ARTICLE

110

Requirements for Electrical Installations

INTRODUCTION TO ARTICLE 110—REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

Article 110 sets the stage for how you'll implement the rest of the *NEC*. This article contains a few of the most important and yet neglected parts of the *Code*. For example:

- How should conductors be terminated?
- What kinds of warnings, markings, and identification does a given installation require?
- What's the right working clearance for a given installation?
- What do the temperature limitations at terminals mean?
- What are the *NEC* requirements for dealing with flash protection?

It's critical that you master Article 110. As you read this article, you're building your foundation for correctly applying the *NEC*. In fact, this article itself is a foundation for much of the *Code*. The purpose for the *National Electrical Code* is to provide a safe installation, but Article 110 is perhaps focused a little more on providing an installation that is safe for the installer and maintenance electrician, so time spent in this article is time well spent.

Essential Rule 7 **110.2**

PART I. GENERAL REQUIREMENTS

110.2 Approval of Conductors and Equipment. The authority having jurisdiction must approve all electrical conductors and equipment. Figure 110–1

Author's Comment: For a better understanding of product approval, review 90.4, 90.7, 110.3 and the definitions for "Approved," "Identified," "Labeled," and "Listed" in Article 100.

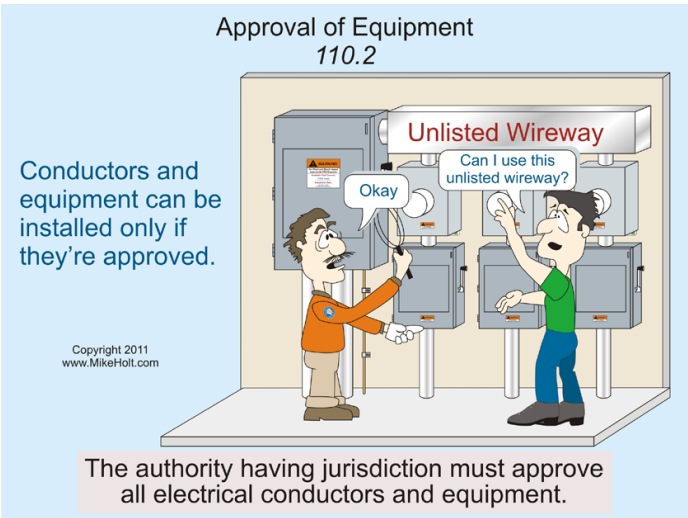


Figure 110–1

Essential Rule 8 **110.3**

110.3 Examination, Identification, Installation, and Use of Equipment.

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

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

Note: Suitability of equipment use may be identified by a description marked on or provided with a product to identify the suitability of the product for a specific purpose, environment, or application. Special conditions of use or other limitations may be marked on the equipment, in the product instructions, or appropriate listing and labeling information. Suitability of equipment may be evidenced by listing or labeling.

(2) Mechanical strength and durability

(3) Wire-bending and connection space

(4) Electrical insulation

(5) Heating effects under all conditions of use

(6) Arcing effects

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

(8) Other factors contributing to the practical safeguarding of persons using or in contact with the equipment

(B) Installation and Use. Equipment must be installed and used in accordance with any instructions included in the listing or labeling requirements. Figure 110–2

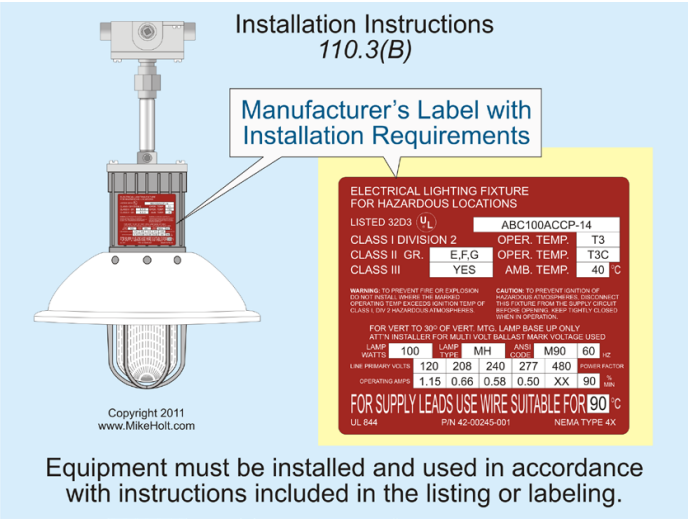


Figure 110–2

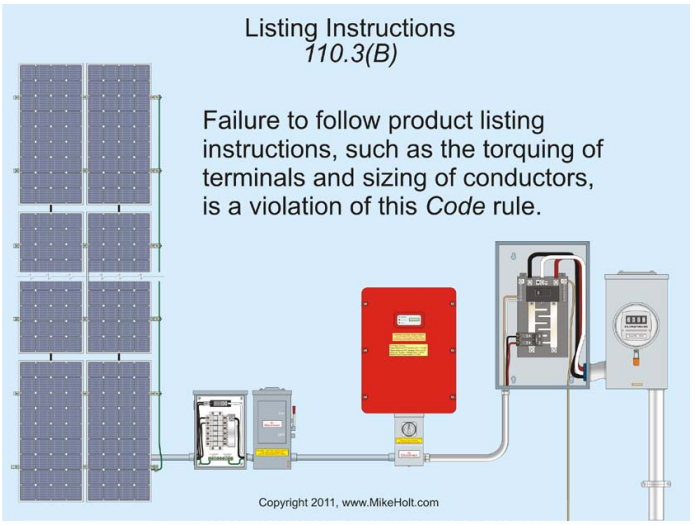


Figure 110–3

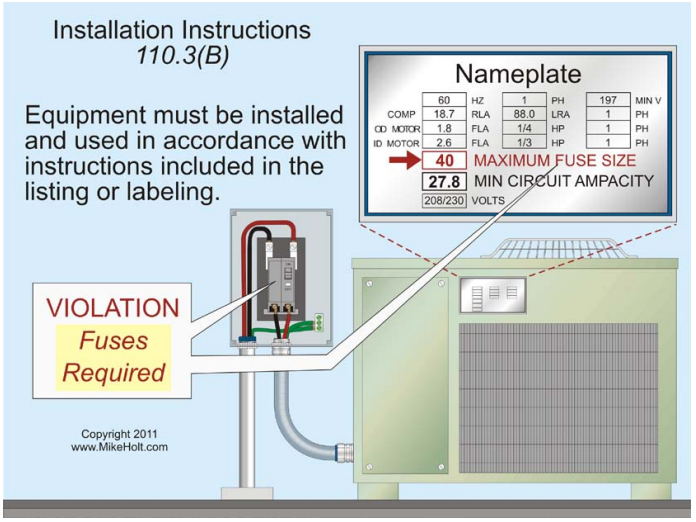


Figure 110–4

Author's Comments:

- See the definitions of "Labeling" and "Listing" in Article 100.
- Failure to follow product listing instructions, such as the torquing of terminals and the sizing of conductors, is a violation of this *Code* rule. Figure 110–3
- When an air conditioner nameplate specifies "Maximum Fuse Size," one-time or dual-element fuses must be used to protect the equipment. Figure 110–4

Essential Rule 9 110.14

110.14 Conductor Termination and Splicing. Conductor terminal and splicing devices must be identified for the conductor material and they must be properly installed and used. Figure 110–5

Connectors and terminals for conductors more finely stranded than Class B and Class C, as shown in Table 10 of Chapter 9, must be identified for the conductor class. Figure 110–6

