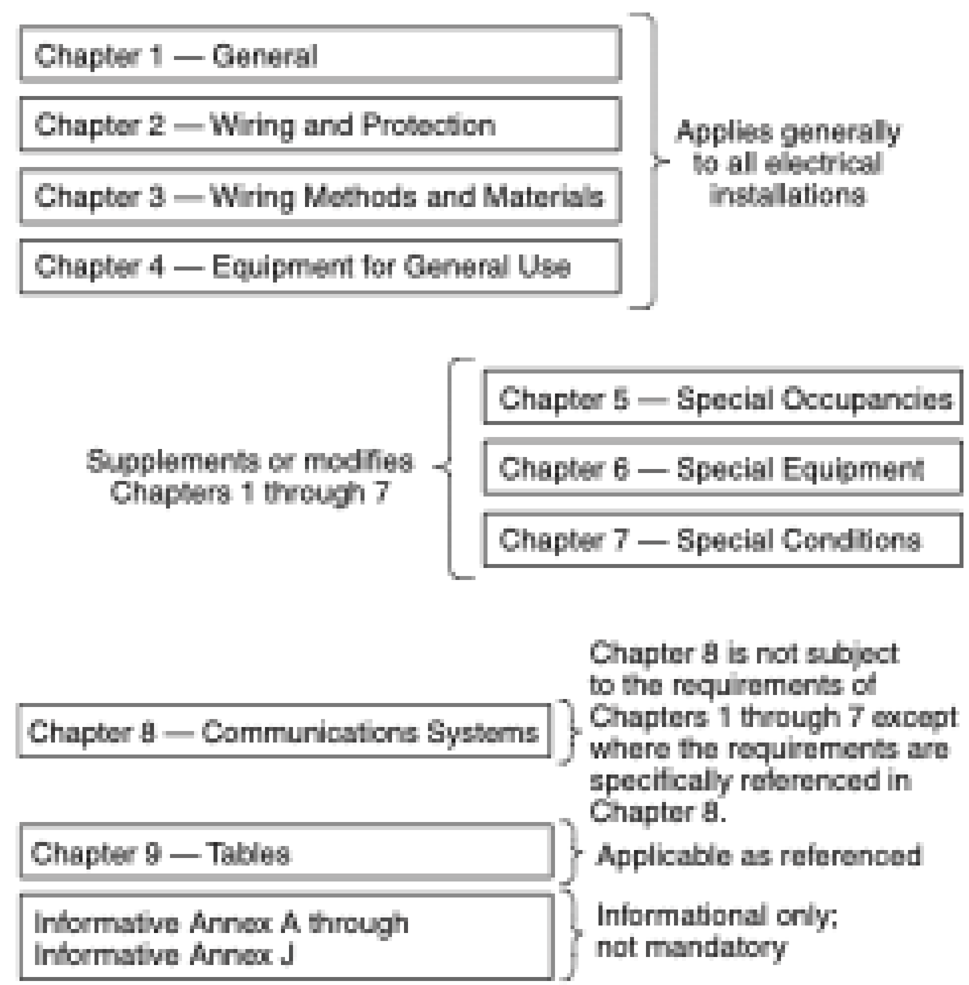



FIGURE 90.3 Code Arrangement.

# NEC Style & Layout (Cont'd)

**Chapter 1 - General :**

- Article 100 - Definitions
- Article 110 - Requirements for Electrical Installation
  - 110.26 Spaces About Electrical Equipment

**Table 110.26(A)(1) Working Spaces**

| Nominal Voltage to Ground | Minimum Clear Distance | | |
|---|---|---|---|
| | Condition 1 | Condition 2 | Condition 3 |
| 0–150 | 900 mm (3 ft) | 900 mm (3 ft) | 900 mm (3 ft) |
| 151–600 | 900 mm (3 ft) | 1.0 m (3 ft 6 in.) | 1.2 m (4 ft) |
| 601–1000 | 900 mm (3 ft) | 1.2 m (4 ft) | 1.5 m (5 ft) |

Note: Where the conditions are as follows:
**Condition 1** — Exposed live parts on one side of the working space and no live or grounded parts on the other side of the working space, or exposed live parts on both sides of the working space that are effectively guarded by insulating materials.
**Condition 2** — Exposed live parts on one side of the working space and grounded parts on the other side of the working space. Concrete, brick, or tile walls shall be considered as grounded.
**Condition 3** — Exposed live parts on both sides of the working space.

# Effective Ground-Fault Current Path to Open Overcurrent Device

## *Article 100 Definition*

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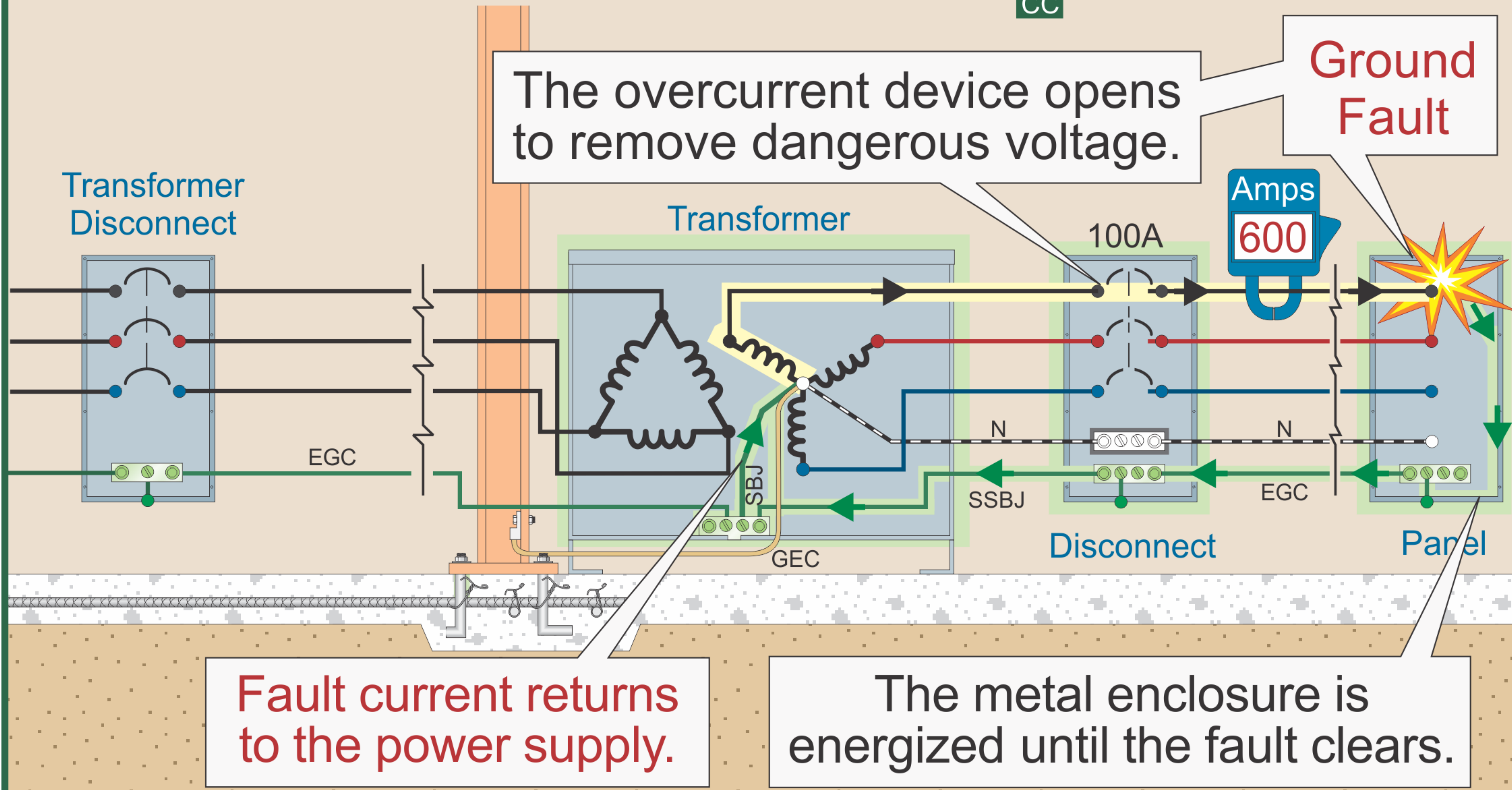



Effective Ground-Fault Current Path
EGC: Equipment Grounding Conductor
GEC: Grounding Electrode Conductor
SBJ: System Bonding Jumper
SSBJ: Supply Side Bonding Jumper
MBJ: Main Bonding Jumper
N: Neutral

# NEC Style & Layout (Cont'd)

**Chapter 2 - Wiring & Protection**

- 200 - Grounded Conductor Use & Identification
- 210 - Branch Circuits
    - GFCI & AFCI Protection requirements found in article 210
- 220 - Branch Circuit, Feeder & Service Calculations
- 230 - Services
- 240 - Overcurrent Protections
- 250 - Grounding & Bonding

**200.6 Means of Identifying Grounded Conductors.**

**(A) Sizes 6 AWG or Smaller.** An insulated grounded conductor of 6 AWG or smaller shall be identified by one of the following means:

(1) A continuous white outer finish.
(2) A continuous gray outer finish.
(3) Three continuous white or gray stripes along the conductor's entire length on other than green insulation.
(4) Wires that have their outer covering finished to show a white or gray color but have colored tracer threads in the braid identifying the source of manufacture shall be considered as meeting the provisions of this section.
(5) The grounded conductor of a mineral-insulated, metal-sheathed cable (Type MI) shall be identified at the time of installation by distinctive marking at its terminations.
(6) A single-conductor, sunlight-resistant, outdoor-rated cable used as a grounded conductor in photovoltaic power systems, as permitted by 690.31, shall be identified at the time of installation by distinctive white marking at all terminations.
(7) Fixture wire shall comply with the requirements for grounded conductor identification as specified in 402.8.
(8) For aerial cable, the identification shall be as above, or by means of a ridge located on the exterior of the cable so as to identify it.

**(B) Sizes 4 AWG or Larger.** An insulated grounded conductor 4 AWG or larger shall be identified by one of the following means:

(1) A continuous white outer finish.
(2) A continuous gray outer finish.
(3) Three continuous white or gray stripes along the conductor's entire length on other than green insulation.
(4) At the time of installation, by a distinctive white or gray marking at its terminations. This marking shall encircle the conductor or insulation.

**250.119 Identification of Equipment Grounding Conductors.** Unless required elsewhere in this *Code*, equipment grounding conductors shall be permitted to be bare, covered, or insulated. Individually covered or insulated equipment grounding conductors shall have a continuous outer finish that is either green or green with one or more yellow stripes except as permitted in this section. Conductors with insulation or individual covering that is green, green with one or more yellow stripes, or otherwise identified as permitted by this section shall not be used for ungrounded or grounded circuit conductors.

*Exception No. 1: Power-limited Class 2 or Class 3 cables, power-limited fire alarm cables, or communications cables containing only circuits operating at less than 50 volts where connected to equipment not required to be grounded in accordance with 250.112(I) shall be permitted to use a conductor with green insulation or green with one or more yellow stripes for other than equipment grounding purposes.*

*Exception No. 2: Flexible cords having an integral insulation and jacket without an equipment grounding conductor shall be permitted to have a continuous outer finish that is green.*

Informational Note: An example of a flexible cord with integral-type insulation is Type SPT-2, 2 conductor.

*Exception No. 3: Conductors with green insulation shall be permitted to be used as ungrounded signal conductors where installed between the output terminations of traffic signal control and traffic signal indicating heads. Signaling circuits installed in accordance with this exception shall include an equipment grounding conductor in accordance with 250.118. Wire-type equipment grounding conductors shall be bare or have insulation or covering that is green with one or more yellow stripes.*

**(A) Conductors 4 AWG and Larger.** Equipment grounding conductors 4 AWG and larger shall comply with 250.119(A)(1) and (A)(2).

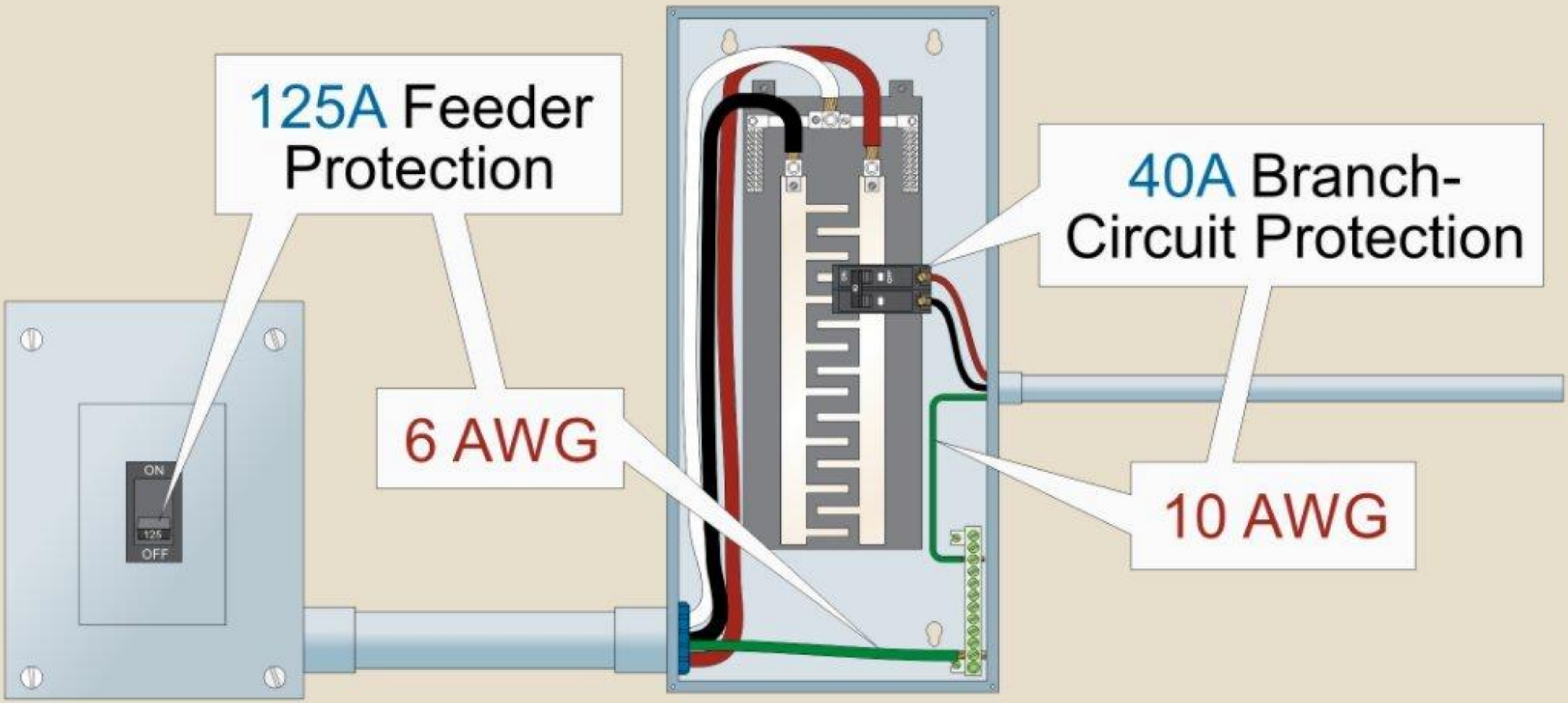
(1) An insulated or covered conductor 4 AWG and larger shall be permitted, at the time of installation, to be permanently identified as an equipment grounding conductor at each end and at every point where the conductor is accessible.

*Exception: Conductors 4 AWG and larger shall not be required to be marked in conduit bodies that contain no splices or unused hubs.*

(2) Identification shall encircle the conductor and shall be accomplished by one of the following:

a. Stripping the insulation or covering from the entire exposed length
b. Coloring the insulation or covering green at the termination
c. Marking the insulation or covering with green tape or green adhesive labels at the termination

# Sizing Equipment Grounding Conductor of the Wire Type
## *250.122(A) Example*



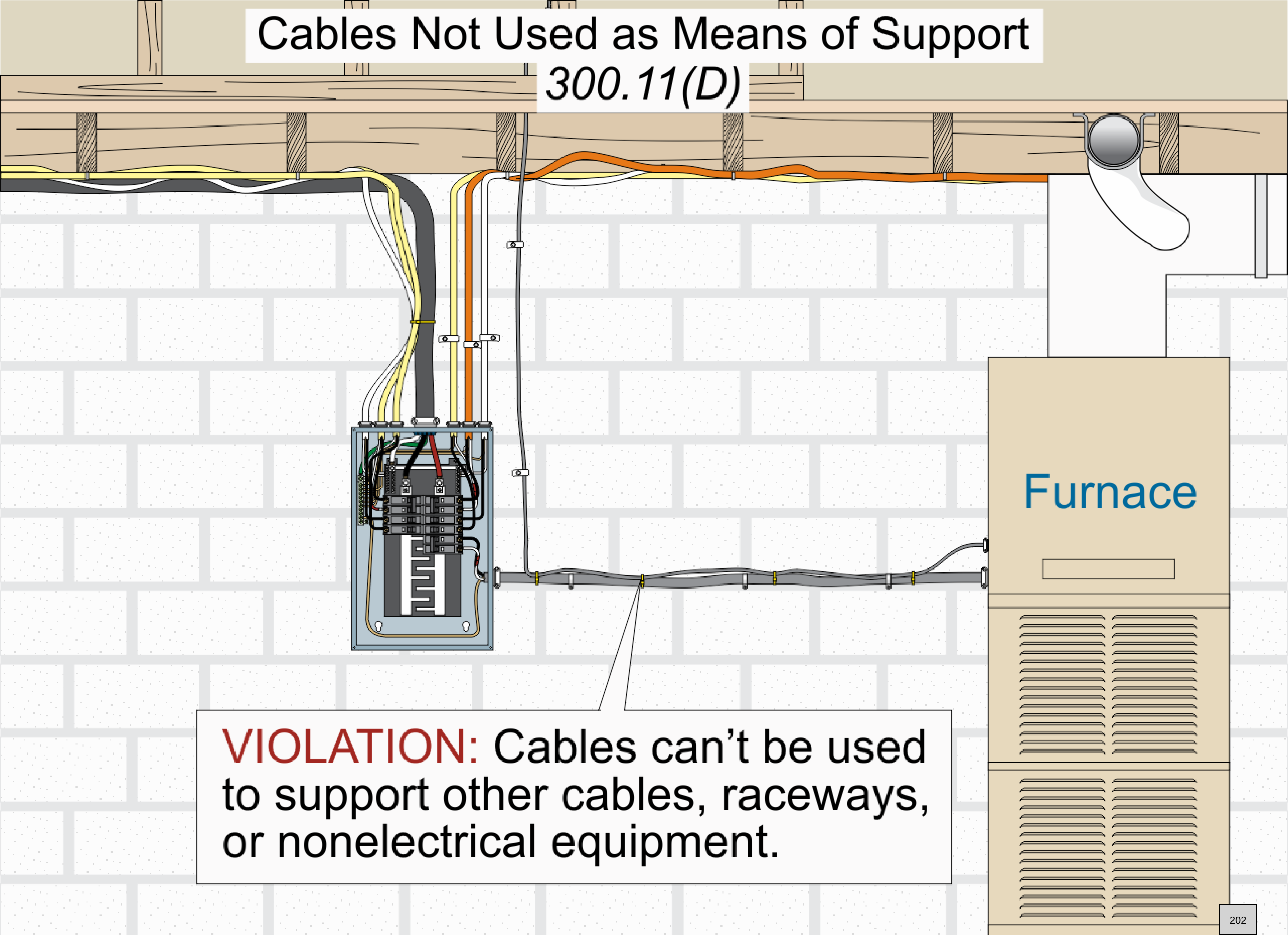

An equipment grounding conductor is sized to the circuit's overcurrent device rating in accordance with Table 250.122.