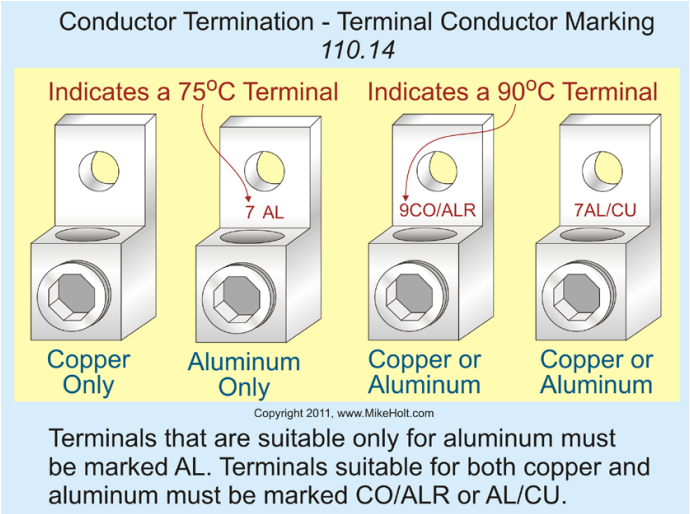


Figure 110–5

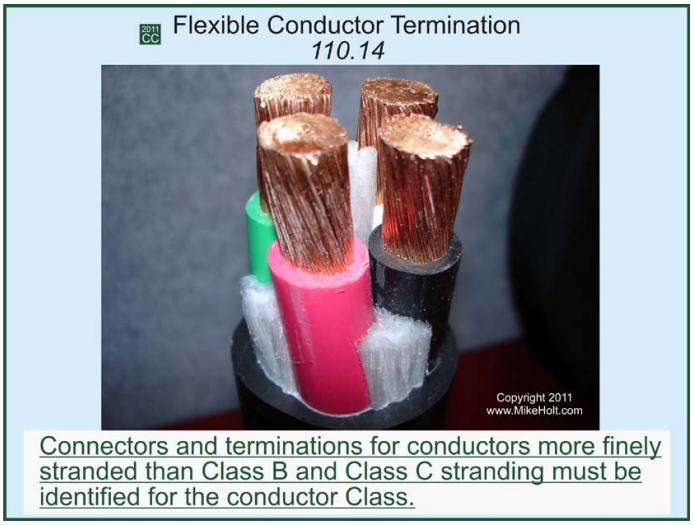


Figure 110–6

Author's Comments:

- According to UL Standard 486 A-B, a terminal/lug/connector must be listed and marked for use with conductors stranded in other than Class B. With no marking or factory literature/instructions to the contrary, terminals may only be used with Class B stranded conductors.
- Class D stranding has 37 strands of wire per conductor in sizes 18-2 AWG, 61 strands in sizes 1-4/0 AWG, and 91 strands in sizes 250-500 kcmil.

Switches and receptacles marked CO/ALR are designed to ensure a good connection through the use of the larger contact area and compatible materials. The terminal screws are plated with the element called "Indium." Indium is an extremely soft metal that forms a gas-sealed connection with the aluminum conductor.

Author's Comments:

- See the definition of "Identified" in Article 100.
- Conductor terminations must comply with the manufacturer's instructions as required by 110.3(B). For example, if the instructions for the device state "Suitable for 18-12 AWG Stranded," then only stranded conductors can be used with the terminating device. If the instructions state "Suitable for 18-12 AWG Solid," then only solid conductors are permitted, and if the instructions state "Suitable for 18-12 AWG," then either solid or stranded conductors can be used with the terminating device.

Copper and Aluminum Mixed. Copper and aluminum conductors must not make contact with each other in a device unless the device is listed and identified for this purpose.

Author's Comment: Few terminations are listed for the mixing of aluminum and copper conductors, but if they are, that will be marked on the product package or terminal device. The reason copper and aluminum shouldn't be in contact with each other is because corrosion develops between the two different metals due to galvanic action, resulting in increased contact resistance at the splicing device. This increased resistance can cause the splice to overheat and cause a fire.

Note: Many terminations and equipment are marked with a tightening torque, see Table I.1 in Informative Annex I.

Author's Comment: Conductors must terminate in devices that have been properly tightened in accordance with the manufacturer's torque specifications included with equipment instructions. Failure to torque terminals can result in excessive heating of terminals or splicing devices due to a loose connection. A loose connection can also lead to arcing which increases the heating effect and also may lead to a short circuit or ground fault. Any of these can result in a fire or other failure, including an arc-flash event. In addition, this is a violation of 110.3(B), which requires all equipment to be installed in accordance with listing or labeling instructions. Figure 110–7

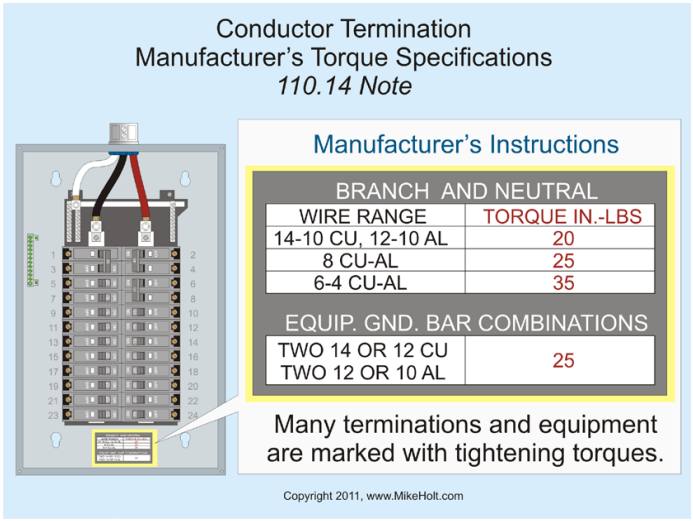


Figure 110–7

Question: *What do you do if the torque value isn't provided with the device?*

Answer: *Call the manufacturer, visit the manufacturer's Website, or have the supplier make a copy of the installation instructions.*

Author's Comment: Terminating conductors without a torque tool can result in an improper and unsafe installation. If a torque screwdriver isn't used, there's a good chance the conductors aren't properly terminated.

(A) Terminations. Conductor terminals must ensure a good connection without damaging the conductors and must be made by pressure connectors (including set screw type) or splices to flexible leads.

Author's Comment: See the definition of "Connector, Pressure" in Article 100.

Question: *What if the conductor is larger than the terminal device?*

Answer: *This condition needs to be anticipated in advance, and the equipment should be ordered with terminals that will accommodate the larger conductor. However, if you're in the field, you should:*

- *Contact the manufacturer and have them express deliver you the proper terminals, bolts, washers, and nuts, or*
- *Order a terminal device that crimps on the end of the larger conductor and reduces the termination size.*

Terminals for more than one conductor and terminals used for aluminum conductors must be identified for this purpose, either within the equipment instructions or on the terminal itself. Figure 110–8

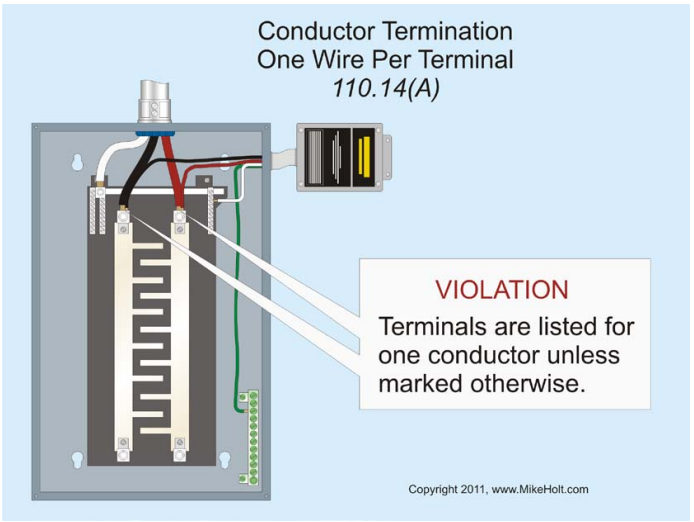


Figure 110–8

Author's Comments:

- Split-bolt connectors are commonly listed for only two conductors, although some are listed for three conductors. However, it's a common industry practice to terminate as many conductors as possible within a split-bolt connector, even though this violates the *NEC*. Figure 110–9
- Many devices are listed for more than one conductor per terminal. For example, some circuit breakers rated 30A or less can have two conductors under each lug. Grounding and bonding terminals are also often listed for more than one conductor under the terminal.
- Each neutral conductor within a panelboard must terminate to an individual terminal [408.41].