# NEC Style & Layout (Cont'd)

**Chapter 3 - Wiring Methods & Materials**

- 300 - General Requirements
- 310 - Conductors for General Wiring
  - 310.15(B)(16) Conductor Ampacities
- 312 - Cabinet, Cutout Boxes and Meter Socket Enclosures
- 314 - Outlet, Device, Pull and Junction Boxes
  - 314.16 Box Fill
- 320-399 - Various Wiring Materials
  - MC Cable, Romex, FMC, LFMC, ETC.

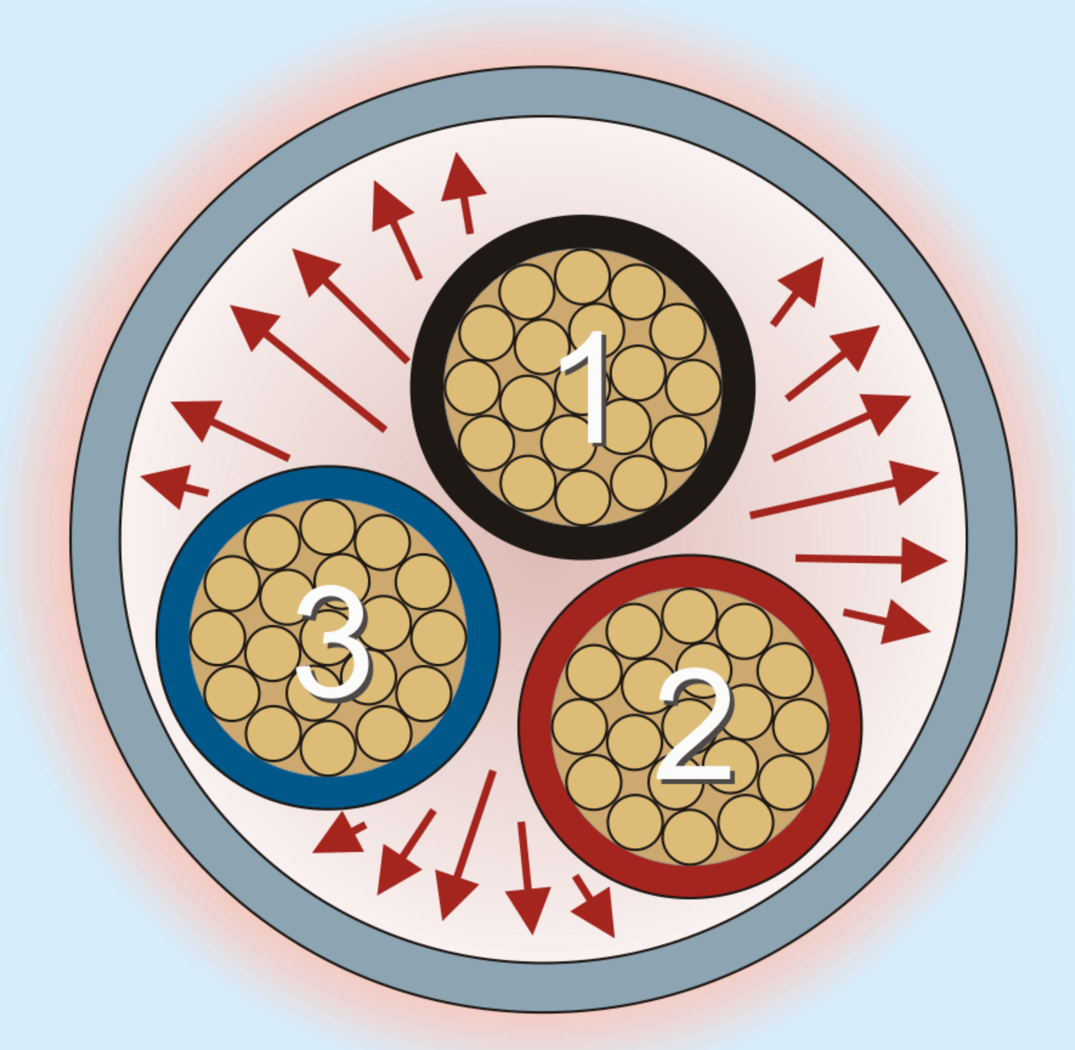
# Cables Not Used as Means of Support
*300.11(D)*




VIOLATION: Cables can't be used to support other cables, raceways, or nonelectrical equipment.

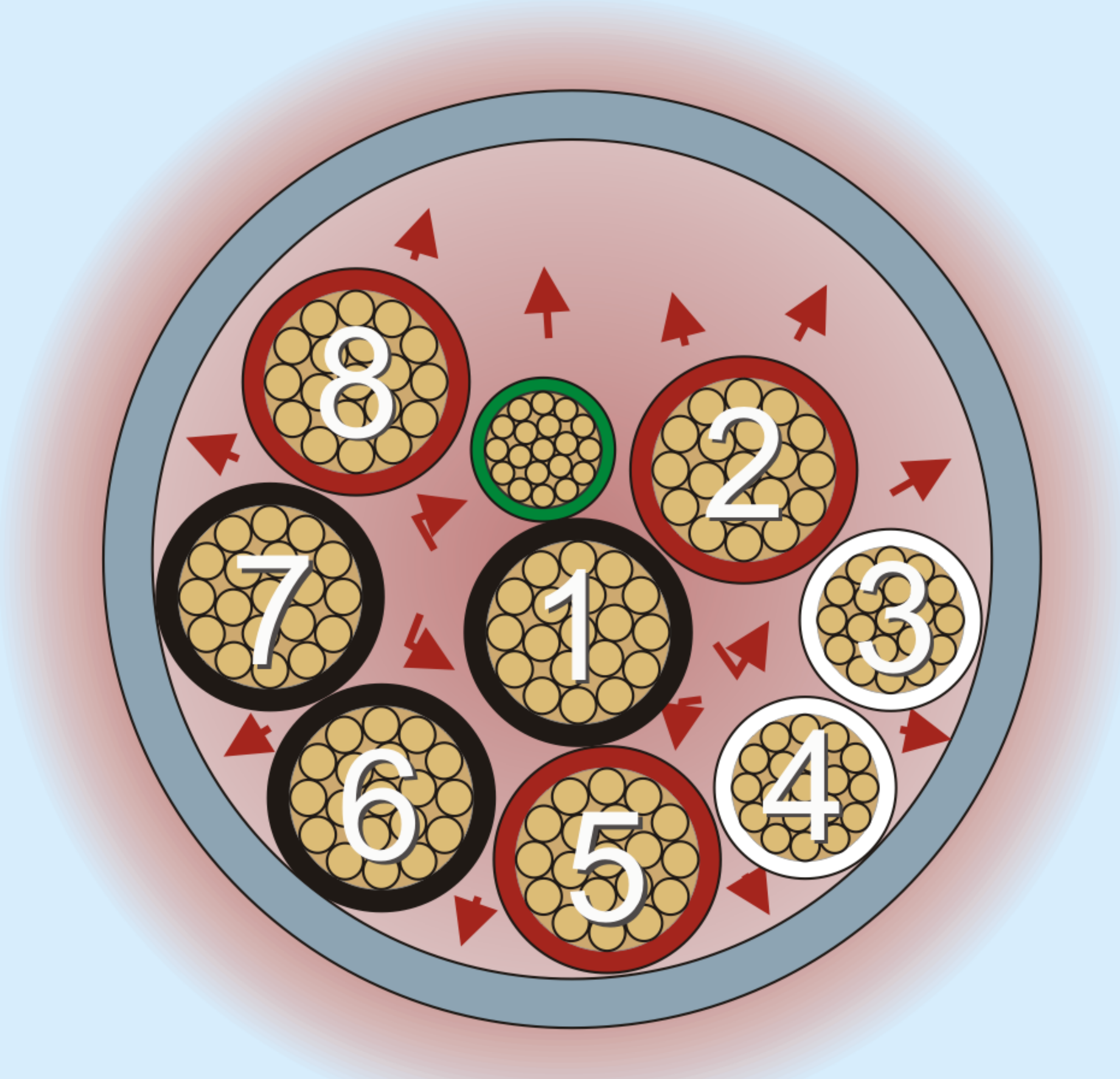
# Conductor Ampacity Adjustment Factor
## *310.15(B)(3)(a)*

## No Ampacity Adjustment Three or Fewer Conductors



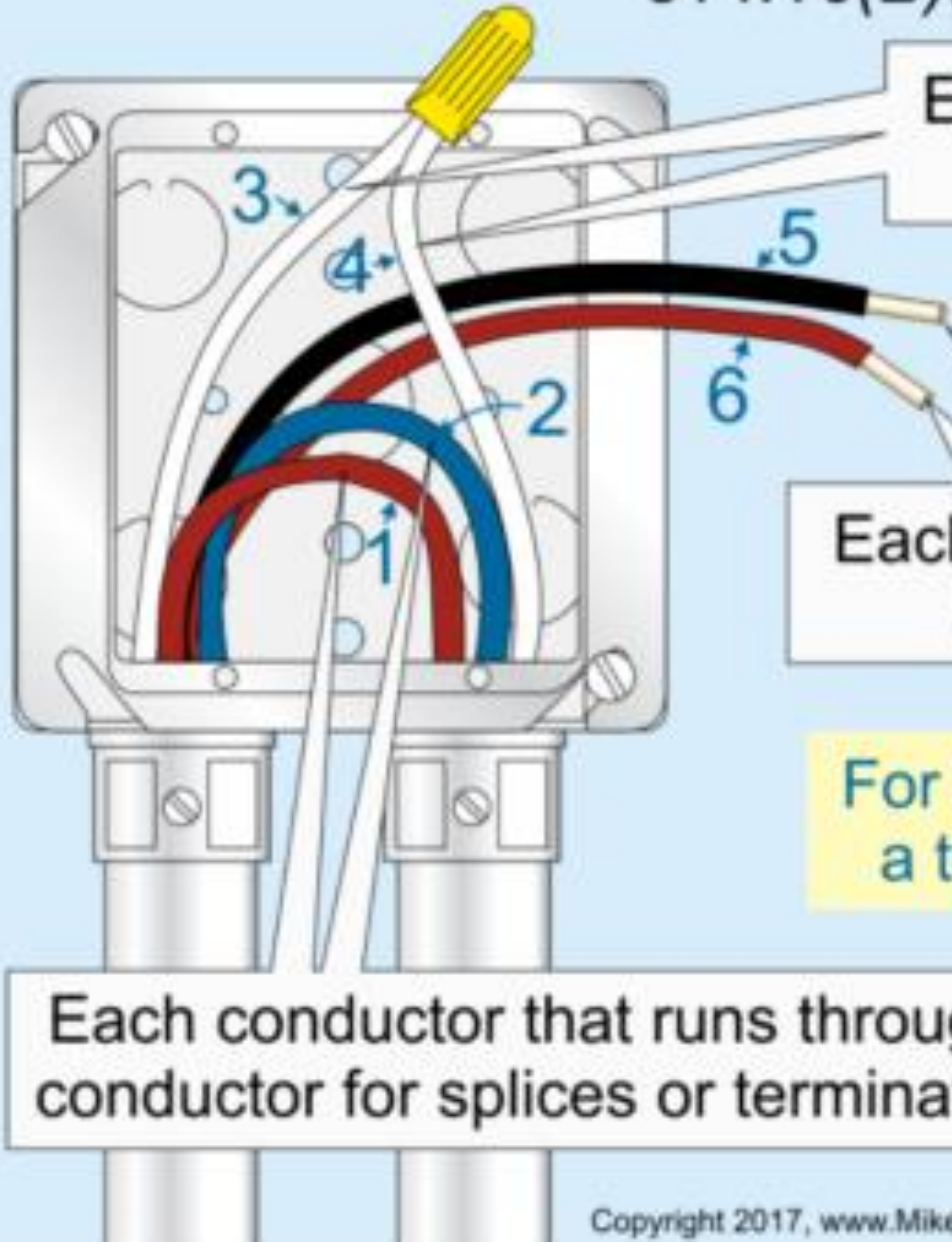

Conductors have more surface area for heat dissipation.

## Ampacity Adjustment Factor = 70%




Bundled conductors have heat held in by other conductors.

# Box Fill Calculations, Conductor Fill
*314.16(B)(1)*



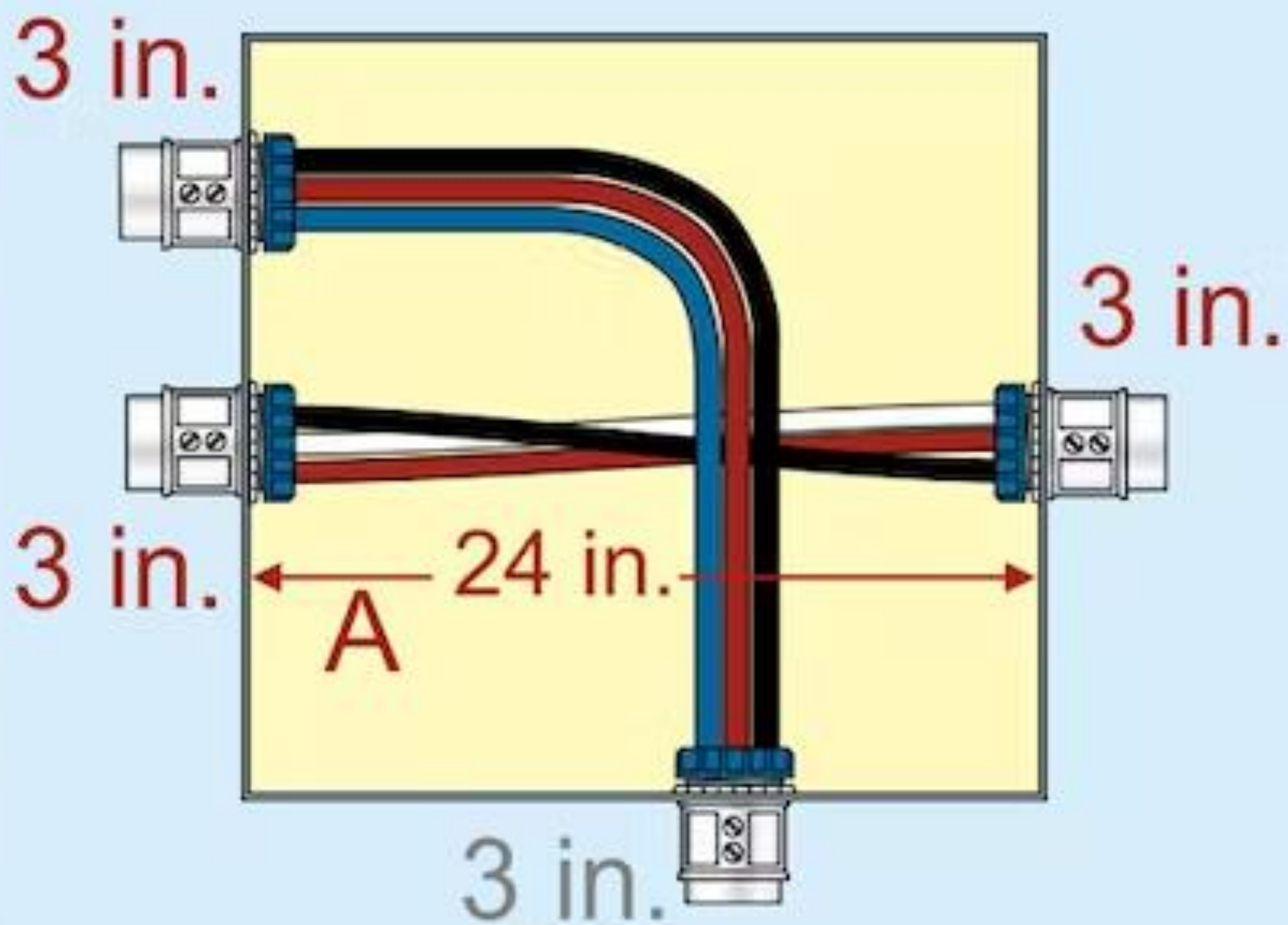

Each spliced conductor is counted as one.

Each terminating conductor is counted as one.

For this example, there are a total of six conductors.

Each conductor that runs through without 12 in. of free conductor for splices or terminations is counted as one.

# Pull and Junction Boxes, Horizontal Conductors 4 AWG and Larger
## *314.28(A) Example*




**Horizontal Dimension A**

**Straight Pull:**
Left to Right: 8 x 3 = 24 in.
Right to Left: 8 x 3 = 24 in.

**Angle Pull:**
Left to Right: (6 x 3) + 3 = 21 in.
Right to Left: No Calculation

**Largest Calculation = 24 in.**

# NEC Style & Layout (Cont'd)

**Chapter 3 - Cont'd**

- Common Subsection Layout for Wiring Materials:
  - xxx.2 - Definitions
  - xxx.10 - Uses Permitted
  - xxx.12 - Uses Not Permitted
  - xxx.24 - Bending Radius
  - xxx.30 - Securing & Supporting

# NEC Style & Layout (Cont’d)

**Chapter 4 - Equipment For General Use**

- 400 - Flexible Cords and Cables
  - Cord Ampacities
- 404 - Switches
  - Maximum mounting height of switches
- 406 - Receptacle, Cord Connectors and Attachment Plugs
  - TR & WR Requirements
- 408 - Switchboards, Switchgear and Panelboards
- 410 - Luminaires
- 430 - Motors
- 450 - Transformers

**Table 400.5(A)(1) Allowable Ampacity for Flexible Cords and Flexible Cables [Based on Ambient Temperature of 30°C (86°F). See 400.13 and Table 400.4.]**

| Copper Conductor Size (AWG) | Thermoplastic Types TPT, TST | Thermoset Types C, E, EO, PD, S, SJ, SJO, SJOW, SJOO, SJOOW, SO, SOW, SOO, SOOW, SP-1, SP-2, SP-3, SRD, SV, SVO, SVOO, NISP-1, NISP-2 / Thermoplastic Types ETP, ETT, NISPE-1, NISPE-2, NISPT-1, NISPT-2, SE, SEW, SEO, SEOO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW, SPE-1, SPE-2, SPE-3, SPT-1, SPT-1W, SPT-2, SPT-2W, SPT-3, ST, STW, SRDE, SRDT, STO, STOW, STOO, STOOW, SVE, SVEO, SVEOO, SVT, SVTO, SVTOO | | Types HPD, HPN, HSJ, HSJO, HSJOW, HSJOO, HSJOOW |
|---|---|---|---|---|
| | | Column A[a] | Column B[b] | |
| 27[c] | 0.5 | — | — | — |
| 20 | — | 5[d] | [e] | — |
| 18 | — | 7 | 10 | 10 |
| 17 | — | 9 | 12 | 13 |
| 16 | — | 10 | 13 | 15 |
| 15 | — | 12 | 16 | 17 |
| 14 | — | 15 | 18 | 20 |
| 13 | — | 17 | 21 | — |
| 12 | — | 20 | 25 | 30 |
| 11 | — | 23 | 27 | — |
| 10 | — | 25 | 30 | 35 |
| 9 | — | 29 | 34 | — |
| 8 | — | 35 | 40 | — |
| 7 | — | 40 | 47 | — |
| 6 | — | 45 | 55 | — |
| 5 | — | 52 | 62 | — |
| 4 | — | 60 | 70 | — |
| 3 | — | 70 | 82 | — |
| 2 | — | 80 | 95 | — |

[a]The allowable currents under Column A apply to three-conductor cords and other multiconductor cords connected to utilization equipment so that only three-conductors are current-carrying.

[b]The allowable currents under Column B apply to two-conductor cords and other multiconductor cords connected to utilization equipment so that only two conductors are current-carrying.

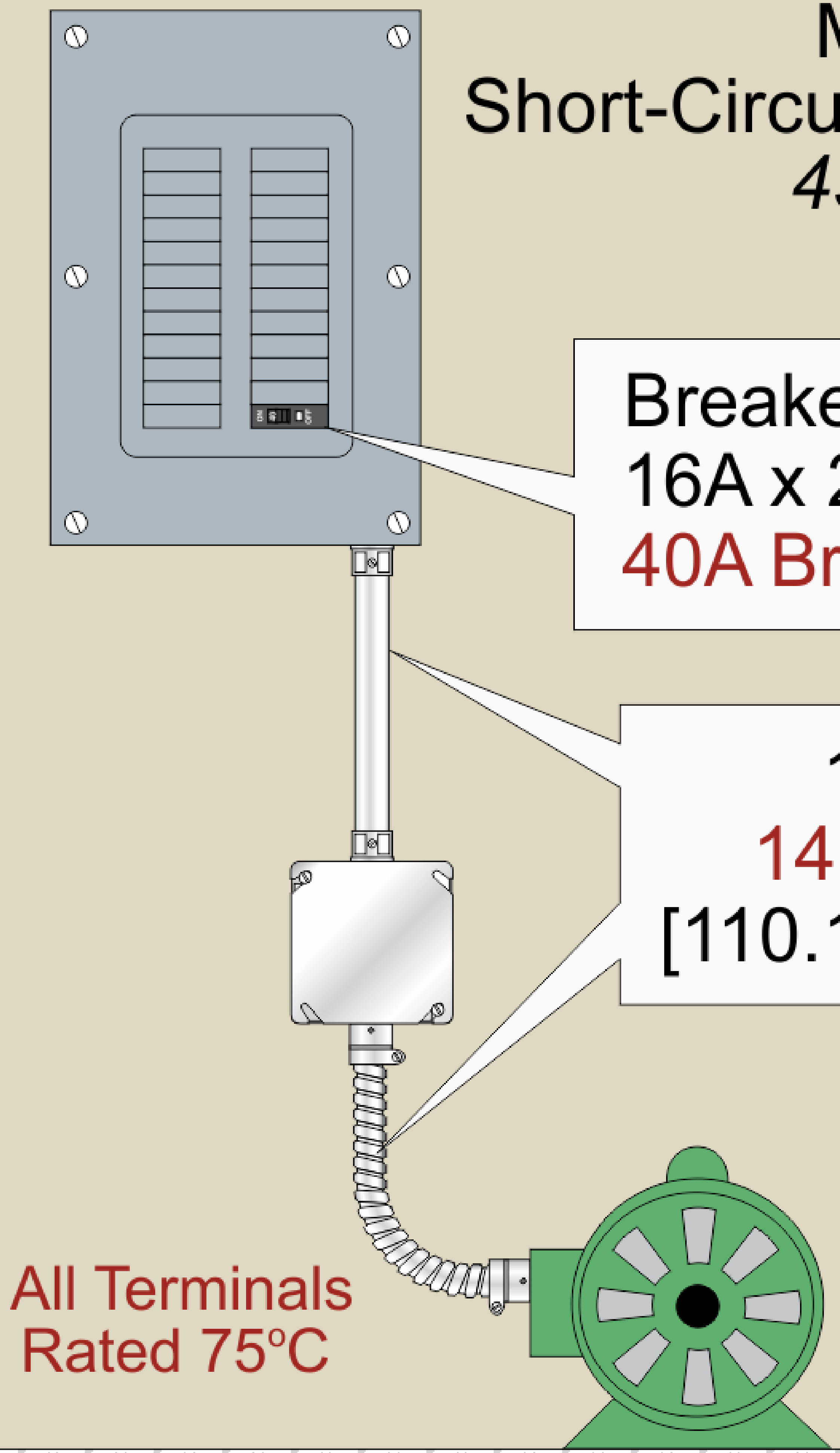
[c]Tinsel cord.

[d]Elevator cables only.

[e]7 amperes for elevator cables only; 2 amperes for other types.

# Motor Branch-Circuit Short-Circuit and Ground-Fault Protection

*430.52(C)(1) Example*




Breaker, FLC x 250%
16A x 250% = 40A
40A Breaker [240.6(A)]

16A FLC x 125% = 20A
14 AWG Rated 20A at 75°C
[110.14(C)(1)(a)(3), Table 310.16]

1 hp,
115 Volt
16A FLC
[Table 430.248]

**Table 430.250 Full-Load Current, Three-Phase Alternating-Current Motors**

The following values of full-load currents are typical for motors running at speeds usual for belted motors and motors with normal torque characteristics. The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.

| | Induction-Type Squirrel Cage and Wound Rotor (Amperes) | | | | | | | Synchronous-Type Unity Power Factor* (Amperes) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Horsepower | 115 Volts | 200 Volts | 208 Volts | 230 Volts | 460 Volts | 575 Volts | 2300 Volts | 230 Volts | 460 Volts | 575 Volts | 2300 Volts |
| ½ | 4.4 | 2.5 | 2.4 | 2.2 | 1.1 | 0.9 | — | — | — | — | — |
| ¾ | 6.4 | 3.7 | 3.5 | 3.2 | 1.6 | 1.3 | — | — | — | — | — |
| 1 | 8.4 | 4.8 | 4.6 | 4.2 | 2.1 | 1.7 | — | — | — | — | — |
| 1½ | 12.0 | 6.9 | 6.6 | 6.0 | 3.0 | 2.4 | — | — | — | — | — |
| 2 | 13.6 | 7.8 | 7.5 | 6.8 | 3.4 | 2.7 | — | — | — | — | — |
| 3 | — | 11.0 | 10.6 | 9.6 | 4.8 | 3.9 | — | — | — | — | — |
| 5 | — | 17.5 | 16.7 | 15.2 | 7.6 | 6.1 | — | — | — | — | — |
| 7½ | — | 25.3 | 24.2 | 22 | 11 | 9 | — | — | — | — | — |
| 10 | — | 32.2 | 30.8 | 28 | 14 | 11 | — | — | — | — | — |
| 15 | — | 48.3 | 46.2 | 42 | 21 | 17 | — | — | — | — | — |
| 20 | — | 62.1 | 59.4 | 54 | 27 | 22 | — | — | — | — | — |
| 25 | — | 78.2 | 74.8 | 68 | 34 | 27 | — | 53 | 26 | 21 | — |
| 30 | — | 92 | 88 | 80 | 40 | 32 | — | 63 | 32 | 26 | — |
| 40 | — | 120 | 114 | 104 | 52 | 41 | — | 83 | 41 | 33 | — |
| 50 | — | 150 | 143 | 130 | 65 | 52 | — | 104 | 52 | 42 | — |
| 60 | — | 177 | 169 | 154 | 77 | 62 | 16 | 123 | 61 | 49 | 12 |
| 75 | — | 221 | 211 | 192 | 96 | 77 | 20 | 155 | 78 | 62 | 15 |
| 100 | — | 285 | 273 | 248 | 124 | 99 | 26 | 202 | 101 | 81 | 20 |
| 125 | — | 359 | 343 | 312 | 156 | 125 | 31 | 253 | 126 | 101 | 25 |
| 150 | — | 414 | 396 | 360 | 180 | 144 | 37 | 302 | 151 | 121 | 30 |
| 200 | | 552 | 528 | 480 | 240 | 192 | 49 | 400 | 201 | 161 | 40 |
| 250 | — | — | — | — | 302 | 242 | 60 | — | — | — | — |
| 300 | — | — | — | — | 361 | 289 | 72 | — | — | — | — |
| 350 | — | — | — | — | 414 | 336 | 83 | — | — | — | — |
| 400 | — | — | — | — | 477 | 382 | 95 | — | — | — | — |
| 450 | — | — | — | — | 515 | 412 | 103 | — | — | — | — |
| 500 | — | — | — | — | 590 | 472 | 118 | — | — | — | — |

*For 90 and 80 percent power factor, the figures shall be multiplied by 1.1 and 1.25, respectively.

**Table 450.3(B) Maximum Rating or Setting of Overcurrent Protection for Transformers 1000 Volts and Less (as a Percentage of Transformer-Rated Current)**

| | Primary Protection | | | Secondary Protection (See Note 2.) | |
|---|---|---|---|---|---|
| Protection Method | Currents of 9 Amperes or More | Currents Less Than 9 Amperes | Currents Less Than 2 Amperes | Currents of 9 Amperes or More | Currents Less Than 9 Amperes |
| Primary only protection | 125% (See Note 1.) | 167% | 300% | Not required | Not required |
| Primary and secondary protection | 250% (See Note 3.) | 250% (See Note 3.) | 250% (See Note 3.) | 125% (See Note 1.) | 167% |

Notes:
1. Where 125 percent of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, a higher rating that does not exceed the next higher standard rating shall be permitted.
2. Where secondary overcurrent protection is required, the secondary overcurrent device shall be permitted to consist of not more than six circuit breakers or six sets of fuses grouped in one location. Where multiple overcurrent devices are utilized, the total of all the device ratings shall not exceed the allowed value of a single overcurrent device.
3. A transformer equipped with coordinated thermal overload protection by the manufacturer and arranged to interrupt the primary current shall be permitted to have primary overcurrent protection rated or set at a current value that is not more than six times the rated current of the transformer for transformers having not more than 6 percent impedance and not more than four times the rated current of the transformer for transformers having more than 6 percent but not more than 10 percent impedance.

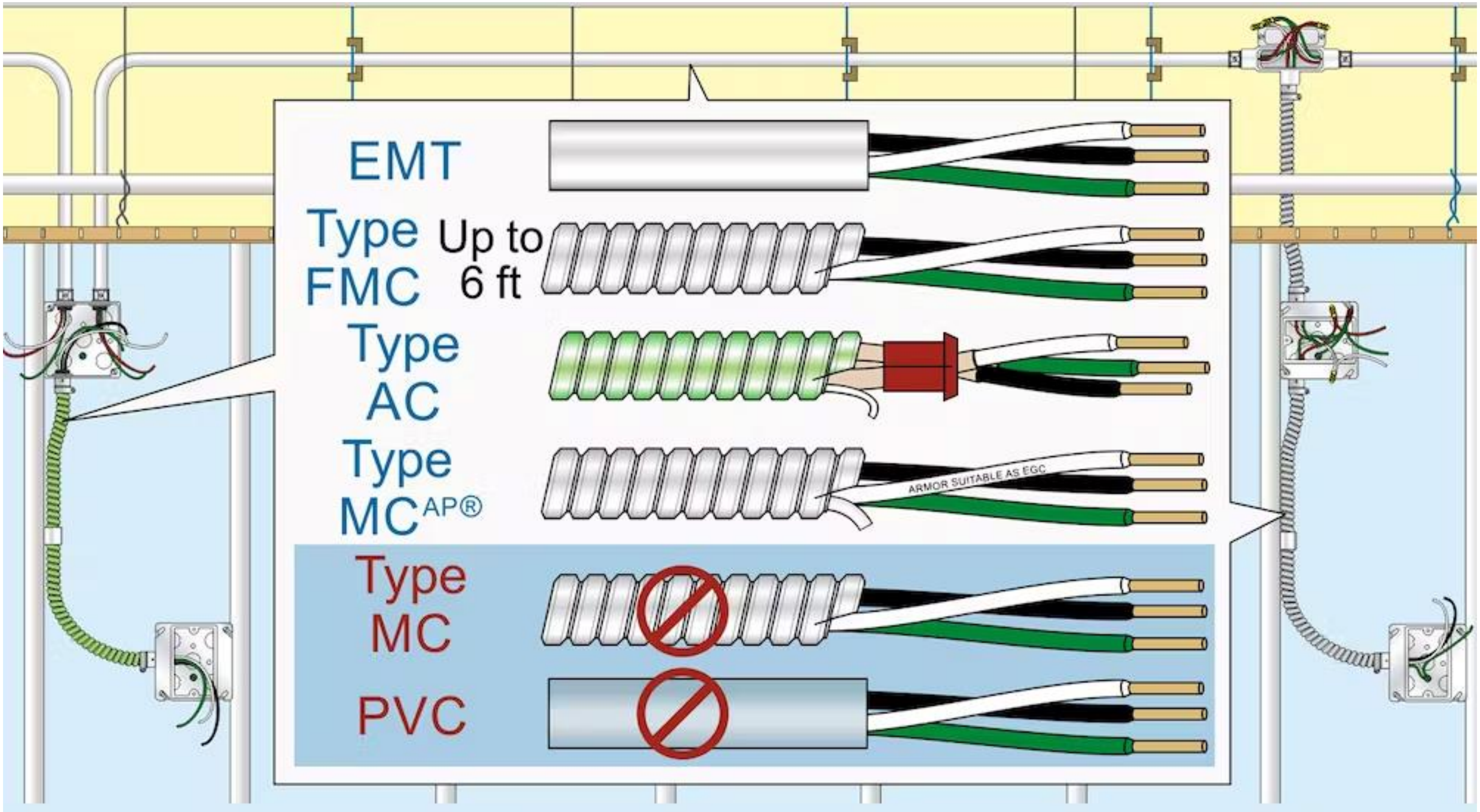
# NEC Style & Layout (Cont'd)

**Chapter 5 - Special Occupancies**

- 500-503 - Hazardous (Classified) Locations
- 511 - Commercial Garages, Repair & Storage
- 517 - Healthcare Facilities

*Chapter 5 supplements or modifies the requirements in Chapters 1-4 (wiring methods, etc.)*

# EGCs in Health Care Facilities



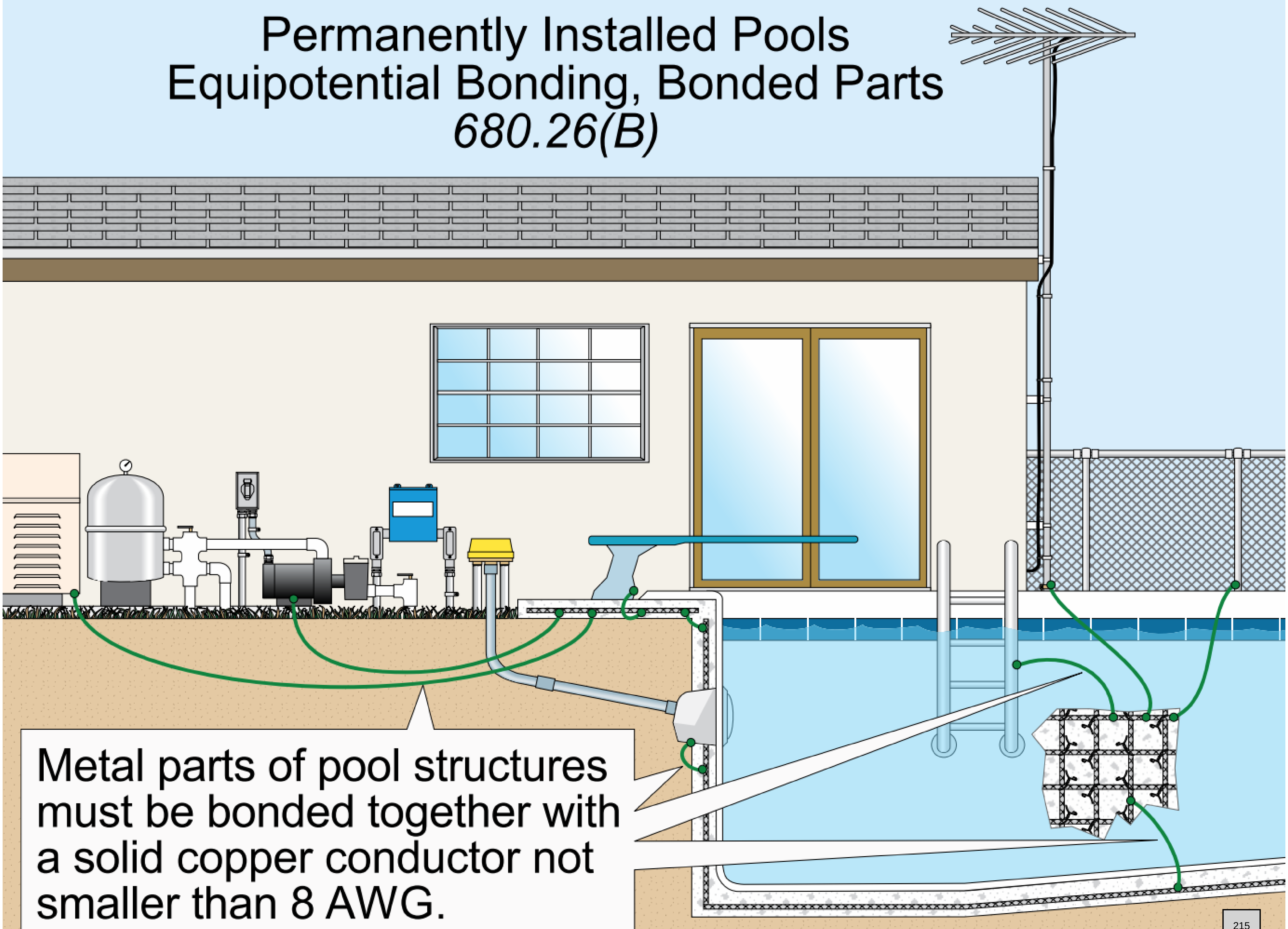
# NEC Style & Layout (Cont'd)