(B) Conductor Splices. Conductors must be spliced by a splicing device identified for the purpose or by exothermic welding.

Author's Comment: Conductors aren't required to be twisted together prior to the installation of a twist-on wire connector, unless specifically required in the installation instructions. Figure 110–10

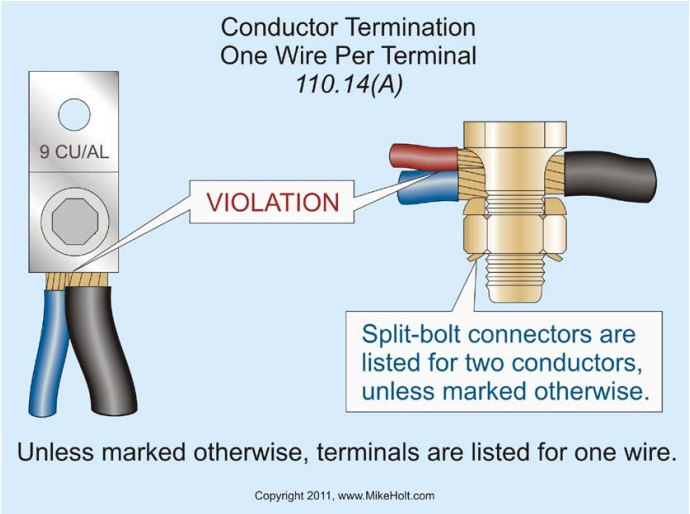


Figure 110–9

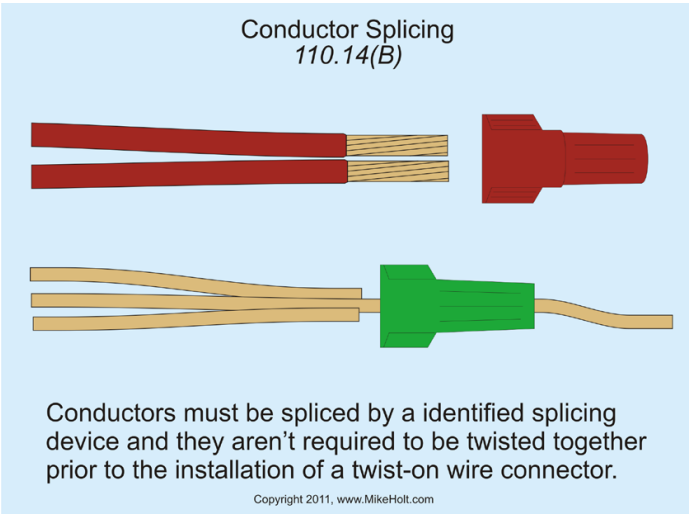


Figure 110–10

Unused circuit conductors aren't required to be removed. However, to prevent an electrical hazard, the free ends of the conductors must be insulated to prevent the exposed end of the conductor from touching energized parts. This requirement can be met by the use of an insulated twist-on or push-on wire connector. Figure 110–11

Author's Comment: See the definition of "Energized" in Article 100.

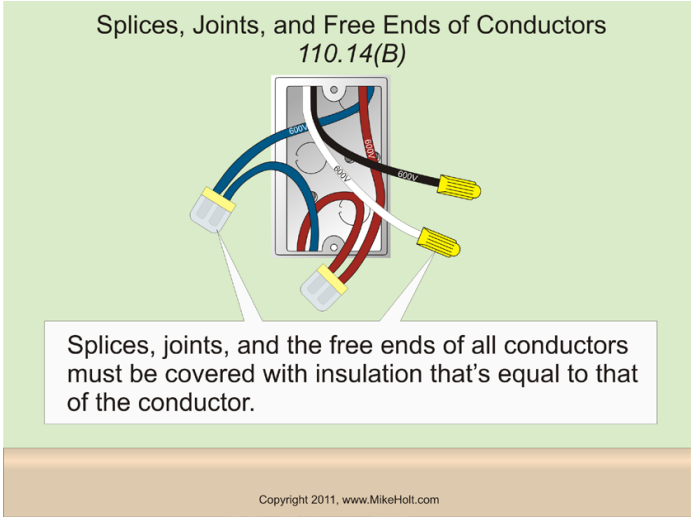


Figure 110–11

Underground Splices:

Single Conductors. Single direct burial conductors of types UF or USE can be spliced underground without a junction box, but the conductors must be spliced with a device listed for direct burial [300.5(E) and 300.15(G)]. Figure 110–12

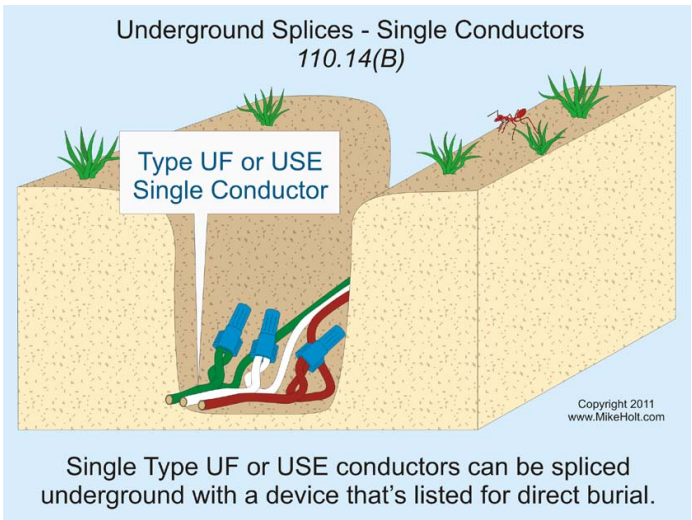


Figure 110–12

Multiconductor Cable. Multiconductor UF or USE cable can have the individual conductors spliced underground without a junction box as long as a listed splice kit that encapsulates the conductors as well as the cable jacket is used.