**Chapter 6 - Special Equipment**

- 600 - Electric Signs
- 625 - Electric Vehicle Charging Systems
- 680 - Swimming Pools, Fountains and Similar Installations
- 690 - Solar (PV)
- 695 - Fire Pumps

***Chapter 6 supplements or modifies the requirements in Chapters 1-4 (wiring methods, etc.)***

# Permanently Installed Pools
# Equipotential Bonding, Bonded Parts
# *680.26(B)*

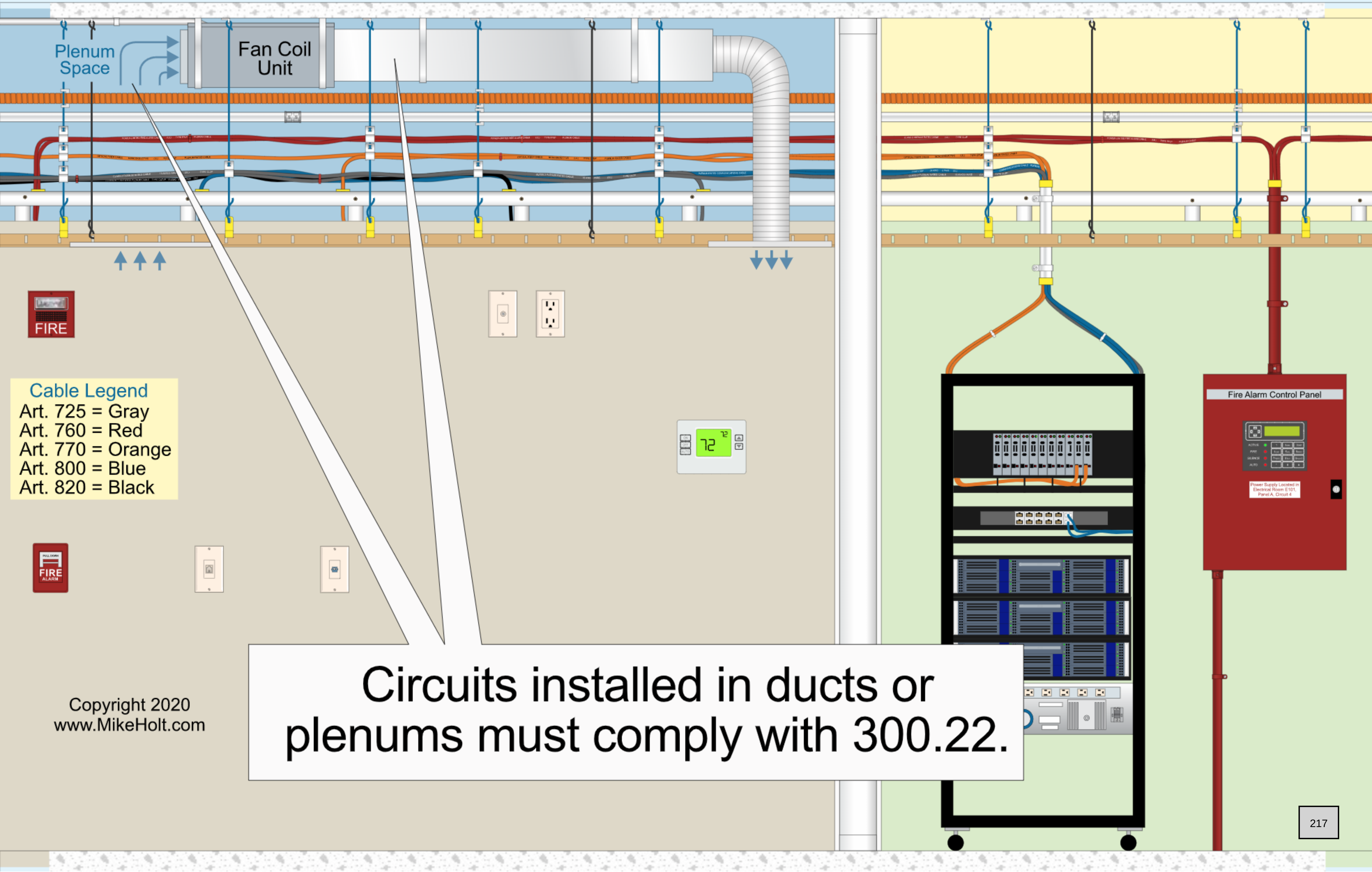


# NEC Style & Layout (Cont’d)

**Chapter 7 - Special Conditions**

- 700 - Emergency Systems
  - What classifies a system as an *emergency system*?
- 701 - Legally Required Standby Systems
- 702 - Optional Standby Systems
- 760 - Fire Alarm Systems

# Class 1 and Class 2 Circuits, Other Articles
# Ducts and Plenums Spaces
# *725.3(C)*



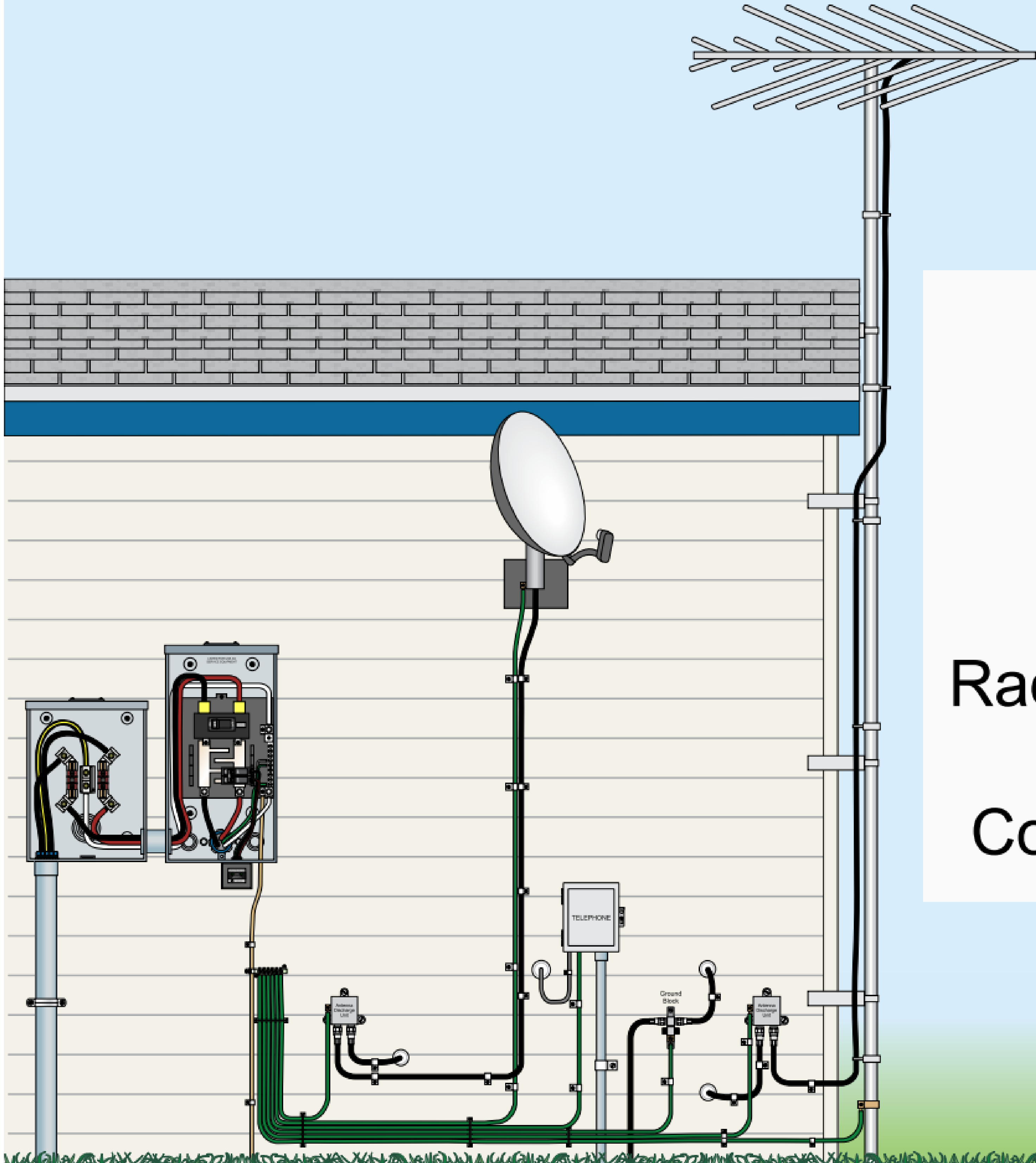
# NEC Style & Layout (Cont'd)

**Chapter 8 - Communication Systems**

- Yeah, it's in our code!

**800.24 Mechanical Execution of Work.** Communications circuits and equipment shall be installed in a neat and workmanlike manner. Cables installed exposed on the surface of ceilings and sidewalls shall be supported by the building structure in such a manner that the cable will not be damaged by normal building use. Such cables shall be secured by hardware, including straps, staples, cable ties, hangers, or similar fittings, designed and installed so as not to damage the cable. The installation shall also conform to 300.4(D) and 300.11. Nonmetallic cable ties and other nonmetallic cable accessories used to secure and support cables in other spaces used for environmental air (plenums) shall be listed as having low smoke and heat release properties in accordance with 800.170(C).

# Chapter 8
# Communications Systems

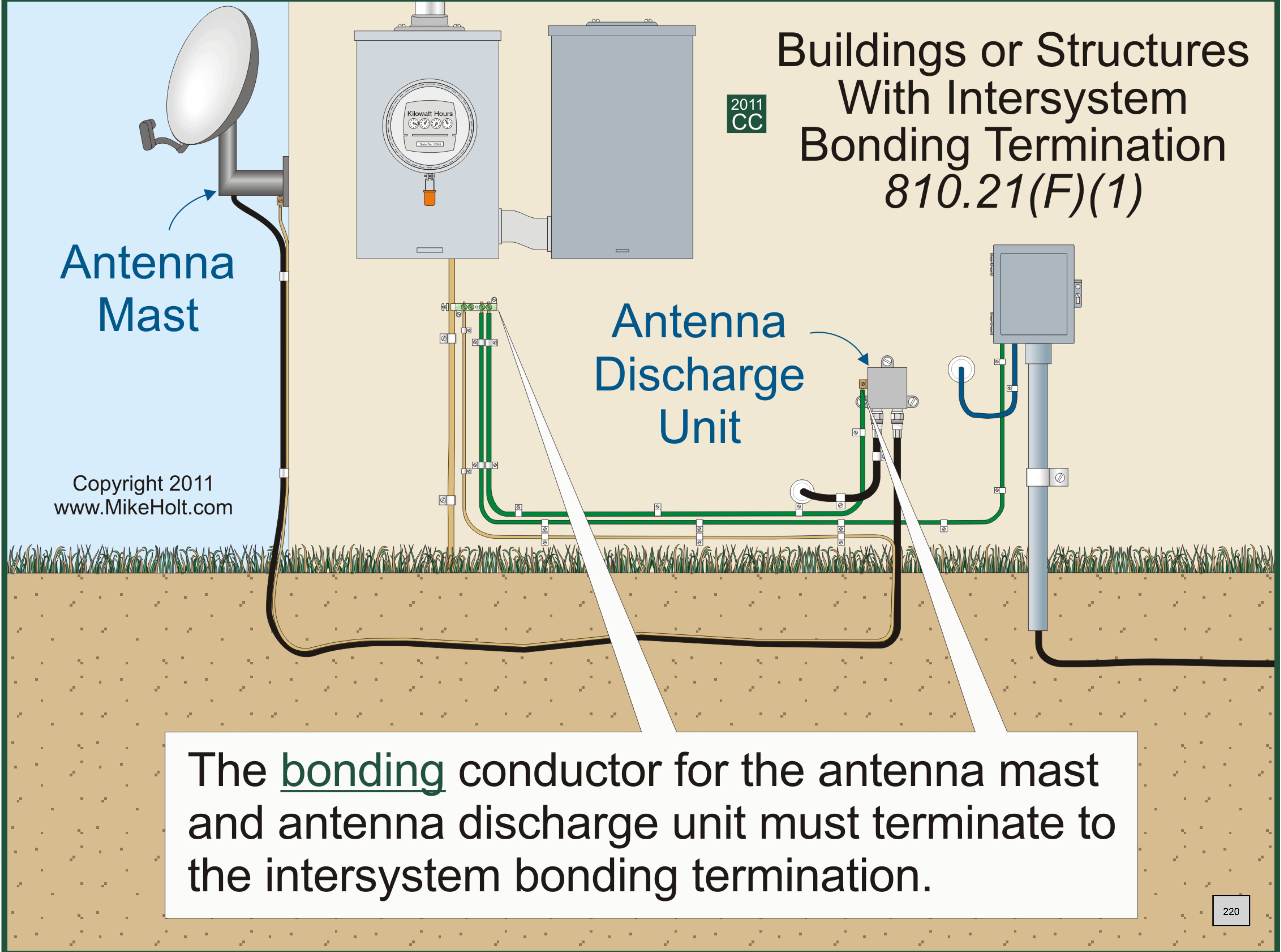



## Article 800
Communications Systems

## Article 805
Communications Circuits

## Article 810
Radio and Television Equipment

## Article 820
Community Antenna Television


Buildings or Structures
With Intersystem
Bonding Termination
810.21(F)(1)
2011
CC
Antenna
Mast
Kilowatt Hours
Antenna
Discharge
Unit
The bonding conductor for the antenna mast and antenna discharge unit must terminate to the intersystem bonding termination.

# NEC Style & Layout (Cont'd)

**Articles**

- The NEC contains approximately 140 articles, each of which covers a specific subject.
- It begins with Article 90, the introduction to the Code, and contains the purpose of the NEC, what's covered and what isn't covered, along with how the Code is arranged. It also gives information on enforcement and how mandatory and permissive rules are written and how explanatory material is included. Article 90 also includes information on formal interpretations, examination of equipment for safety, wiring planning, and information about format- ting units of measurement.

# NEC Style & Layout (Cont'd)

- Here are some other examples of articles you'll find in the NEC:

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

***Can you give other examples of articles you'll find in the NEC???***

# NEC Style & Layout (Cont’d)

**Parts**

- Larger articles are subdivided into parts. Because the parts of a Code article aren’t included in the section numbers, we have a tendency to forget what “part” an NEC rule is relating to.
    - For example, Table 110.34(A) contains working space clearances for electrical equipment. If we aren’t careful, we might think this table applies to all electrical installations, but Table 110.34(A) is located in **Part III**, which only contains requirements for “Over 1,000 Volts, Nominal” installations. The rules for working clearances for electrical equipment for systems 1,000V, nominal, or less are contained in Table 110.26(A)(1), which is located in **Part II**—1,000 Volts, Nominal, or Less.