(C) Temperature Limitations (Conductor Size). Conductors are to be sized using their ampacity from the insulation temperature rating column of Table 310.15(B)(16) that corresponds to the lowest temperature rating of any terminal, device, or conductor of the circuit. Figure 110–13

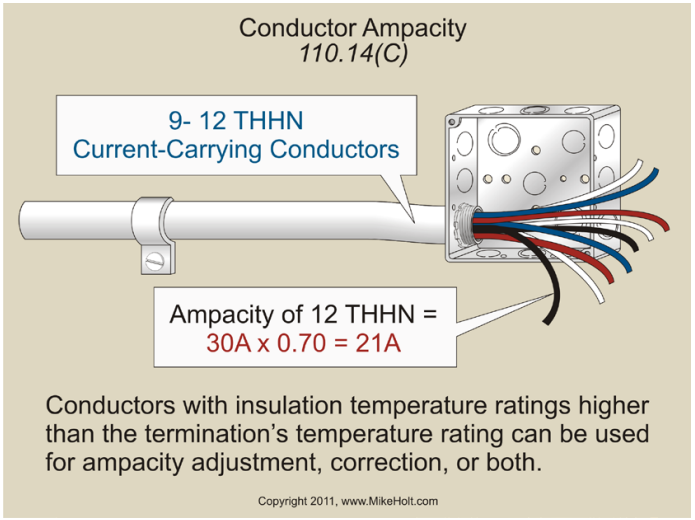


Figure 110–13

(1) Equipment Temperature Rating Provisions. Unless the equipment is listed and marked otherwise, conductor sizing for equipment terminations must be based on Table 310.15(B)(16) in accordance with (a) or (b):

(a) Equipment Rated 100A or Less. Figure 110–14

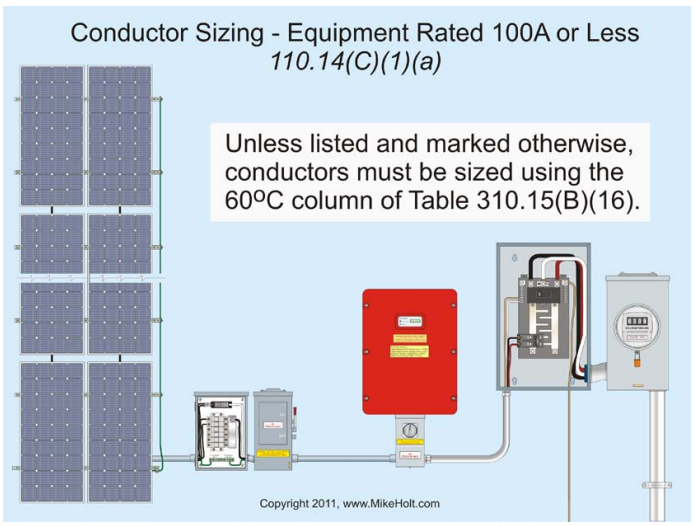


Figure 110–14

(1) Conductors must be sized using the 60°C temperature column of Table 310.15(B)(16).

(3) Conductors terminating on terminals rated 75°C are sized in accordance with the ampacities listed in the 75°C temperature column of Table 310.15(B)(16). Figure 110–15

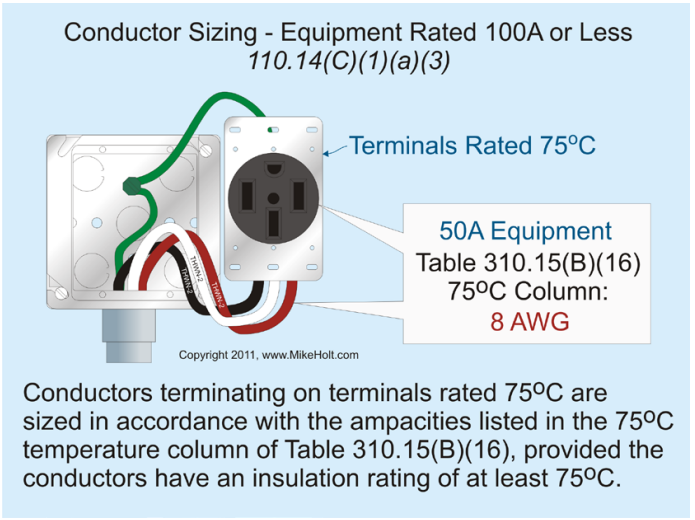


Figure 110–15

(b) Equipment Rated Over 100A.

(1) Conductors must be sized using the 75°C temperature column of Table 310.15(B)(16). Figure 110–16

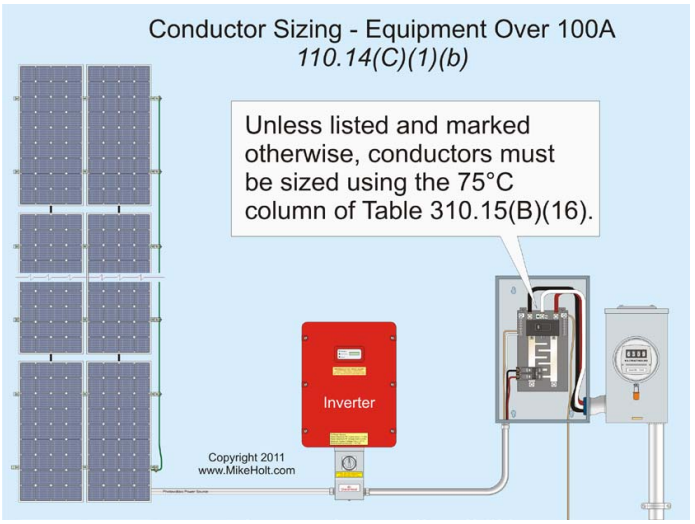


Figure 110–16

(2) Separate Connector Provisions. Conductors can be sized to the 90°C column of Table 310.15(B)(16) if the conductors and pressure connectors are rated at least 90°C. Figure 110–17

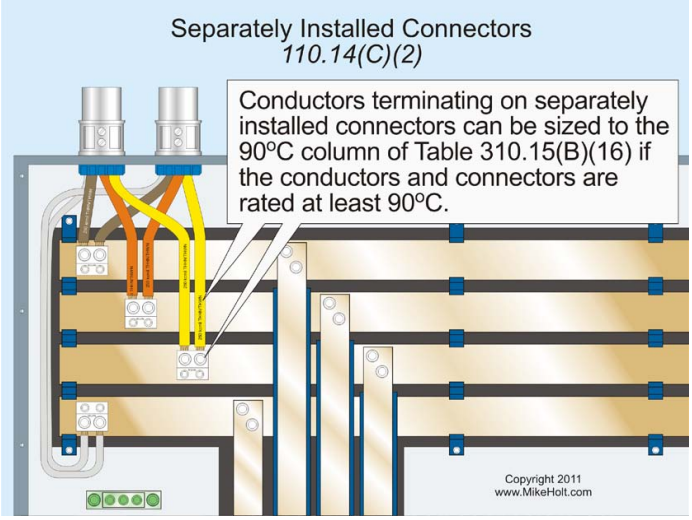


Figure 110–17

Essential Rule 10 110.16

110.16 Arc-Flash Hazard Warning. Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers in other than dwelling units that are likely to require examination, adjustment, servicing, or maintenance while energized must be field-marked to warn qualified persons of the danger associated with an arc flash from short circuits or ground faults. The field-marking must be clearly visible to qualified persons before they examine, adjust, service, or perform maintenance on the equipment. Figure 110–18

Author's Comments:

- See the definition of "Qualified Person" in Article 100.
- This rule is meant to warn qualified persons who work on energized electrical systems that an arc flash hazard exists so they'll select proper personal protective equipment (PPE) in accordance with industry accepted safe work practice standards.

Note 1: NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides assistance in determining the severity of potential exposure, planning safe work practices, and selecting personal protective equipment.

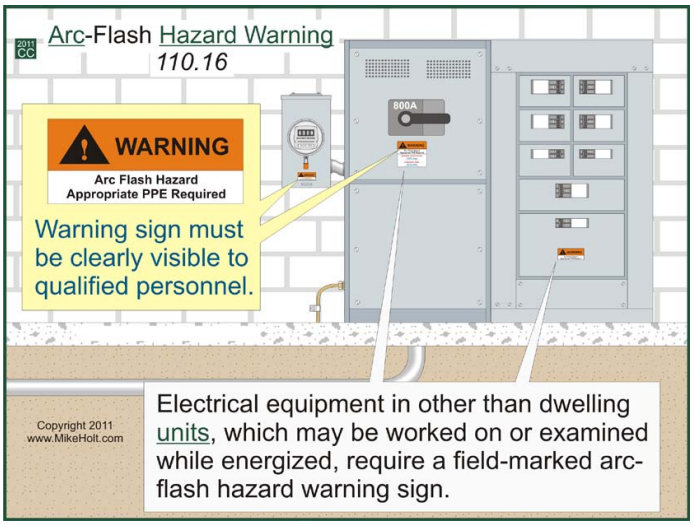


Figure 110–18

Essential Rule 11 110.24

110.24 Available Fault Current.

(A) Field Marking. Service equipment in other than dwelling units must be legibly field-marked with the maximum available fault current, including the date the fault current calculation was performed and be of sufficient durability to withstand the environment involved. Figure 110–19

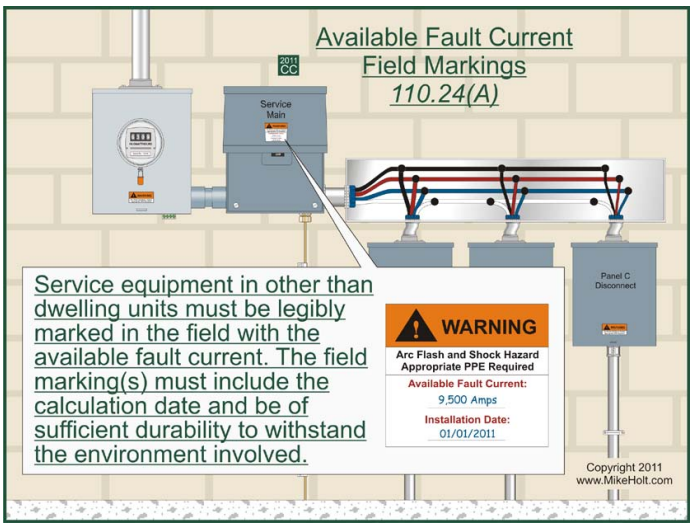


Figure 110–19

(B) Modifications. When modifications to the electrical installation affect the maximum available fault current at the service, the maximum available fault current must be recalculated to ensure the service equipment ratings are sufficient for the maximum available fault current at the line terminals of the equipment. The required field marking(s) in 110.24(A) must be adjusted to reflect the new level of maximum available fault current.

Ex: Field markings aren't required for industrial installations where conditions of maintenance and supervision ensure that only qualified persons service the equipment.

Essential Rule 12 110.26

PART II. 600V, NOMINAL, OR LESS

110.26 Spaces About Electrical Equipment. For the purpose of safe operation and maintenance of equipment, access and working space must be provided about all electrical equipment.

(A) Working Space. Equipment that may need examination, adjustment, servicing, or maintenance while energized must have working space provided in accordance with (1), (2), and (3):

> **Author's Comment:** The phrase "while energized" is the root of many debates. As always, check with the AHJ to see what equipment he or she believes needs a clear working space.

(1) Depth of Working Space. The working space, which is measured from the enclosure front, must not be less than the distances contained in Table 110.26(A)(1). Figure 110–20

Table 110.26(A)(1) Working Space

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

- *Condition 1—Exposed live parts on one side of the working space and no live or grounded parts, including concrete, brick, or tile walls are on the other side of the working space.*
- *Condition 2—Exposed live parts on one side of the working space and grounded parts, including concrete, brick, or tile walls are on the other side of the working space.*
- *Condition 3—Exposed live parts on both sides of the working space.*

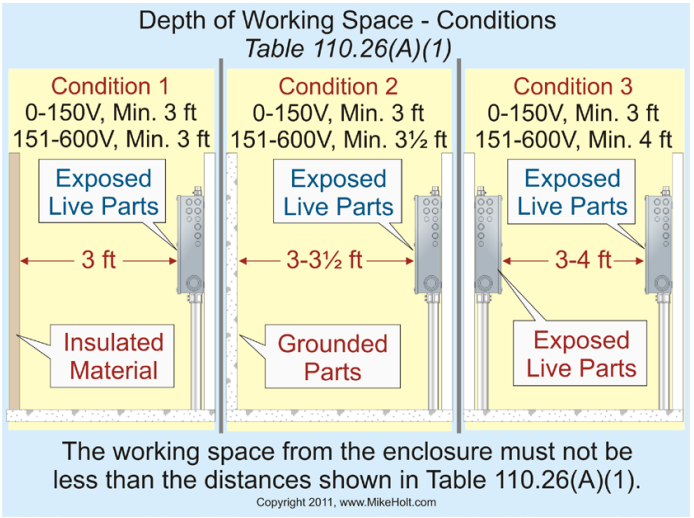


Figure 110–20

(a) Rear and Sides. Working space isn't required for the back or sides of assemblies where all connections and all renewable or adjustable parts are accessible from the front. Figure 110–21

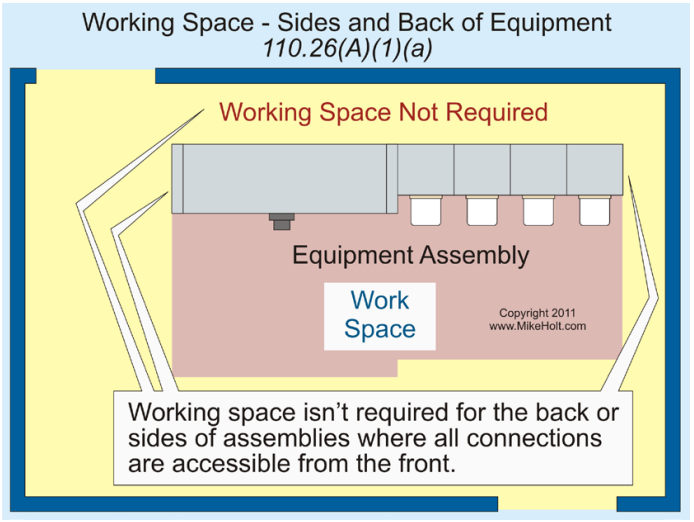


Figure 110–21

(b) Low Voltage. If special permission is granted in accordance with 90.4, working space for equipment that operates at not more than 30V ac or 60V dc can be less than the distance in Table 110.26(A)(1). Figure 110–22

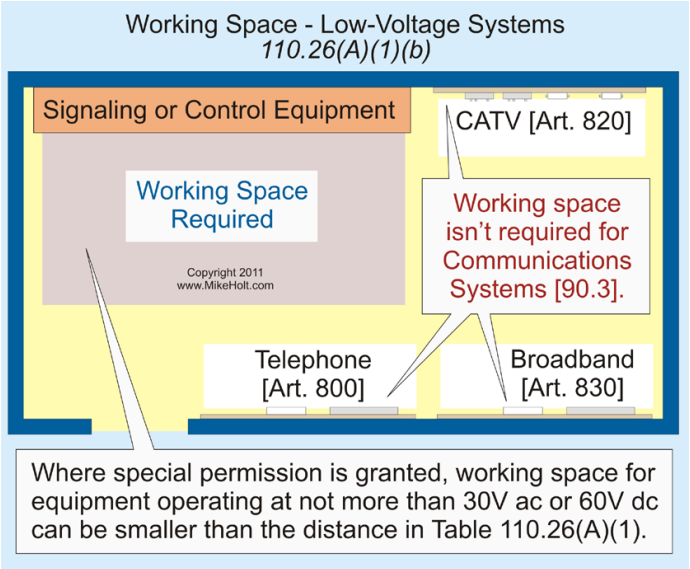


Figure 110–22

Author's Comment: See the definition of "Special Permission" in Article 100.