# NEC Style & Layout (Cont'd)

***Here's the part(s) layout for Article 250 (Grounding & Bonding) and Article 430 (Motors)***

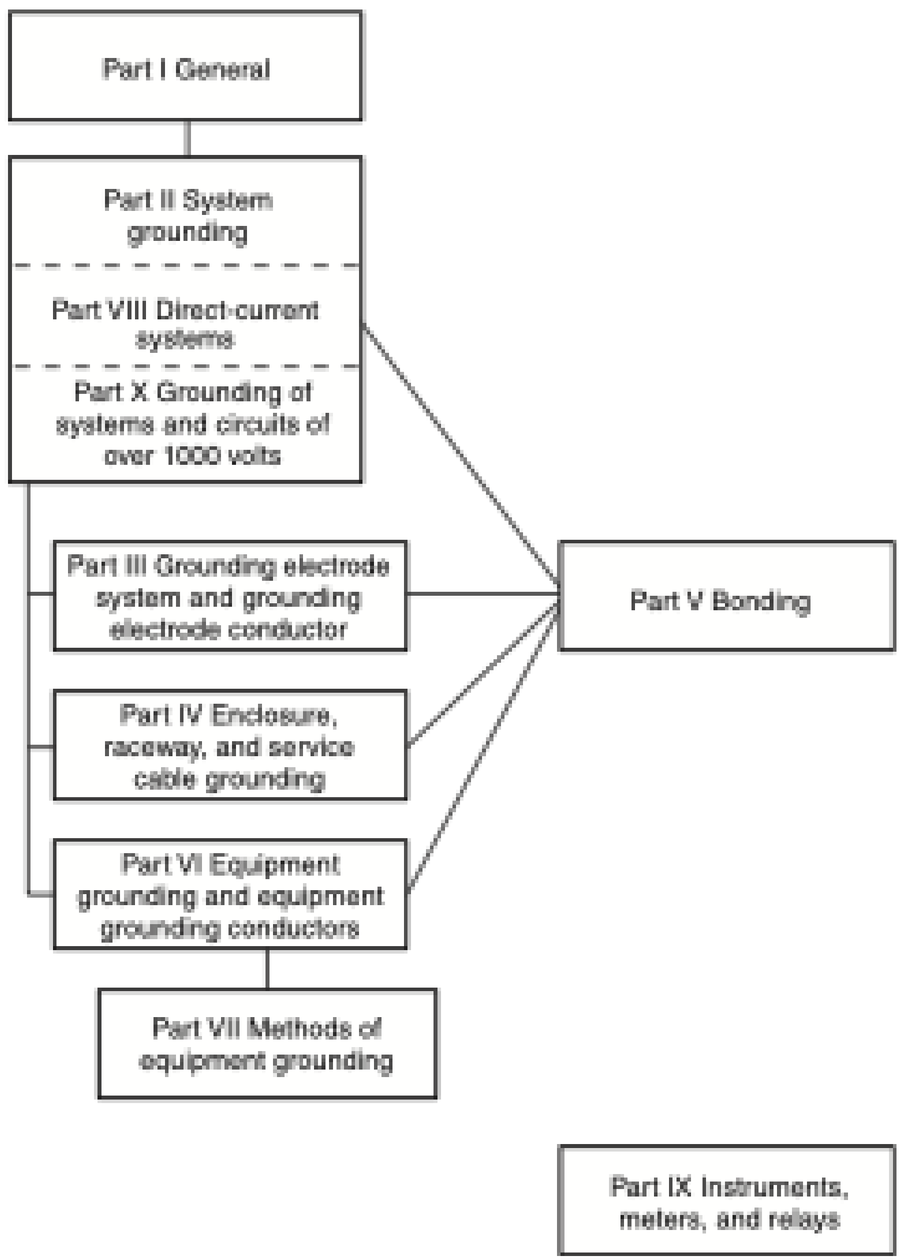



**FIGURE 250.1** Grounding and Bonding.

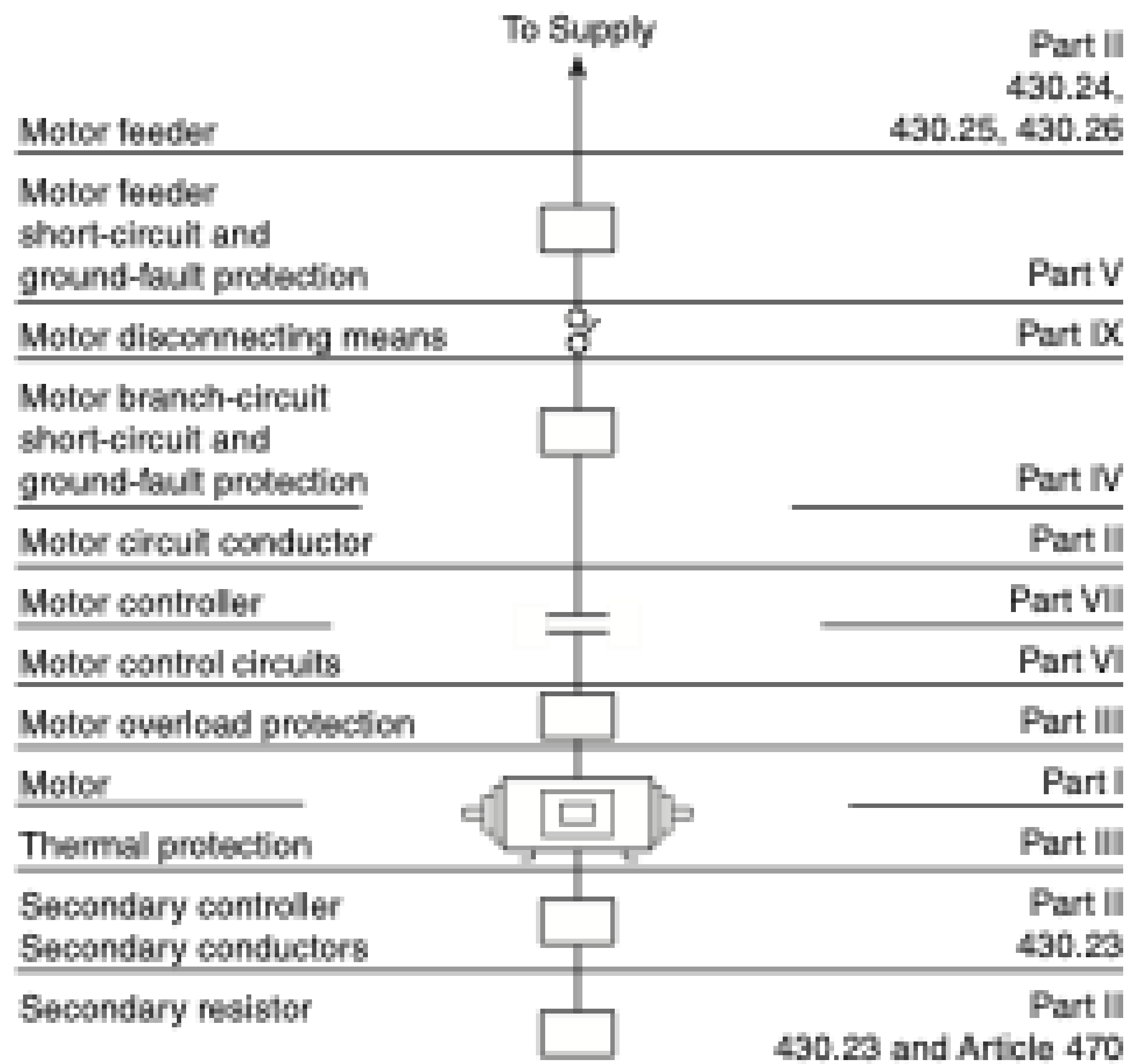
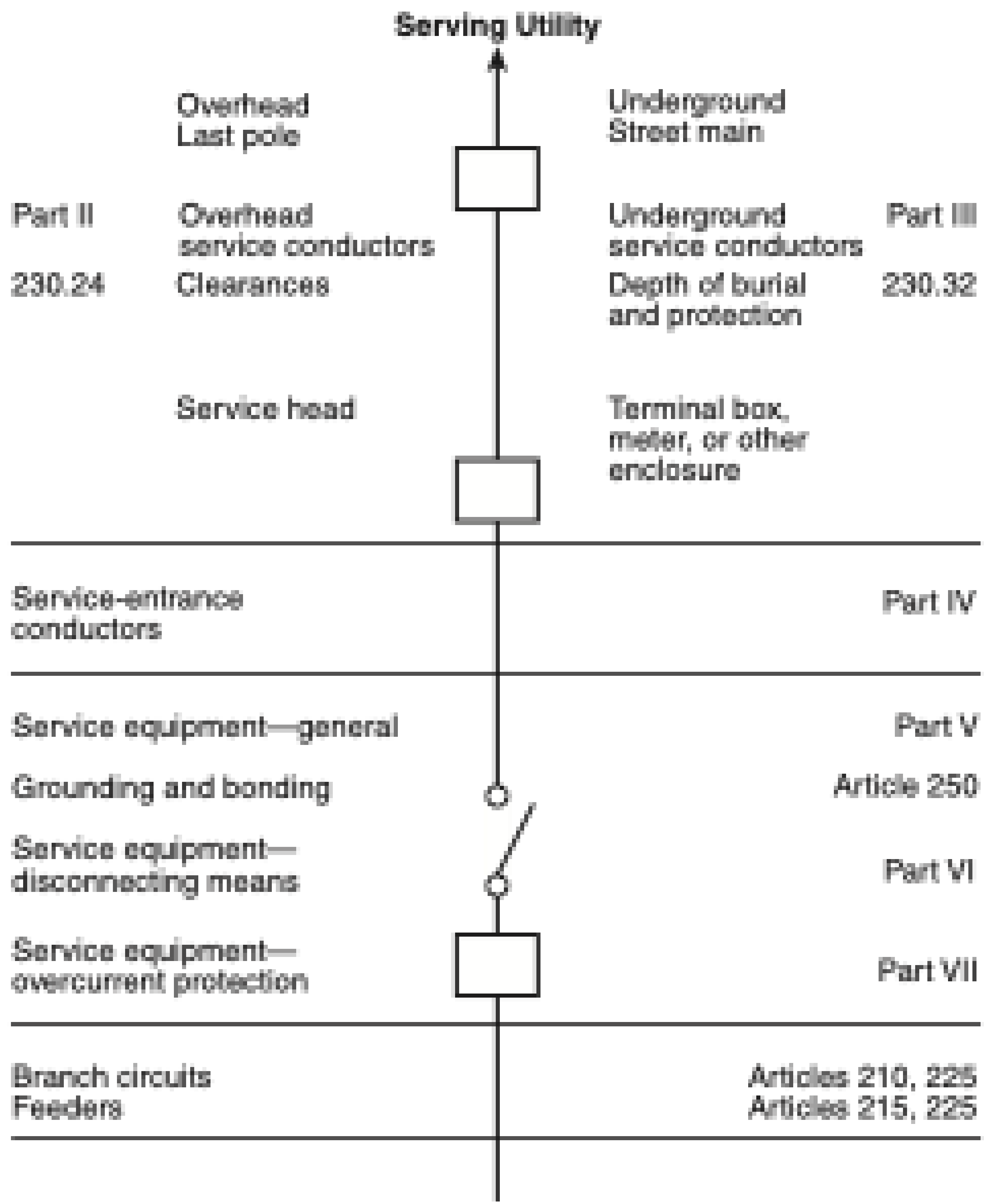



**FIGURE 430.1** Article 430 Contents.


Serving Utility
Overhead
Last pole
Underground
Street main
Part II
Overhead
service conductors
Underground
service conductors
Part III
230.24
Clearances
Depth of burial
and protection
230.32
Service head
Terminal box,
meter, or other
enclosure
Service-entrance
conductors
Part IV
Service equipment—general
Part V
Grounding and bonding
Article 250
Service equipment—
disconnecting means
Part VI
Service equipment—
overcurrent protection
Part VII
Branch circuits
Feeders
Articles 210, 225
Articles 215, 225

# NEC Style & Layout (Cont'd)

**Sections & Subsections**

- Each NEC rule is called a "Code Section." A Code section may be broken down into subsections by letters in parentheses like (A), numbers in parentheses like (1), and lowercase letters like (a), (b), and so on, to further break the rule down to the second and third level.
  - For example, the rule requiring all receptacles in a dwelling unit bathroom to be GFCI protected is contained in Section 210.8(A)(1) which is located in Chapter 2, Article 210, Section 8, Subsection (A), Sub-subsection (1).
- Many in the industry incorrectly use the term "Article" when refer- ring to a Code section.
  - For example, they say "Article 210.8," when they should say "Section 210.8." Section numbers in this textbook are shown without the word "Section," unless they begin a sentence. For example, Section 210.8(A) is shown as simply 210.8(A).

# NEC Style & Layout (Cont'd)

**Tables and Figures**

- Many NEC requirements are contained within tables, which are lists of Code rules placed in a systematic arrangement. *The titles of the tables are extremely important; you must read them carefully in order to understand the contents, applications and limitations of each table.*

- Many times notes are provided in or below a table; be sure to read them as well since they're also part of the requirement.

  - For example, Note 1 for Table 300.5 explains how to measure the cover when burying cables and raceways, and Note 5 explains what to do if solid rock is encountered.

**Table 300.5 Minimum Cover Requirements, 0 to 1000 Volts, Nominal, Burial in Millimeters (Inches)**

| Location of Wiring Method or Circuit | Type of Wiring Method or Circuit | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Column 1 Direct Burial Cables or Conductors | | Column 2 Rigid Metal Conduit or Intermediate Metal Conduit | | Column 3 Nonmetallic Raceways Listed for Direct Burial Without Concrete Encasement or Other Approved Raceways | | Column 4 Residential Branch Circuits Rated 120 Volts or Less with GFCI Protection and Maximum Overcurrent Protection of 20 Amperes | | Column 5 Circuits for Control of Irrigation and Landscape Lighting Limited to Not More Than 30 Volts and Installed with Type UF or in Other Identified Cable or Raceway | |
| | mm | in. | mm | in. | mm | in. | mm | in. | mm | in. |
| All locations not specified below | 600 | 24 | 150 | 6 | 450 | 18 | 300 | 12 | 150[a,b] | 6[a,b] |
| In trench below 50 mm (2 in.) thick concrete or equivalent | 450 | 18 | 150 | 6 | 300 | 12 | 150 | 6 | 150 | 6 |
| Under a building | 0 (in raceway or Type MC or Type MI cable identified for direct burial) | 0 | 0 | 0 | 0 | 0 | 0 (in raceway or Type MC or Type MI cable identified for direct burial) | 0 | 0 (in raceway or Type MC or Type MI cable identified for direct burial) | 0 |
| Under minimum of 102 mm (4 in.) thick concrete exterior slab with no vehicular traffic and the slab extending not less than 152 mm (6 in.) beyond the underground installation | 450 | 18 | 100 | 4 | 100 | 4 | 150 (direct burial)<br>100 (in raceway) | 6<br>4 | 150 (direct burial)<br>100 (in raceway) | 6<br>4 |
| Under streets, highways, roads, alleys, driveways, and parking lots | 600 | 24 | 600 | 24 | 600 | 24 | 600 | 24 | 600 | 24 |
| One- and two-family dwelling driveways and outdoor parking areas, and used only for dwelling-related purposes | 450 | 18 | 450 | 18 | 450 | 18 | 300 | 12 | 450 | 18 |
| In or under airport runways, including adjacent areas where trespassing prohibited | 450 | 18 | 450 | 18 | 450 | 18 | 450 | 18 | 450 | 18 |

[a]A lesser depth shall be permitted where specified in the installation instructions of a listed low-voltage lighting system.
[b]A depth of 150 mm (6 in.) shall be permitted for pool, spa, and fountain lighting, installed in a nonmetallic raceway, limited to not more than 30 volts where part of a listed low-voltage lighting system.

Notes:

1. Cover is defined as the shortest distance in mm (in.) measured between a point on the top surface of any direct-buried conductor, cable, conduit, or other raceway and the top surface of finished grade, concrete, or similar cover.
2. Raceways approved for burial only where concrete encased shall require concrete envelope not less than 50 mm (2 in.) thick.
3. Lesser depths shall be permitted where cables and conductors rise for terminations or splices or where access is otherwise required.
4. Where one of the wiring method types listed in Columns 1 through 3 is used for one of the circuit types in Columns 4 and 5, the shallowest depth of burial shall be permitted.
5. Where solid rock prevents compliance with the cover depths specified in this table, the wiring shall be installed in a metal raceway, or a nonmetallic raceway permitted for direct burial. The raceways shall be covered by a minimum of 50 mm (2 in.) of concrete extending down to rock.

**Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)***

| Size AWG or kcmil | Temperature Rating of Conductor [See Table 310.104(A).] | | | | | | Size AWG or 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) | |
| | Types TW, UF | Types RHW, THHW, THW, THWN, XHHW, USE, ZW | Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2 | Types TW, UF | Types RHW, THHW, THW, THWN, XHHW, USE | Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2 | |
| | COPPER | | | ALUMINUM OR COPPER-CLAD ALUMINUM | | | |
| 18** | — | — | 14 | — | — | — | — |
| 16** | — | — | 18 | — | — | — | — |
| 14** | 15 | 20 | 25 | — | — | — | — |
| 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 |
| 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 |
| 600 | 350 | 420 | 475 | 285 | 340 | 385 | 600 |
| 700 | 385 | 460 | 520 | 315 | 375 | 425 | 700 |
| 750 | 400 | 475 | 535 | 320 | 385 | 435 | 750 |
| 800 | 410 | 490 | 555 | 330 | 395 | 445 | 800 |
| 900 | 435 | 520 | 585 | 355 | 425 | 480 | 900 |
| 1000 | 455 | 545 | 615 | 375 | 445 | 500 | 1000 |
| 1250 | 495 | 590 | 665 | 405 | 485 | 545 | 1250 |
| 1500 | 525 | 625 | 705 | 435 | 520 | 585 | 1500 |
| 1750 | 545 | 650 | 735 | 455 | 545 | 615 | 1750 |
| 2000 | 555 | 665 | 750 | 470 | 560 | 630 | 2000 |

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F). Refer to 310.15(B)(3)(a) for more than three current-carrying conductors.

**Refer to 240.4(D) for conductor overcurrent protection limitations.

**Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems**

| Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil) | | Size of Grounding Electrode Conductor (AWG/kcmil) | |
|---|---|---|---|
| Copper | Aluminum or Copper-Clad Aluminum | Copper | Aluminum or Copper-Clad Aluminum[b] |
| 2 or smaller | 1/0 or smaller | 8 | 6 |
| 1 or 1/0 | 2/0 or 3/0 | 6 | 4 |
| 2/0 or 3/0 | 4/0 or 250 | 4 | 2 |
| Over 3/0 through 350 | Over 250 through 500 | 2 | 1/0 |
| Over 350 through 600 | Over 500 through 900 | 1/0 | 3/0 |
| Over 600 through 1100 | Over 900 through 1750 | 2/0 | 4/0 |
| Over 1100 | Over 1750 | 3/0 | 250 |

Notes:

1. If multiple sets of service-entrance conductors connect directly to a service drop, set of overhead service conductors, set of underground service conductors, or service lateral, the equivalent size of the largest service-entrance conductor shall be determined by the largest sum of the areas of the corresponding conductors of each set.

2. Where there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

[a]This table also applies to the derived conductors of separately derived ac systems.

[b]See installation restrictions in 250.64(A).

**Table 250.102(C)(1) Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating-Current Systems**

| Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil) | | Size of Grounded Conductor or Bonding Jumper* (AWG/kcmil) | |
|---|---|---|---|
| Copper | Aluminum or Copper-Clad Aluminum | Copper | Aluminum or Copper-Clad Aluminum |
| 2 or smaller | 1/0 or smaller | 8 | 6 |
| 1 or 1/0 | 2/0 or 3/0 | 6 | 4 |
| 2/0 or 3/0 | 4/0 or 250 | 4 | 2 |
| Over 3/0 through 350 | Over 250 through 500 | 2 | 1/0 |
| Over 350 through 600 | Over 500 through 900 | 1/0 | 3/0 |
| Over 600 through 1100 | Over 900 through 1750 | 2/0 | 4/0 |
| Over 1100 | Over 1750 | See Notes 1 and 2. | |

Notes:

1. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½ percent of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.

2. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum and if the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper and will have an ampacity equivalent to that of the installed ungrounded supply conductors.

3. If multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, or if multiple sets of ungrounded supply conductors are installed for a separately derived system, the equivalent size of the largest ungrounded supply conductor(s) shall be determined by the largest sum of the areas of the corresponding conductors of each set.

4. If there are no service-entrance conductors, the supply conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

*For the purposes of applying this table and its notes, the term *bonding jumper* refers to main bonding jumpers, system bonding jumpers, and supply-side bonding jumpers.

# NEC Style & Layout (Cont'd)

**Exceptions**

- Exceptions are Code requirements or permissions that provide an alternative method to a specific rule. There are two types of exceptions—mandatory and permissive. When a rule has several exceptions, those exceptions with mandatory requirements are listed before the permissive exceptions.
- **Mandatory Exceptions.** A mandatory exception uses the words "shall" or "shall not." The word "shall" in an exception means that if you're using the exception, you're required to do it in a particular way. The phrase "shall not" means it isn't permitted.
- **Permissive Exceptions.** A permissive exception uses words such as "shall be permitted," which means it's acceptable (but not mandatory) to do it in this way.

# NEC Style & Layout (Cont’d)

**Informational Notes**

- An Informational Note contains explanatory material intended to clarify a rule or give assistance, but it isn’t a Code requirement.

**210.19 Conductors — Minimum Ampacity and Size.**

**(A) Branch Circuits Not More Than 600 Volts.**

Informational Note No. 1: See 310.15 for ampacity ratings of conductors.

Informational Note No. 2: See Part II of Article 430 for minimum rating of motor branch-circuit conductors.

Informational Note No. 3: See 310.15(A)(3) for temperature limitation of conductors.

Informational Note No. 4: Conductors for branch circuits as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where 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. See Informational Note No. 2 of 215.2(A)(1) for voltage drop on feeder conductors.

**250.4 General Requirements for Grounding and Bonding.** The following general requirements identify what grounding and bonding of electrical systems are required to accomplish. The prescriptive methods contained in Article 250 shall be followed to comply with the performance requirements of this section.

**(A) Grounded Systems.**

**(1) Electrical System Grounding.** Electrical systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.

Informational Note No. 1: An important consideration for limiting the imposed voltage is the routing of bonding and grounding electrode conductors so that they are not any longer than necessary to complete the connection without disturbing the permanent parts of the installation and so that unnecessary bends and loops are avoided.