(c) Existing Buildings. If electrical equipment is being replaced, Condition 2 working space is permitted between dead-front switchboards, panelboards, or motor control centers located across the aisle from each other where conditions of maintenance and supervision ensure that written procedures have been adopted to prohibit equipment on both sides of the aisle from being open at the same time, and only authorized, qualified persons will service the installation.

Author's Comment: The working space requirements of 110.26 don't apply to equipment included in Chapter 8—Communications Circuits [90.3].

(2) Width of Working Space. The width of the working space must be a minimum of 30 in., but in no case less than the width of the equipment. Figure 110–23

Author's Comment: The width of the working space can be measured from left-to-right, from right-to-left, or simply centered on the equipment, and the working space can overlap the working space for other electrical equipment. Figure 110–24

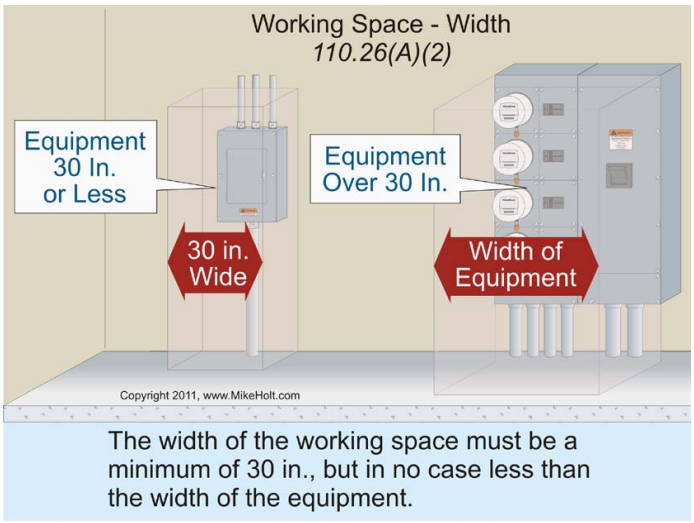


Figure 110–23

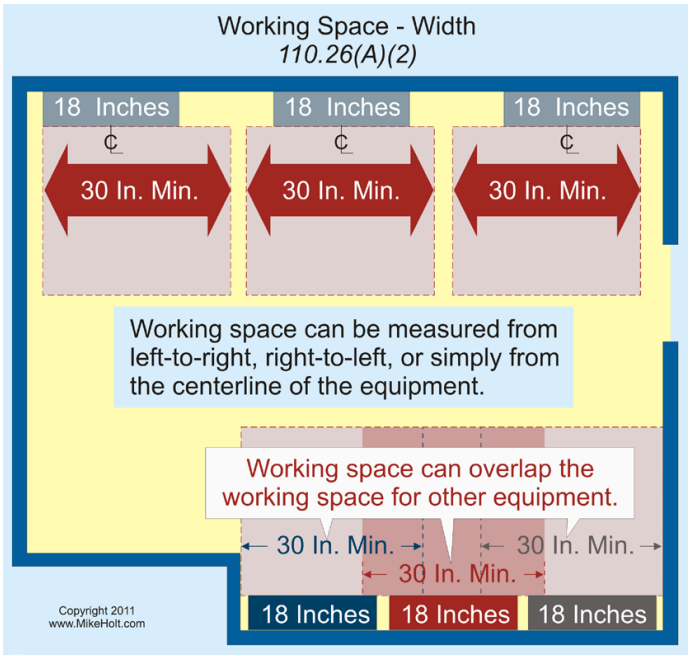


Figure 110–24

In all cases, the working space must be of sufficient width, depth, and height to permit all equipment doors to open 90 degrees. Figure 110–25

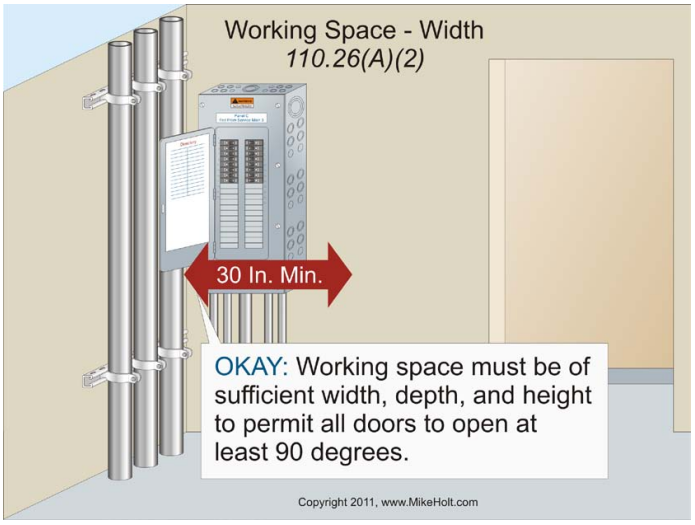


Figure 110–25

(3) Height of Working Space (Headroom). The height of the working space in front of equipment must not be less than 6½ ft, measured from the grade, floor, platform, or the equipment height, whichever is greater. Figure 110–26

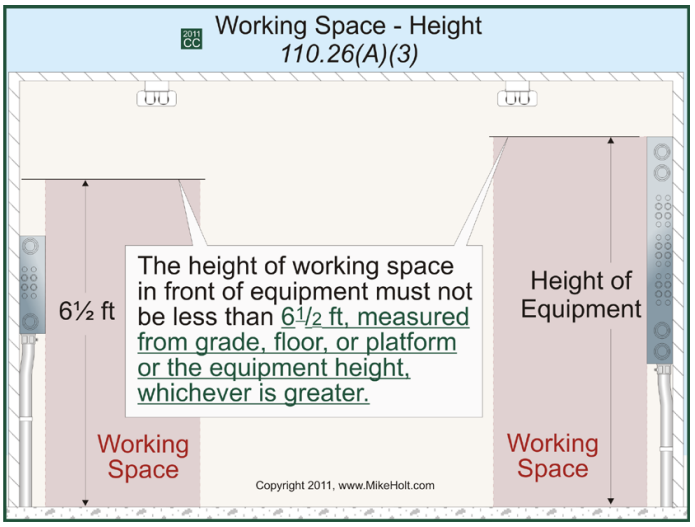


Figure 110–26

Equipment such as raceways, cables, wireways, cabinets, panels, and so on, can be located above or below electrical equipment, but must not extend more than 6 in. into the equipment's working space. Figure 110–27

Ex 1: The minimum headroom requirement doesn't apply to service equipment or panelboards rated 200A or less located in an existing dwelling unit.

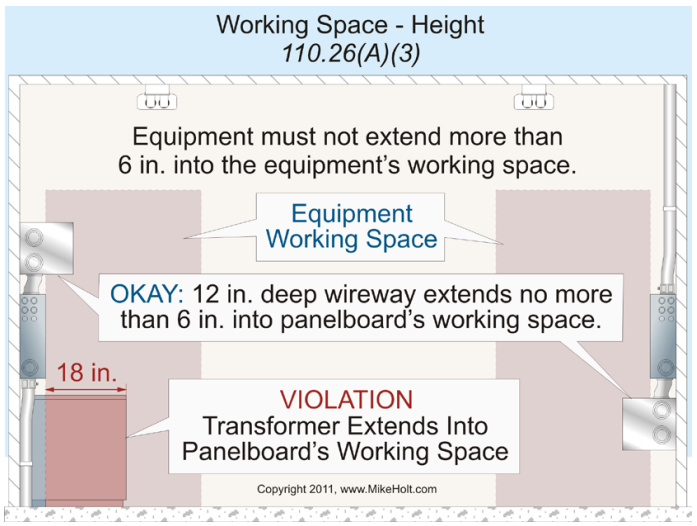


Figure 110–27

Author's Comment: See the definition of "Dwelling Unit" in Article 100.

Ex 2: Meters are permitted to extend beyond the other equipment.

(B) Clear Working Space. The working space required by this section must be clear at all times. Therefore, this space isn't permitted for storage. When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, must be suitably guarded.

Author's Comment: When working in a passageway, the working space should be guarded from occupants using the passageway. When working on electrical equipment in a passageway one must be mindful of a fire alarm evacuation with numerous occupants congregated and moving through the passageway.

CAUTION: *It's very dangerous to service energized parts in the first place, and it's unacceptable to be subjected to additional dangers by working around bicycles, boxes, crates, appliances, and other impediments.* Figure 110–28

Author's Comment: Signaling and communications equipment must not be installed in a manner that encroaches on the working space of the electrical equipment.

(C) Entrance to and Egress from Working Space.

(1) Minimum Required. At least one entrance of sufficient area must provide access to and egress from the working space.

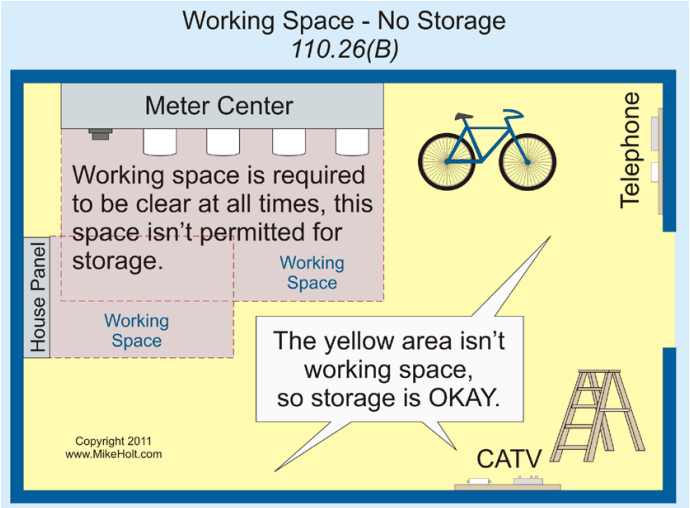
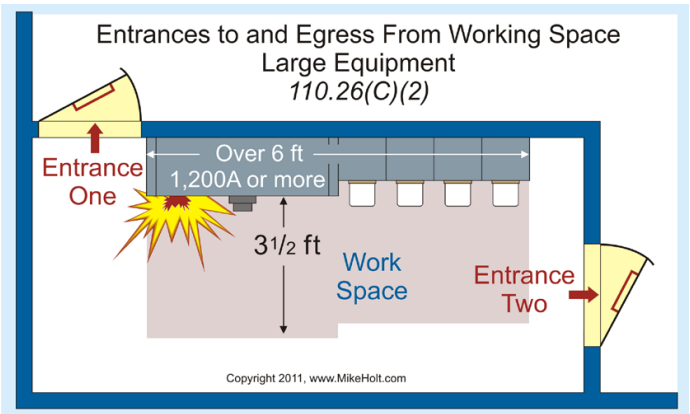


Figure 110–28

Author's Comment: Check to see what the authority having jurisdiction considers "Sufficient Area." Building codes contain minimum dimensions for doors and openings for personnel travel.

(2) Large Equipment. An entrance to and egress from each end of the working space of electrical equipment rated 1,200A or more that's over 6 ft wide is required. The opening must be a minimum of 24 in. wide and 6½ ft high. Figure 110–29. A single entrance to and egress from the required working space is permitted where either of the following conditions is met:

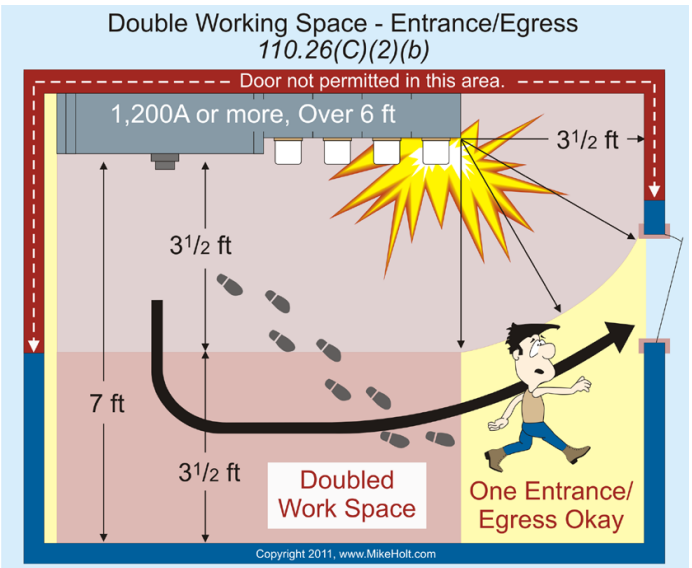


For equipment rated 1,200A or more and over 6 ft wide, an entrance to and egress from (2 ft x 6 ½ ft) is required at each end of the working space.

Figure 110–29

(a) Unobstructed Egress. Only one entrance is required where the location permits a continuous and unobstructed way of egress travel.

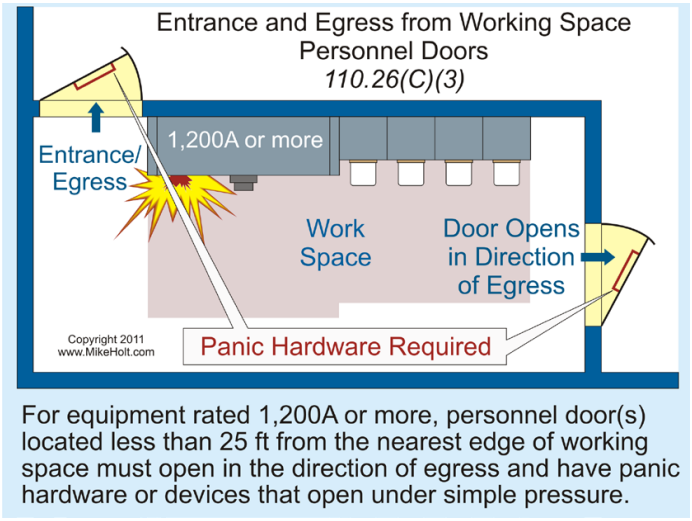
(b) Double Workspace. Only one entrance is required where the required working space depth is doubled, and the equipment is located so the edge of the entrance is no closer than the required working space distance. Figure 110–30



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

Figure 110–30

(3) Personnel Doors. If equipment with overcurrent or switching devices rated 1,200A or more is installed, personnel door(s) for entrance to and egress from the working space located less than 25 ft from the nearest edge of the working space must have the door(s) open in the direction of egress and be equipped with panic hardware or other devices that open under simple pressure. Figure 110–31



For equipment rated 1,200A or more, personnel door(s) located less than 25 ft from the nearest edge of working space must open in the direction of egress and have panic hardware or devices that open under simple pressure.