# NEC Style & Layout (Cont'd)

**Tables**

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

**Chapter 9 Tables**

**Table 1 Percent of Cross Section of Conduit and Tubing for Conductors and Cables**

| Number of Conductors and/or Cables | Cross-Sectional Area (%) |
|---|---|
| 1 | 53 |
| 2 | 31 |
| Over 2 | 40 |

Informational Note No. 1: Table 1 is based on common conditions of proper cabling and alignment of conductors where the length of the pull and the number of bends are within reasonable limits. It should be recognized that, for certain conditions, a larger size conduit or a lesser conduit fill should be considered.

Informational Note No. 2: When pulling three conductors or cables into a raceway, if the ratio of the raceway (inside diameter) to the conductor or cable (outside diameter) is between 2.8 and 3.2, jamming can occur. While jamming can occur when pulling four or more conductors or cables into a raceway, the probability is very low.

**Notes to Tables**

(1) See Informative Annex C for the maximum number of conductors and fixture wires, all of the same size (total cross-sectional area including insulation) permitted in trade sizes of the applicable conduit or tubing.

(2) Table 1 applies only to complete conduit or tubing systems and is not intended to apply to sections of conduit or tubing used to protect exposed wiring from physical damage.

(3) Equipment grounding or bonding conductors, where installed, shall be included when calculating conduit or tubing fill. The actual dimensions of the equipment grounding or bonding conductor (insulated or bare) shall be used in the calculation.

(4) Where conduit or tubing nipples having a maximum length not to exceed 600 mm (24 in.) are installed between boxes, cabinets, and similar enclosures, the nipples shall be permitted to be filled to 60 percent of their total cross-sectional area, and 310.15(B)(3)(a) adjustment factors need not apply to this condition.

(5) For conductors not included in Chapter 9, such as multiconductor cables and optical fiber cables, the actual dimensions shall be used.

(6) For combinations of conductors of different sizes, use actual dimensions or Table 5 and Table 5A for dimensions of conductors and Table 4 for the applicable conduit or tubing dimensions.

(7) When calculating the maximum number of conductors or cables permitted in a conduit or tubing, all of the same size (total cross-sectional area including insulation), the next higher whole number shall be used to determine the maximum number of conductors permitted when the calculation results in a decimal greater than or equal to 0.8. When calculating the size for conduit or tubing permitted for a single conductor, one conductor shall be permitted when the calculation results in a decimal greater than or equal to 0.8.

(8) Where bare conductors are permitted by other sections of this *Code*, the dimensions for bare conductors in Table 8 shall be permitted.

(9) A multiconductor cable, optical fiber cable, or flexible cord of two or more conductors shall be treated as a single conductor for calculating percentage conduit or tubing fill area. For cables that have elliptical cross sections, the cross-sectional area calculation shall be based on using the major diameter of the ellipse as a circle diameter. Assemblies of single insulated conductors without an overall covering shall not be considered a cable when determining conduit or tubing fill area. The conduit or tubing fill for the assemblies shall be calculated based upon the individual conductors.

(10) The values for approximate conductor diameter and area shown in Table 5 are based on worst-case scenario and indicate round concentric-lay-stranded conductors. Solid and round concentric-lay-stranded conductor values are grouped together for the purpose of Table 5. Round compact-stranded conductor values are shown in Table 5A. If the actual values of the conductor diameter and area are known, they shall be permitted to be used.

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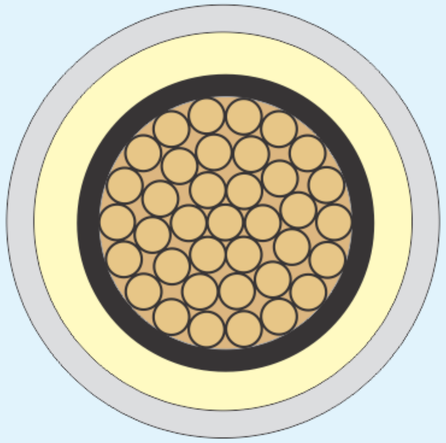
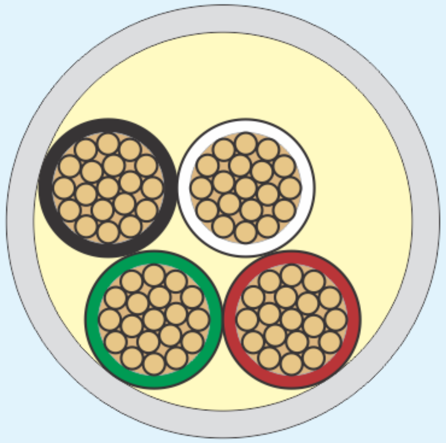
# Raceway Fill Limitation

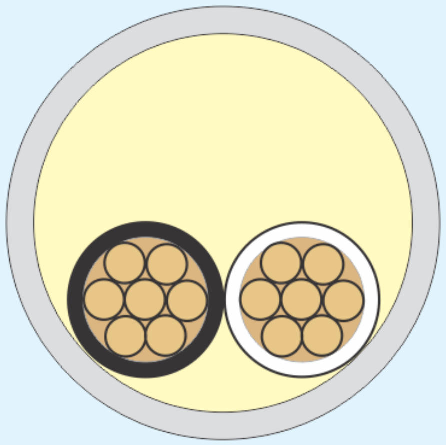
*Chapter 9, Table 1*



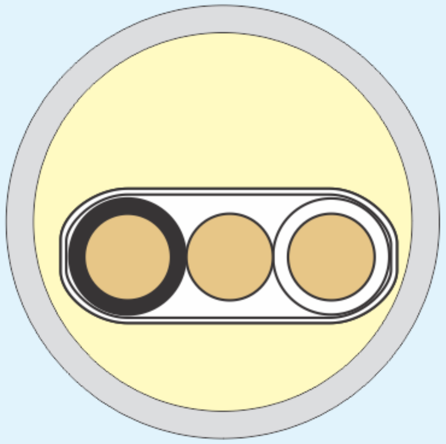
**One Conductor**
53% Fill



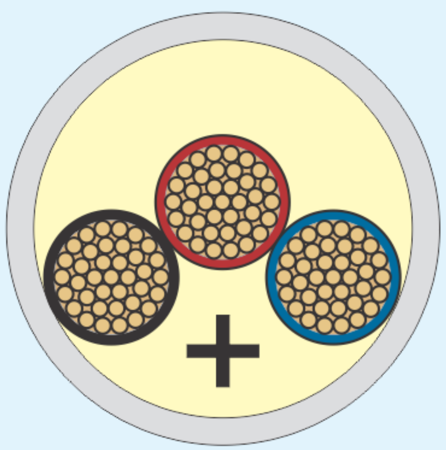
**Raceway Length 24 in. or Less:**
60% Fill
Note (4)



**Two Conductors**
31% Fill



**Cable** is Treated as 1 Conductor
53% Fill, Note (9)




**Three or More Conductors**
40% Fill



When conductors and/or cables are installed in a raceway, conductor fill is limited to the above percentages.

**Table 8 Conductor Properties**

| Size (AWG or kcmil) | Area | | Conductors | | | | | | | Direct-Current Resistance at 75°C (167°F) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Stranding | | | Overall | | | | Copper | | | | | |
| | | | | Diameter | | Diameter | | Area | | Uncoated | | Coated | | Aluminum | |
| | mm² | Circular mils | Quantity | mm | in. | mm | in. | mm² | in.² | ohm/km | ohm/kFT | ohm/km | ohm/kFT | ohm/km | ohm/kFT |
| 18 | 0.823 | 1620 | 1 | — | — | 1.02 | 0.040 | 0.823 | 0.001 | 25.5 | 7.77 | 26.5 | 8.08 | 42.0 | 12.8 |
| 18 | 0.823 | 1620 | 7 | 0.39 | 0.015 | 1.16 | 0.046 | 1.06 | 0.002 | 26.1 | 7.95 | 27.7 | 8.45 | 42.8 | 13.1 |
| 16 | 1.31 | 2580 | 1 | — | — | 1.29 | 0.051 | 1.31 | 0.002 | 16.0 | 4.89 | 16.7 | 5.08 | 26.4 | 8.05 |
| 16 | 1.31 | 2580 | 7 | 0.49 | 0.019 | 1.46 | 0.058 | 1.68 | 0.003 | 16.4 | 4.99 | 17.3 | 5.29 | 26.9 | 8.21 |
| 14 | 2.08 | 4110 | 1 | — | — | 1.63 | 0.064 | 2.08 | 0.003 | 10.1 | 3.07 | 10.4 | 3.19 | 16.6 | 5.06 |
| 14 | 2.08 | 4110 | 7 | 0.62 | 0.024 | 1.85 | 0.073 | 2.68 | 0.004 | 10.3 | 3.14 | 10.7 | 3.26 | 16.9 | 5.17 |
| 12 | 3.31 | 6530 | 1 | — | — | 2.05 | 0.081 | 3.31 | 0.005 | 6.34 | 1.93 | 6.57 | 2.01 | 10.45 | 3.18 |
| 12 | 3.31 | 6530 | 7 | 0.78 | 0.030 | 2.32 | 0.092 | 4.25 | 0.006 | 6.50 | 1.98 | 6.73 | 2.05 | 10.69 | 3.25 |
| 10 | 5.261 | 10380 | 1 | — | — | 2.588 | 0.102 | 5.26 | 0.008 | 3.984 | 1.21 | 4.148 | 1.26 | 6.561 | 2.00 |
| 10 | 5.261 | 10380 | 7 | 0.98 | 0.038 | 2.95 | 0.116 | 6.76 | 0.011 | 4.070 | 1.24 | 4.226 | 1.29 | 6.679 | 2.04 |
| 8 | 8.367 | 16510 | 1 | — | — | 3.264 | 0.128 | 8.37 | 0.013 | 2.506 | 0.764 | 2.579 | 0.786 | 4.125 | 1.26 |
| 8 | 8.367 | 16510 | 7 | 1.23 | 0.049 | 3.71 | 0.146 | 10.76 | 0.017 | 2.551 | 0.778 | 2.653 | 0.809 | 4.204 | 1.28 |
| 6 | 13.30 | 26240 | 7 | 1.56 | 0.061 | 4.67 | 0.184 | 17.09 | 0.027 | 1.608 | 0.491 | 1.671 | 0.510 | 2.652 | 0.808 |
| 4 | 21.15 | 41740 | 7 | 1.96 | 0.077 | 5.89 | 0.232 | 27.19 | 0.042 | 1.010 | 0.308 | 1.053 | 0.321 | 1.666 | 0.508 |
| 3 | 26.67 | 52620 | 7 | 2.20 | 0.087 | 6.60 | 0.260 | 34.28 | 0.053 | 0.802 | 0.245 | 0.833 | 0.254 | 1.320 | 0.403 |
| 2 | 33.62 | 66360 | 7 | 2.47 | 0.097 | 7.42 | 0.292 | 43.23 | 0.067 | 0.634 | 0.194 | 0.661 | 0.201 | 1.045 | 0.319 |
| 1 | 42.41 | 83690 | 19 | 1.69 | 0.066 | 8.43 | 0.332 | 55.80 | 0.087 | 0.505 | 0.154 | 0.524 | 0.160 | 0.829 | 0.253 |
| 1/0 | 53.49 | 105600 | 19 | 1.89 | 0.074 | 9.45 | 0.372 | 70.41 | 0.109 | 0.399 | 0.122 | 0.415 | 0.127 | 0.660 | 0.201 |
| 2/0 | 67.43 | 133100 | 19 | 2.13 | 0.084 | 10.62 | 0.418 | 88.74 | 0.137 | 0.3170 | 0.0967 | 0.329 | 0.101 | 0.523 | 0.159 |
| 3/0 | 85.01 | 167800 | 19 | 2.39 | 0.094 | 11.94 | 0.470 | 111.9 | 0.173 | 0.2512 | 0.0766 | 0.2610 | 0.0797 | 0.413 | 0.126 |
| 4/0 | 107.2 | 211600 | 19 | 2.68 | 0.106 | 13.41 | 0.528 | 141.1 | 0.219 | 0.1996 | 0.0608 | 0.2050 | 0.0626 | 0.328 | 0.100 |
| 250 | 127 | — | 37 | 2.09 | 0.082 | 14.61 | 0.575 | 168 | 0.260 | 0.1687 | 0.0515 | 0.1753 | 0.0535 | 0.2778 | 0.0847 |
| 300 | 152 | — | 37 | 2.29 | 0.090 | 16.00 | 0.630 | 201 | 0.312 | 0.1409 | 0.0429 | 0.1463 | 0.0446 | 0.2318 | 0.0707 |
| 350 | 177 | — | 37 | 2.47 | 0.097 | 17.30 | 0.681 | 235 | 0.364 | 0.1205 | 0.0367 | 0.1252 | 0.0382 | 0.1984 | 0.0605 |
| 400 | 203 | — | 37 | 2.64 | 0.104 | 18.49 | 0.728 | 268 | 0.416 | 0.1053 | 0.0321 | 0.1084 | 0.0331 | 0.1737 | 0.0529 |
| 500 | 253 | — | 37 | 2.95 | 0.116 | 20.65 | 0.813 | 336 | 0.519 | 0.0845 | 0.0258 | 0.0869 | 0.0265 | 0.1391 | 0.0424 |
| 600 | 304 | — | 61 | 2.52 | 0.099 | 22.68 | 0.893 | 404 | 0.626 | 0.0704 | 0.0214 | 0.0732 | 0.0223 | 0.1159 | 0.0353 |
| 700 | 355 | — | 61 | 2.72 | 0.107 | 24.49 | 0.964 | 471 | 0.730 | 0.0603 | 0.0184 | 0.0622 | 0.0189 | 0.0994 | 0.0303 |
| 750 | 380 | — | 61 | 2.82 | 0.111 | 25.35 | 0.998 | 505 | 0.782 | 0.0563 | 0.0171 | 0.0579 | 0.0176 | 0.0927 | 0.0282 |
| 800 | 405 | — | 61 | 2.91 | 0.114 | 26.16 | 1.030 | 538 | 0.834 | 0.0528 | 0.0161 | 0.0544 | 0.0166 | 0.0868 | 0.0265 |
| 900 | 456 | — | 61 | 3.09 | 0.122 | 27.79 | 1.094 | 606 | 0.940 | 0.0470 | 0.0143 | 0.0481 | 0.0147 | 0.0770 | 0.0235 |
| 1000 | 507 | — | 61 | 3.25 | 0.128 | 29.26 | 1.152 | 673 | 1.042 | 0.0423 | 0.0129 | 0.0434 | 0.0132 | 0.0695 | 0.0212 |
| 1250 | 633 | — | 91 | 2.98 | 0.117 | 32.74 | 1.289 | 842 | 1.305 | 0.0338 | 0.0103 | 0.0347 | 0.0106 | 0.0554 | 0.0169 |
| 1500 | 760 | — | 91 | 3.26 | 0.128 | 35.86 | 1.412 | 1011 | 1.566 | 0.02814 | 0.00858 | 0.02814 | 0.00883 | 0.0464 | 0.0141 |
| 1750 | 887 | — | 127 | 2.98 | 0.117 | 38.76 | 1.526 | 1180 | 1.829 | 0.02410 | 0.00735 | 0.02410 | 0.00756 | 0.0397 | 0.0121 |
| 2000 | 1013 | — | 127 | 3.19 | 0.126 | 41.45 | 1.632 | 1349 | 2.092 | 0.02109 | 0.00643 | 0.02109 | 0.00662 | 0.0348 | 0.0106 |

Notes:

1. These resistance values are valid **only** for the parameters as given. Using conductors having coated strands, different stranding type, and, especially, other temperatures changes the resistance.
2. Equation for temperature change: $R_2 = R_1 [1 + \alpha (T_2 - 75)]$, where $\alpha_{cu} = 0.00323$, $\alpha_{AL} = 0.00330$ at 75°C.
3. Conductors with compact and compressed stranding have about 9 percent and 3 percent, respectively, smaller bare conductor diameters than those shown. See Table 5A for actual compact cable dimensions.
4. The IACS conductivities used: bare copper = 100%, aluminum = 61%.
5. Class B stranding is listed as well as solid for some sizes. Its overall diameter and area are those of its circumscribing circle.

Informational Note: The construction information is in accordance with NEMA WC/70-2009 or ANSI/UL 1581-2011. The resistance is calculated in accordance with National Bureau of Standards Handbook 100, dated 1966, and Handbook 109, dated 1972.

**Table 4 Dimensions and Percent Area of Conduit and Tubing (Areas of Conduit or Tubing for the Combinations of Wires Permitted in Table 1, Chapter 9)**

**Article 358 — Electrical Metallic Tubing (EMT)**

| Metric Designator | Trade Size | Over 2 Wires 40% | | 60% | | 1 Wire 53% | | 2 Wires 31% | | Nominal Internal Diameter | | Total Area 100% | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mm² | in.² | mm² | in.² | mm² | in.² | mm² | in.² | mm | in. | mm² | in.² |
| 16 | ½ | 78 | 0.122 | 118 | 0.182 | 104 | 0.161 | 61 | 0.094 | 15.8 | 0.622 | 196 | 0.304 |
| 21 | ¾ | 137 | 0.213 | 206 | 0.320 | 182 | 0.283 | 106 | 0.165 | 20.9 | 0.824 | 343 | 0.533 |
| 27 | 1 | 222 | 0.346 | 333 | 0.519 | 295 | 0.458 | 172 | 0.268 | 26.6 | 1.049 | 556 | 0.864 |
| 35 | 1¼ | 387 | 0.598 | 581 | 0.897 | 513 | 0.793 | 300 | 0.464 | 35.1 | 1.380 | 968 | 1.496 |
| 41 | 1½ | 526 | 0.814 | 788 | 1.221 | 696 | 1.079 | 407 | 0.631 | 40.9 | 1.610 | 1314 | 2.036 |
| 53 | 2 | 866 | 1.342 | 1299 | 2.013 | 1147 | 1.778 | 671 | 1.040 | 52.5 | 2.067 | 2165 | 3.356 |
| 63 | 2½ | 1513 | 2.343 | 2270 | 3.515 | 2005 | 3.105 | 1173 | 1.816 | 69.4 | 2.731 | 3783 | 5.858 |
| 78 | 3 | 2280 | 3.538 | 3421 | 5.307 | 3022 | 4.688 | 1767 | 2.742 | 85.2 | 3.356 | 5701 | 8.846 |
| 91 | 3½ | 2980 | 4.618 | 4471 | 6.927 | 3949 | 6.119 | 2310 | 3.579 | 97.4 | 3.834 | 7451 | 11.545 |
| 103 | 4 | 3808 | 5.901 | 5712 | 8.852 | 5046 | 7.819 | 2951 | 4.573 | 110.1 | 4.334 | 9521 | 14.753 |

**Article 362 — Electrical Nonmetallic Tubing (ENT)**

| Metric Designator | Trade Size | Over 2 Wires 40% | | 60% | | 1 Wire 53% | | 2 Wires 31% | | Nominal Internal Diameter | | Total Area 100% | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mm² | in.² | mm² | in.² | mm² | in.² | mm² | in.² | mm | in. | mm² | in.² |
| 16 | ½ | 73 | 0.114 | 110 | 0.171 | 97 | 0.151 | 57 | 0.088 | 15.3 | 0.602 | 184 | 0.285 |
| 21 | ¾ | 131 | 0.203 | 197 | 0.305 | 174 | 0.269 | 102 | 0.157 | 20.4 | 0.804 | 328 | 0.508 |
| 27 | 1 | 215 | 0.333 | 322 | 0.499 | 284 | 0.441 | 166 | 0.258 | 26.1 | 1.029 | 537 | 0.832 |
| 35 | 1¼ | 375 | 0.581 | 562 | 0.872 | 497 | 0.770 | 291 | 0.450 | 34.5 | 1.36 | 937 | 1.453 |
| 41 | 1½ | 512 | 0.794 | 769 | 1.191 | 679 | 1.052 | 397 | 0.616 | 40.4 | 1.59 | 1281 | 1.986 |
| 53 | 2 | 849 | 1.316 | 1274 | 1.975 | 1125 | 1.744 | 658 | 1.020 | 52 | 2.047 | 2123 | 3.291 |
| 63 | 2½ | — | — | — | — | — | — | — | — | — | — | — | — |
| 78 | 3 | — | — | — | — | — | — | — | — | — | — | — | — |
| 91 | 3½ | — | — | — | — | — | — | — | — | — | — | — | — |

**Article 348 — Flexible Metal Conduit (FMC)**

| Metric Designator | Trade Size | Over 2 Wires 40% | | 60% | | 1 Wire 53% | | 2 Wires 31% | | Nominal Internal Diameter | | Total Area 100% | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mm² | in.² | mm² | in.² | mm² | in.² | mm² | in.² | mm | in. | mm² | in.² |
| 12 | ⅜ | 30 | 0.046 | 44 | 0.069 | 39 | 0.061 | 23 | 0.036 | 9.7 | 0.384 | 74 | 0.116 |
| 16 | ½ | 81 | 0.127 | 122 | 0.190 | 108 | 0.168 | 63 | 0.098 | 16.1 | 0.635 | 204 | 0.317 |
| 21 | ¾ | 137 | 0.213 | 206 | 0.320 | 182 | 0.283 | 106 | 0.165 | 20.9 | 0.824 | 343 | 0.533 |
| 27 | 1 | 211 | 0.327 | 316 | 0.490 | 279 | 0.433 | 163 | 0.253 | 25.9 | 1.020 | 527 | 0.817 |
| 35 | 1¼ | 330 | 0.511 | 495 | 0.766 | 437 | 0.677 | 256 | 0.396 | 32.4 | 1.275 | 824 | 1.277 |
| 41 | 1½ | 480 | 0.743 | 720 | 1.115 | 636 | 0.985 | 372 | 0.576 | 39.1 | 1.538 | 1201 | 1.858 |
| 53 | 2 | 843 | 1.307 | 1264 | 1.961 | 1117 | 1.732 | 653 | 1.013 | 51.8 | 2.040 | 2107 | 3.269 |
| 63 | 2½ | 1267 | 1.963 | 1900 | 2.945 | 1678 | 2.602 | 982 | 1.522 | 63.5 | 2.500 | 3167 | 4.909 |
| 78 | 3 | 1824 | 2.827 | 2736 | 4.241 | 2417 | 3.746 | 1414 | 2.191 | 76.2 | 3.000 | 4560 | 7.069 |
| 91 | 3½ | 2483 | 3.848 | 3724 | 5.773 | 3290 | 5.099 | 1924 | 2.983 | 88.9 | 3.500 | 6207 | 9.621 |
| 103 | 4 | 3243 | 5.027 | 4864 | 7.540 | 4297 | 6.660 | 2513 | 3.896 | 101.6 | 4.000 | 8107 | 12.566 |

**Article 342 — Intermediate Metal Conduit (IMC)**

| Metric Designator | Trade Size | Over 2 Wires 40% | | 60% | | 1 Wire 53% | | 2 Wires 31% | | Nominal Internal Diameter | | Total Area 100% | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mm² | in.² | mm² | in.² | mm² | in.² | mm² | in.² | mm | in. | mm² | in.² |
| 12 | ⅜ | — | — | — | — | — | — | — | — | — | — | — | — |
| 16 | ½ | 89 | 0.137 | 133 | 0.205 | 117 | 0.181 | 69 | 0.106 | 16.8 | 0.660 | 222 | 0.342 |
| 21 | ¾ | 151 | 0.235 | 226 | 0.352 | 200 | 0.311 | 117 | 0.182 | 21.9 | 0.864 | 377 | 0.586 |

*(continues)*

**Table 5 Dimensions of Insulated Conductors and Fixture Wires**

| Type | Size (AWG or kcmil) | Approximate Area | | Approximate Diameter | |
|---|---|---|---|---|---|
| | | mm² | in.² | mm | in. |
| **Type: FFH-2, RFH-1, RFH-2, RFHH-2, RHH*, RHW* , RHW-2*, RHH, RHW, RHW-2, SF-1, SF-2, SFF-1, SFF-2, TF, TFF, THHW, THW, THW-2, TW, XF, XFF** | | | | | |
| RFH-2, FFH-2, RFHH-2 | 18 | 9.355 | 0.0145 | 3.454 | 0.136 |
| | 16 | 11.10 | 0.0172 | 3.759 | 0.148 |
| RHH, RHW, RHW-2 | 14 | 18.90 | 0.0293 | 4.902 | 0.193 |
| | 12 | 22.77 | 0.0353 | 5.385 | 0.212 |
| | 10 | 28.19 | 0.0437 | 5.994 | 0.236 |
| | 8 | 53.87 | 0.0835 | 8.280 | 0.326 |
| | 6 | 67.16 | 0.1041 | 9.246 | 0.364 |
| | 4 | 86.00 | 0.1333 | 10.46 | 0.412 |
| | 3 | 98.13 | 0.1521 | 11.18 | 0.440 |
| | 2 | 112.9 | 0.1750 | 11.99 | 0.472 |
| | 1 | 171.6 | 0.2660 | 14.78 | 0.582 |
| | 1/0 | 196.1 | 0.3039 | 15.80 | 0.622 |
| | 2/0 | 226.1 | 0.3505 | 16.97 | 0.668 |
| | 3/0 | 262.7 | 0.4072 | 18.29 | 0.720 |
| | 4/0 | 306.7 | 0.4754 | 19.76 | 0.778 |
| | 250 | 405.9 | 0.6291 | 22.73 | 0.895 |
| | 300 | 457.3 | 0.7088 | 24.13 | 0.950 |
| | 350 | 507.7 | 0.7870 | 25.43 | 1.001 |
| | 400 | 556.5 | 0.8626 | 26.62 | 1.048 |
| | 500 | 650.5 | 1.0082 | 28.78 | 1.133 |
| | 600 | 782.9 | 1.2135 | 31.57 | 1.243 |
| | 700 | 874.9 | 1.3561 | 33.38 | 1.314 |
| | 750 | 920.8 | 1.4272 | 34.24 | 1.348 |
| | 800 | 965.0 | 1.4957 | 35.05 | 1.380 |
| | 900 | 1057 | 1.6377 | 36.68 | 1.444 |
| | 1000 | 1143 | 1.7719 | 38.15 | 1.502 |
| | 1250 | 1515 | 2.3479 | 43.92 | 1.729 |
| | 1500 | 1738 | 2.6938 | 47.04 | 1.852 |
| | 1750 | 1959 | 3.0357 | 49.94 | 1.966 |
| | 2000 | 2175 | 3.3719 | 52.63 | 2.072 |
| SF-2, SFF-2 | 18 | 7.419 | 0.0115 | 3.073 | 0.121 |
| | 16 | 8.968 | 0.0139 | 3.378 | 0.133 |
| | 14 | 11.10 | 0.0172 | 3.759 | 0.148 |
| SF-1, SFF-1 | 18 | 4.194 | 0.0065 | 2.311 | 0.091 |
| RFH-1,TF, TFF, XF, XFF | 18 | 5.161 | 0.0088 | 2.692 | 0.106 |
| TF, TFF, XF, XFF | 16 | 7.032 | 0.0109 | 2.997 | 0.118 |
| TW, XF, XFF, THHW, THW, THW-2 | 14 | 8.968 | 0.0139 | 3.378 | 0.133 |
| TW, THHW, THW, THW-2 | 12 | 11.68 | 0.0181 | 3.861 | 0.152 |
| | 10 | 15.68 | 0.0243 | 4.470 | 0.176 |
| | 8 | 28.19 | 0.0437 | 5.994 | 0.236 |
| RHH*, RHW*, RHW-2* | 14 | 13.48 | 0.0209 | 4.140 | 0.163 |
| RHH*, RHW*, RHW-2*, XF, XFF | 12 | 16.77 | 0.0260 | 4.623 | 0.182 |
| **Type: RHH*, RHW*, RHW-2*, THHN, THHW, THW, THW-2, TFN, TFFN, THWN, THWN-2, XF, XFF** | | | | | |
| RHH,* RHW,* RHW-2,* XF, XFF | 10 | 21.48 | 0.0333 | 5.232 | 0.206 |

*(continues)*

# NEC Style & Layout (Cont'd)

**Annexes**

- Annexes aren't a part of the NEC requirements, and are included in the Code for informational purposes only.

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

**Table C.1 Maximum Number of Conductors or Fixture Wires in Electrical Metallic Tubing (EMT) (Based on Chapter 9: Table 1, Table 4, and Table 5)**

| Type | Conductor Size (AWG/kcmil) | Trade Size (Metric Designator) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3/8 (12) | 1/2 (16) | 3/4 (21) | 1 (27) | 1 1/4 (35) | 1 1/2 (41) | 2 (53) | 2 1/2 (63) | 3 (78) | 3 1/2 (91) | 4 (103) | 5 (129) | 6 (155) |
| **CONDUCTORS** | | | | | | | | | | | | | | |
| RHH, RHW, RHW-2 | 14 | — | 4 | 7 | 11 | 20 | 27 | 46 | 80 | 120 | 157 | 201 | — | — |
| | 12 | — | 3 | 6 | 9 | 17 | 23 | 38 | 66 | 100 | 131 | 167 | — | — |
| | 10 | — | 2 | 5 | 8 | 13 | 18 | 30 | 53 | 81 | 105 | 135 | — | — |
| | 8 | — | 1 | 2 | 4 | 7 | 9 | 16 | 28 | 42 | 55 | 70 | — | — |
| | 6 | — | 1 | 1 | 3 | 5 | 8 | 13 | 22 | 34 | 44 | 56 | — | — |
| | 4 | — | 1 | 1 | 2 | 4 | 6 | 10 | 17 | 26 | 34 | 44 | — | — |
| | 3 | — | 1 | 1 | 1 | 4 | 5 | 9 | 15 | 23 | 30 | 38 | — | — |
| | 2 | — | 1 | 1 | 1 | 3 | 4 | 7 | 13 | 20 | 26 | 33 | — | — |
| | 1 | — | 0 | 1 | 1 | 1 | 3 | 5 | 9 | 13 | 17 | 22 | — | — |
| | 1/0 | — | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 11 | 15 | 19 | — | — |
| | 2/0 | — | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 10 | 13 | 17 | — | — |
| | 3/0 | — | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 14 | — | — |
| | 4/0 | — | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 9 | 12 | — | — |
| | 250 | — | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 9 | — | — |
| | 300 | — | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | — | — |
| | 350 | — | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | — | — |
| | 400 | — | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | — | — |
| | 500 | — | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | 6 | — | — |
| | 600 | — | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | — | — |
| | 700 | — | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | — | — |
| | 750 | — | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | — | — |
| | 800 | — | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | — | — |
| | 900 | — | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | — | — |
| | 1000 | — | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | — | — |
| | 1250 | — | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | — | — |
| | 1500 | — | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | — | — |
| | 1750 | — | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | — | — |
| | 2000 | — | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | — | — |
| TW, THHW, THW, THW-2 | 14 | — | 8 | 15 | 25 | 43 | 58 | 96 | 168 | 254 | 332 | 424 | — | — |
| | 12 | — | 6 | 11 | 19 | 33 | 45 | 74 | 129 | 195 | 255 | 326 | — | — |
| | 10 | — | 5 | 8 | 14 | 24 | 33 | 55 | 96 | 145 | 190 | 243 | — | — |
| | 8 | — | 2 | 5 | 8 | 13 | 18 | 30 | 53 | 81 | 105 | 135 | — | — |
| RHH*, RHW*, RHW-2* | 14 | — | 6 | 10 | 16 | 28 | 39 | 64 | 112 | 169 | 221 | 282 | — | — |
| | 12 | — | 4 | 8 | 13 | 23 | 31 | 51 | 90 | 136 | 177 | 227 | — | — |
| | 10 | — | 3 | 6 | 10 | 18 | 24 | 40 | 70 | 106 | 138 | 177 | — | — |
| | 8 | — | 1 | 4 | 6 | 10 | 14 | 24 | 42 | 63 | 83 | 106 | — | — |
| TW, THW, THHW, THW-2, RHH*, RHW*, RHW-2* | 6 | — | 1 | 3 | 4 | 8 | 11 | 18 | 32 | 48 | 63 | 81 | — | — |
| | 4 | — | 1 | 1 | 3 | 6 | 8 | 13 | 24 | 36 | 47 | 60 | — | — |
| | 3 | — | 1 | 1 | 3 | 5 | 7 | 12 | 20 | 31 | 40 | 52 | — | — |
| | 2 | — | 1 | 1 | 2 | 4 | 6 | 10 | 17 | 26 | 34 | 44 | — | — |
| | 1 | — | 1 | 1 | 1 | 3 | 4 | 7 | 12 | 18 | 24 | 31 | — | — |
| | 1/0 | — | 0 | 1 | 1 | 2 | 3 | 6 | 10 | 16 | 20 | 26 | — | — |
| | 2/0 | — | 0 | 1 | 1 | 1 | 3 | 5 | 9 | 13 | 17 | 22 | — | — |
| | 3/0 | — | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 11 | 15 | 19 | — | — |
| | 4/0 | — | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 9 | 12 | 16 | — | — |
| | 250 | — | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 | — | — |
| | 300 | — | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 11 | — | — |
| | 350 | — | 0 | 0 | 0 | 1 | 1 | 1 | 4 | 6 | 7 | 10 | — | — |
| | 400 | — | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 9 | — | — |
| | 500 | — | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | — | — |
| | 600 | — | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 6 | — | — |
| | 700 | — | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | — | — |
| | 750 | — | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | — | — |

*(continues)*

# Informative Annex D Examples

*This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.*

**Selection of Conductors.** In the following examples, the results are generally expressed in amperes (A). To select conductor sizes, refer to the 0 through 2000 volt (V) ampacity tables of Article 310 and the rules of 310.15 that pertain to these tables.

**Voltage.** For uniform application of Articles 210, 215, and 220, a nominal voltage of 120, 120/240, 240, and 208Y/120 V is used in calculating the ampere load on the conductor.

**Fractions of an Ampere.** Except where the calculations result in a major fraction of an ampere (0.5 or larger), such fractions are permitted to be dropped.

**Power Factor.** Calculations in the following examples are based, for convenience, on the assumption that all loads have the same power factor (PF).

**Ranges.** For the calculation of the range loads in these examples, Column C of Table 220.55 has been used. For optional methods, see Columns A and B of Table 220.55. Except where the calculations result in a major fraction of a kilowatt (0.5 or larger), such fractions are permitted to be dropped.

**SI Units.** For metric conversions, 0.093 $m^2$ = 1 $ft^2$ and 0.3048 m = 1 ft.

## Example D1(a) One-Family Dwelling

The dwelling has a floor area of 1500 $ft^2$, exclusive of an unfinished cellar not adaptable for future use, unfinished attic, and open porches. Appliances are a 12-kW range and a 5.5-kW, 240-V dryer. Assume range and dryer kW ratings equivalent to kVA ratings in accordance with 220.54 and 220.55.

**Calculated Load** *(see 220.40)*

**General Lighting Load** 1500 $ft^2$ at 3 VA/$ft^2$ = 4500 VA

**Minimum Number of Branch Circuits Required** *[see 210.11(A)]*

**General Lighting Load:** 4500 VA ÷ 120 V = 38 A

This requires three 15-A, 2-wire or two 20-A, 2-wire circuits.

Small-Appliance Load: Two 2-wire, 20-A circuits *[see 210.11(C)(1)]*

Laundry Load: One 2-wire, 20-A circuit *[see 210.11(C)(2)]*

Bathroom Branch Circuit: One 2-wire, 20-A circuit (no additional load calculation is required for this circuit) *[see 210.11(C)(3)]*

**Minimum Size Feeder Required** *[see 220.40]*

| | | |
|---|---|---|
| General Lighting | | 4,500 VA |
| Small Appliance | | 3,000 VA |
| Laundry | | 1,500 VA |
| | Total | 9,000 VA |
| 3000 VA at 100% | | 3,000 VA |
| 9000 VA − 3000 VA = 6000 VA at 35% | | 2,100 VA |
| | Net Load | 5,100 VA |
| Range *(see Table 220.55)* | | 8,000 VA |
| Dryer Load *(see Table 220.54)* | | 5,500 VA |
| Net Calculated Load | | 18,600 VA |

**Net Calculated Load for 120/240-V, 3-wire, single-phase service or feeder**

18,600 VA ÷ 240 V = 78 A

Sections 230.42(B) and 230.79 require service conductors and disconnecting means rated not less than 100 amperes.

**Calculation for Neutral for Feeder and Service**

| | | |
|---|---|---|
| Lighting and Small-Appliance Load | | 5,100 VA |
| Range: 8000 VA at 70% *(see 220.61)* | | 5,600 VA |
| Dryer: 5500 VA at 70% *(see 220.61)* | | 3,850 VA |
| | Total | 14,550 VA |

**Calculated Load for Neutral**

14,550 VA ÷ 240 V = 61 A

## Example D1(b) One-Family Dwelling

Assume same conditions as Example No. D1(a), plus addition of one 6-A, 230-V, room air-conditioning unit and one 12-A, 115-V, room air-conditioning unit,* one 8-A, 115-V, rated waste disposer, and one 10-A, 120-V, rated dishwasher. See Article 430 for general motors and Article 440, Part VII, for air-conditioning equipment. Motors have nameplate ratings of 115 V and 230 V for use on 120-V and 240-V nominal voltage systems.

*(For feeder neutral, use larger of the two appliances for unbalance.)

# Informative Annex I Recommended Tightening Torque Tables from UL Standard 486A-B

*This informative annex is not a part of the requirements of this NFPA document, but is included for informational purposes only.*

In the absence of connector or equipment manufacturer's recommended torque values, Table I.1, Table I.2, and Table I.3 may be used to correctly tighten screw-type connections for power and lighting circuits*. Control and signal circuits may require different torque values, and the manufacturer should be contacted for guidance.

*For proper termination of conductors, it is very important that field connections be properly tightened. In the absence of manufacturer's instructions on the equipment, the torque values given in these tables are recommended. Because it is normal for some relaxation to occur in service, checking torque values sometime after installation is not a reliable means of determining the values of torque applied at installation.

**Table I.1 Tightening Torque for Screws**

| Test Conductor Installed in Connector | | Tightening Torque, N-m (lbf-in.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Slotted head No. 10 and larger[a] | | | | | | | |
| | | Slot width 1.2 mm (0.047 in.) or less and slot length 6.4 mm (1/4 in.) or less | | Slot width over 1.2 mm (0.047 in.) or slot length over 6.4 mm (1/4 in.) | | Split-bolt connectors | | Other connectors | |
| AWG or kcmil | mm² | | | | | | | | |
| 30–10 | 0.05–5.3 | 2.3 | (20) | 4.0 | (35) | 9.0 | (80) | 8.5 | (75) |
| 8 | 8.4 | 2.8 | (25) | 4.5 | (40) | 9.0 | (80) | 8.5 | (75) |
| 6–4 | 13.2–21.2 | 4.0 | (35) | 5.1 | (45) | 18.5 | (165) | 12.4 | (110) |
| 3 | 26.7 | 4.0 | (35) | 5.6 | (50) | 31.1 | (275) | 16.9 | (150) |
| 2 | 33.6 | 4.5 | (40) | 5.6 | (50) | 31.1 | (275) | 16.9 | (150) |
| 1 | 42.4 | — | | 5.6 | (50) | 31.1 | (275) | 16.9 | (150) |
| 1/0–2/0 | 53.5–67.4 | — | | 5.6 | (50) | 43.5 | (385) | 20.3 | (180) |
| 3/0–4/0 | 85.0–107.2 | — | | 5.6 | (50) | 56.5 | (500) | 28.2 | (250) |
| 250–350 | 127–177 | — | | 5.6 | (50) | 73.4 | (650) | 36.7 | (325) |
| 400 | 203 | — | | 5.6 | (50) | 93.2 | (825) | 36.7 | (325) |
| 500 | 253 | — | | 5.6 | (50) | 93.2 | (825) | 42.4 | (375) |
| 600–750 | 304–380 | — | | 5.6 | (50) | 113.0 | (1000) | 42.4 | (375) |
| 800–1000 | 405–508 | — | | 5.6 | (50) | 124.3 | (1100) | 56.5 | (500) |
| 1250–2000 | 635–1010 | — | | — | | 124.3 | (1100) | 67.8 | (600) |

[a]For values of slot width or length not corresponding to those specified, select the largest torque value associated with the conductor size. Slot width is the nominal design value. Slot length shall be measured at the bottom of the slot.

**Table I.2 Tightening Torque for Slotted Head Screws Smaller Than No. 10 Intended for Use with 8 AWG (8.4 mm²) or Smaller Conductors**

| Slot Length of Screw[a] | | Tightening Torque, N-m (lbf-in.) | |
|---|---|---|---|
| mm | in. | Slot width of screw smaller than 1.2 mm (0.047 in.)[b] | Slot width of screw 1.2 mm (0.047 in.) and larger[b] |
| Less than 4 | Less than 5/32 | 0.79 (7) | 1.0 (9) |
| 4 | 5/32 | 0.79 (7) | 1.4 (12) |
| 4.8 | 3/16 | 0.79 (7) | 1.4 (12) |
| 5.5 | 7/32 | 0.79 (7) | 1.4 (12) |
| 6.4 | 1/4 | 1.0 (9) | 1.4 (12) |
| 7.1 | 9/32 | | 1.7 (15) |
| Above 7.1 | Above 9/32 | | 2.3 (20) |

[a]For slot lengths of intermediate values, select torques pertaining to next shorter slot lengths. Also, see 9.1.9.6 of UL 486A-2003, *Wire Connectors and Soldering Lugs for Use with Copper Conductors*, for screws with multiple tightening means. Slot length shall be measured at the bottom of the slot.
[b]Slot width is the nominal design value.

**Table I.3 Tightening Torque for Screws with Recessed Allen or Square Drives**

| Socket Width Across Flats[a] | | | |
|---|---|---|---|
| mm | in. | Tightening Torque, N-m (lbf-in.) | |
| 3.2 | 1/8 | 5.1 | (45) |
| 4.0 | 5/32 | 11.3 | (100) |
| 4.8 | 3/16 | 13.5 | (120) |
| 5.5 | 7/32 | 16.9 | (150) |
| 6.4 | 1/4 | 22.5 | (200) |
| 7.9 | 5/16 | 31.1 | (275) |
| 9.5 | 3/8 | 42.4 | (375) |
| 12.7 | 1/2 | 56.5 | (500) |
| 14.3 | 9/16 | 67.8 | (600) |

[a]See 9.1.9.6 of UL 486A-2003, *Wire Connectors and Soldering Lugs for Use with Copper Conductors*, for screws with multiple tightening means.

# Informative Annex J ADA Standards for Accessible Design

*This informative annex is not a part of the requirements of this NFPA document, but is included for informational purposes only.*

The provisions cited in Informative Annex J are intended to assist the users of the *Code* in properly considering the various electrical design constraints of other building systems and are part of the 2010 ADA Standards for Accessible Design. They are the same provisions as those found in ANSI/ICC A117.1-2009, *Accessible and Usable Buildings and Facilities.*

**J.1 Protruding Objects.** Protruding objects shall comply with Section J.2.

**J.2 Protrusion Limits.** Objects with leading edges more than 685 mm (27 in.) and not more than 2030 mm (80 in.) above the finish floor or ground shall protrude a maximum of 100 mm (4 in.) horizontally into the circulation path. *(See Figure J.2.)*

*Exception: Handrails shall be permitted to protrude 115 mm (4½ in.) maximum.*

**J.3 Post-Mounted Objects.** Freestanding objects mounted on posts or pylons shall overhang circulation paths 305 mm (12 in.) maximum where located 685 mm (27 in.) minimum and 2030 mm (80 in.) maximum above the finish floor or ground. Where a sign or other obstruction is mounted between posts or pylons, and the clear distance between the posts or pylons is greater than 305 mm (12 in.), the lowest edge of such sign or obstruction shall be 685 mm (27 in.) maximum or 2030 mm (80 in.) minimum above the finish floor or ground. *(See Figure J.3.)*

*Exception: The sloping portions of handrails serving stairs and ramps shall not be required to comply with Section J.3.*

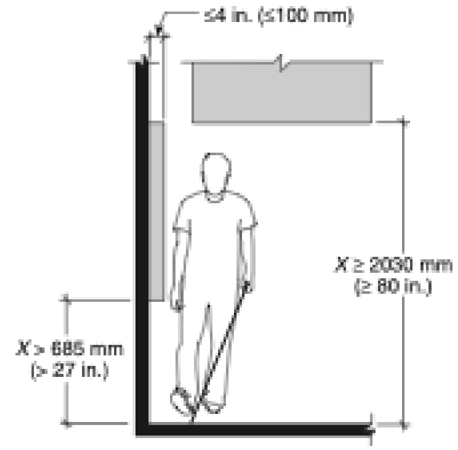



**FIGURE J.2 Limits of Protruding Objects.**

**J.4 Vertical Clearance.** Vertical clearance shall be 2030 mm (80 in.) high minimum. Guardrails or other barriers shall be provided where the vertical clearance is less than 2030 mm (80 in.) high. The leading edge of such guardrail or barrier shall be located 685 mm (27 in.) maximum above the finish floor or ground. *(See Figure J.4.)*

*Exception: Door closers and door stops shall be permitted to be 1980 mm (78 in.) minimum above the finish floor or ground.*

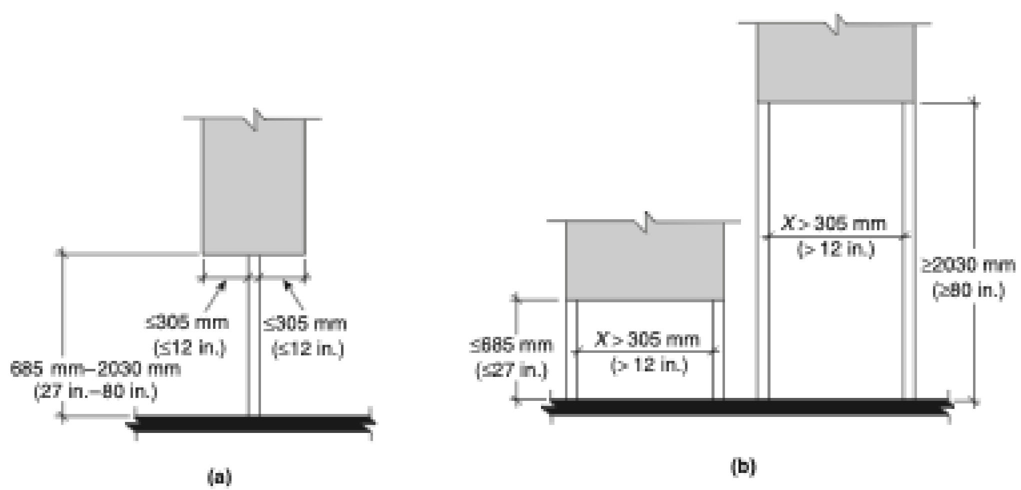



**FIGURE J.3 Post-Mounted Protruding Objects.**

# How to Locate a Specific Requirement in the NEC

- 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 of 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?***

# How to Locate a Specific Requirement in the NEC (Cont'd)

**Table of Contents Method**

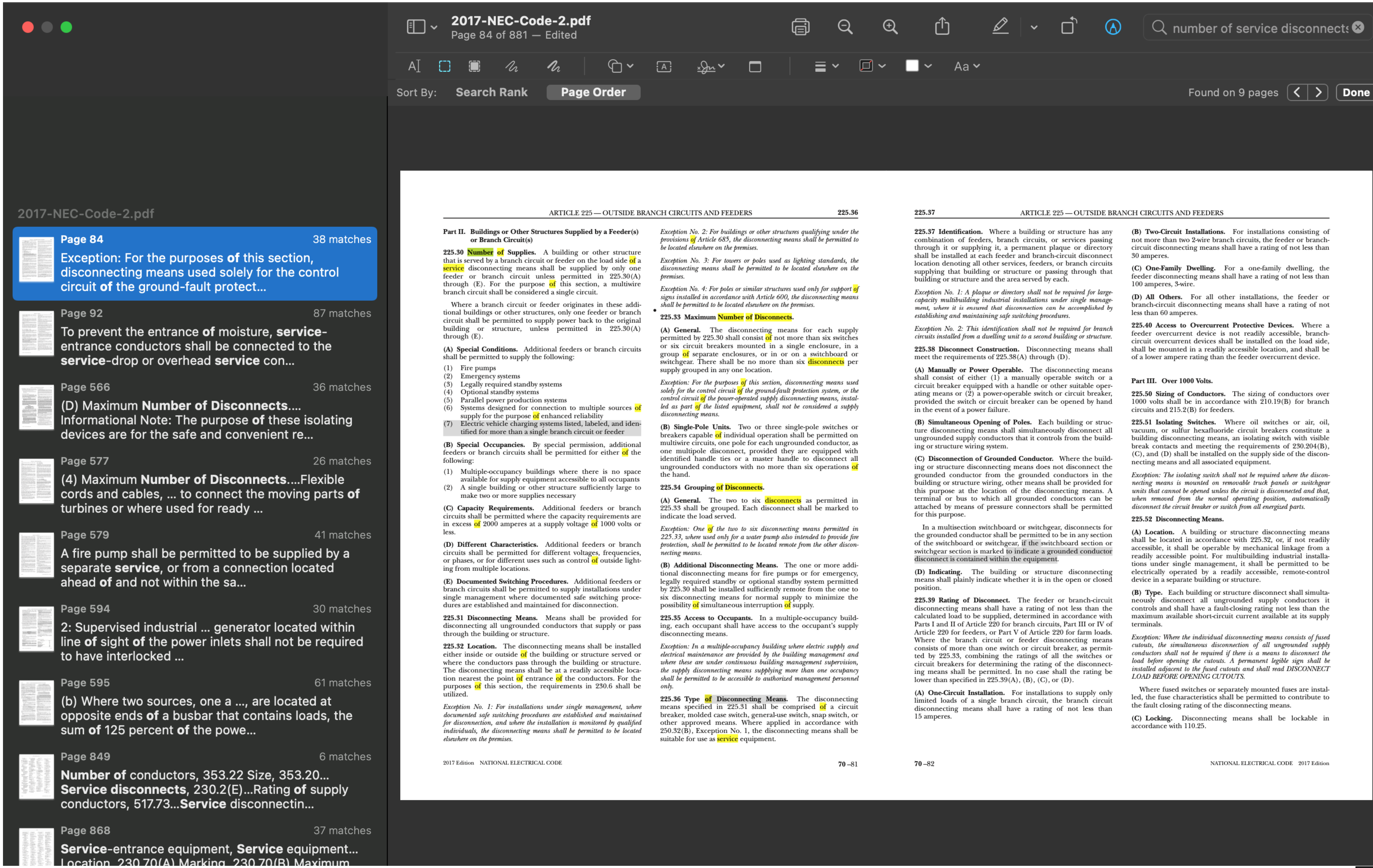
- If you're an experienced Code user, you might use the Table of Contents. You'll know Article 230 applies to "Services," and because this article is so large, it's divided up into multiple parts (actually eight parts). With this knowledge, you can quickly go to the Table of Contents and see it lists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

# How to Locate a Specific Requirement in the NEC (Cont’d)

**Index Method**

- 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 located 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.
- Many people complain that the NEC only confuses them by taking them in circles. Once you gain experience in using the Code and deepen your understanding of words, terms, principles, and practices, you’ll find the NEC much easier to understand and use than you originally thought.

# USING WORD SEARCH FOR ELECTRONIC VERSIONS OF THE NEC



# Practice Questions

- Electrical nonmetallic tubing (ENT) shall be securely fastened in place within __________ of each cabinet, device box, fitting, junction box, or outlet box where it terminates.

**362.30 Securing and Supporting.** ENT shall be installed as a complete system in accordance with 300.18 and shall be securely fastened in place by an approved means and supported in accordance with 362.30(A) and (B).

**(A) Securely Fastened.** ENT shall be securely fastened at intervals not exceeding 900 mm (3 ft). In addition, ENT shall be securely fastened in place within 900 mm (3 ft) of each outlet box, device box, junction box, cabinet, or fitting where it terminates. Where used, cable ties shall be listed as suitable for the application and for securing and supporting.

*Exception No. 1: Lengths not exceeding a distance of 1.8 m (6 ft) from a luminaire terminal connection for tap connections to lighting luminaires shall be permitted without being secured.*

*Exception No. 2: Lengths not exceeding 1.8 m (6 ft) from the last point where the raceway is securely fastened for connections within an accessible ceiling to luminaire(s) or other equipment.*

*Exception No. 3: For concealed work in finished buildings or prefinished wall panels where such securing is impracticable, unbroken lengths (without coupling) of ENT shall be permitted to be fished.*

# Practice Questions

- What is the minimum size for a copper grounding electrode conductor attached to the concrete-encased steel reinforcing bars used as a grounding electrode, when the ungrounded service-entrance conductors for a residence are size 3/0 AWG copper conductors?

**Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems**

| Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil) | | Size of Grounding Electrode Conductor (AWG/kcmil) | |
|---|---|---|---|
| Copper | Aluminum or Copper-Clad Aluminum | Copper | Aluminum or Copper-Clad Aluminum[b] |
| 2 or smaller | 1/0 or smaller | 8 | 6 |
| 1 or 1/0 | 2/0 or 3/0 | 6 | 4 |
| 2/0 or 3/0 | 4/0 or 250 | 4 | 2 |
| Over 3/0 through 350 | Over 250 through 500 | 2 | 1/0 |
| Over 350 through 600 | Over 500 through 900 | 1/0 | 3/0 |
| Over 600 through 1100 | Over 900 through 1750 | 2/0 | 4/0 |
| Over 1100 | Over 1750 | 3/0 | 250 |

Notes:

1. If multiple sets of service-entrance conductors connect directly to a service drop, set of overhead service conductors, set of underground service conductors, or service lateral, the equivalent size of the largest service-entrance conductor shall be determined by the largest sum of the areas of the corresponding conductors of each set.
2. Where there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

[a]This table also applies to the derived conductors of separately derived ac systems.

[b]See installation restrictions in 250.64(A).

# Practice Questions

- Capable of being reached quickly for operation, renewal, or inspections without resorting to portable ladders or the use of tools (other than keys) is known as “_____.”

**Accessible, Readily (Readily Accessible).** Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to take actions such as to use tools (other than keys), to climb over or under, to remove obstacles, or to resort to portable ladders, and so forth. (CMP-1)

Informational Note: Use of keys is a common practice under controlled or supervised conditions and a common alternative to the ready access requirements under such supervised conditions as provided elsewhere in the NEC.

# Practice Questions

- Receptacles outlets in or on floors shall not be considered as the required number of receptacle outlets unless the installed receptacles located _____ inches of wall
- 18” of the wall
- NEC 210.52(A)(3)

**(3) Floor Receptacles.** Receptacle outlets in or on floors shall not be counted as part of the required number of receptacle outlets unless located within 450 mm (18 in.) of the wall.

# Practice Questions

- In dwelling units, at least one receptacle outlet shall be installed in bathrooms within ___ of the outside edge of each basin.
- 36”
- 210.52(D)

**(D) Bathrooms.** At least one receptacle outlet shall be installed in bathrooms within 900 mm (3 ft) of the outside edge of each basin. The receptacle outlet shall be located on a wall or partition that is adjacent to the basin or basin countertop, loca-

# Practice Questions

- What is the unit load in volt ampere per square foot for stores?

Table 220.12 General Lighting Loads by Occupancy

| Type of Occupancy | Unit Load: Volt-amperes/ $m^2$ | Unit Load: Volt-amperes/ $ft^2$ |
|---|---|---|
| Armories and auditoriums | 11 | 1 |
| Banks | 39[b] | 3½ [b] |
| Barber shops and beauty parlors | 33 | 3 |
| Churches | 11 | 1 |
| Clubs | 22 | 2 |
| Courtrooms | 22 | 2 |
| Dwelling units[a] | 33 | 3 |
| Garages — commercial (storage) | 6 | ½ |
| Hospitals | 22 | 2 |
| Hotels and motels, including apartment houses without provision for cooking by tenants[a] | 22 | 2 |
| Industrial commercial (loft) buildings | 22 | 2 |
| Lodge rooms | 17 | 1½ |
| Office buildings | 39[b] | 3½ [b] |
| Restaurants | 22 | 2 |
| Schools | 33 | 3 |
| Stores | 33 | 3 |
| Warehouses (storage) | 3 | ¼ |
| In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings: | | |
| Assembly halls and auditoriums | 11 | 1 |
| Halls, corridors, closets, stairways | 6 | ½ |
| Storage spaces | 3 | ¼ |

[a]See 220.14(J).
[b]See 220.14(K).