Figure 110–31

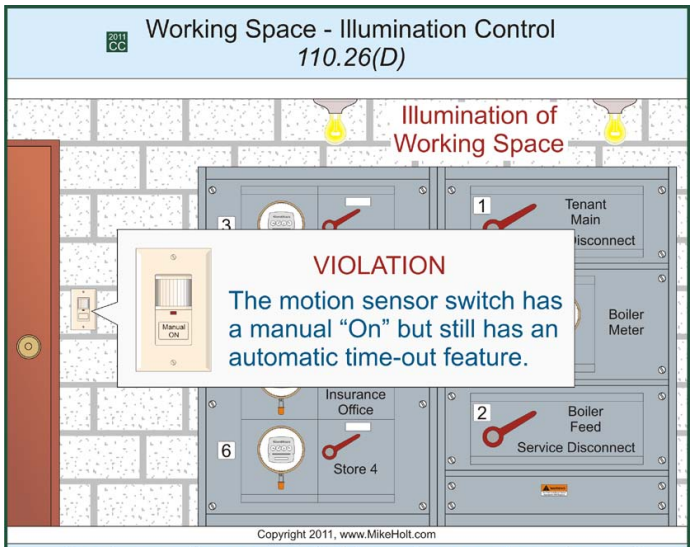
Author's Comments:

- History has shown that electricians who suffer burns on their hands in electrical arc flash or arc blast events often can't open doors equipped with knobs that must be turned.
- Since this requirement is in the *NEC*, the electrical contractor is responsible for ensuring that panic hardware is installed where required. Some electrical contractors are offended at being held liable for nonelectrical responsibilities, but this rule is designed to save the lives of electricians. For this and other reasons, many construction professionals routinely hold "pre-construction" or "pre-con" meetings to review potential opportunities for miscommunication—before the work begins.

(D) Illumination. Service equipment, switchboards, panelboards, as well as motor control centers located indoors must have illumination located indoors and must not be controlled by automatic means only. Figure 110–32

Author's Comment: The *Code* doesn't provide the minimum foot-candles required to provide proper illumination. Proper illumination of electrical equipment rooms is essential for the safety of those qualified to work on such equipment.

(E) Dedicated Equipment Space. Switchboards, panelboards, and motor control centers must have dedicated equipment space as follows:



Service equipment, switchboards, panelboards, and motor control centers located indoors must have illumination not controlled by automatic means only.

Figure 110–32

(1) Indoors.

(a) Dedicated Electrical Space. The footprint space (width and depth of the equipment) extending from the floor to a height of 6 ft above the equipment or to the structural ceiling, whichever is lower, must be dedicated for the electrical installation. No piping, ducts, or other equipment foreign to the electrical installation can be installed in this dedicated footprint space. Figure 110–33

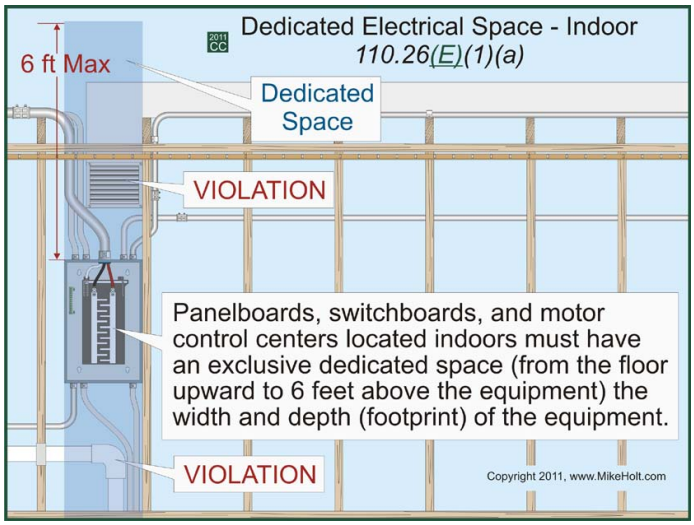


Figure 110–33

Ex: Suspended ceilings with removable panels can be within the dedicated footprint space [110.26(E)(1)(d)].

> **Author's Comment:** Electrical raceways and cables not associated with the dedicated space can be within the dedicated space. These aren't considered "equipment foreign to the electrical installation." Figure 110–34

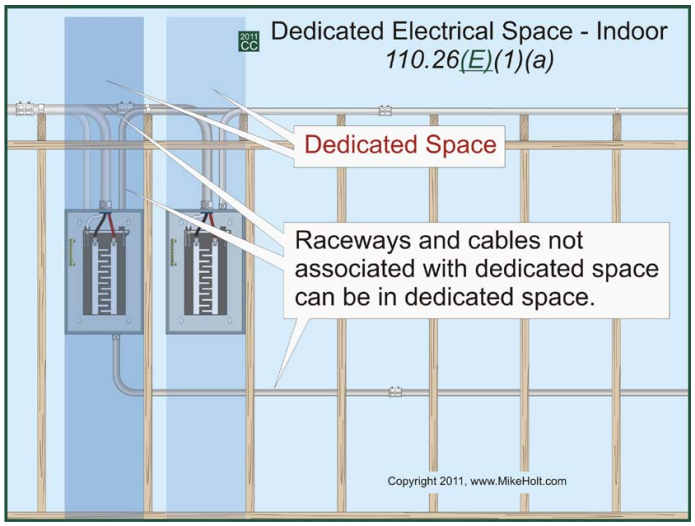


Figure 110–34

(b) Foreign Systems. Foreign systems can be located above the dedicated space if protection is installed to prevent damage to the electrical equipment from condensation, leaks, or breaks in the foreign systems, which can be as simple as a drip-pan. Figure 110–35

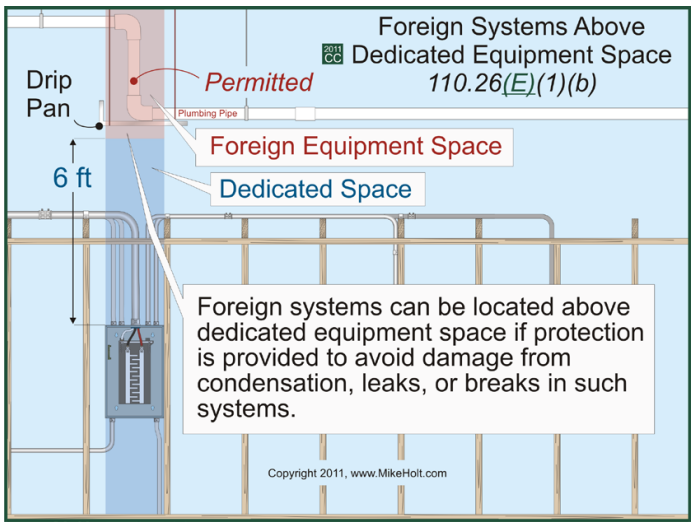


Figure 110–35

(c) Sprinkler Protection. Sprinkler protection piping isn't permitted in the dedicated space, but the *NEC* doesn't prohibit sprinklers from spraying water on electrical equipment.

(d) Suspended Ceilings. A dropped, suspended, or similar ceiling isn't considered a structural ceiling.

(F) Locked Electrical Equipment Rooms or Enclosures. Electrical equipment rooms and enclosures housing electrical equipment can be controlled by locks because they are still considered to be accessible to qualified persons who require access. Figure 110–36

> **Author's Comment:** See the definition of "Accessible as it applies to equipment" in Article 100.

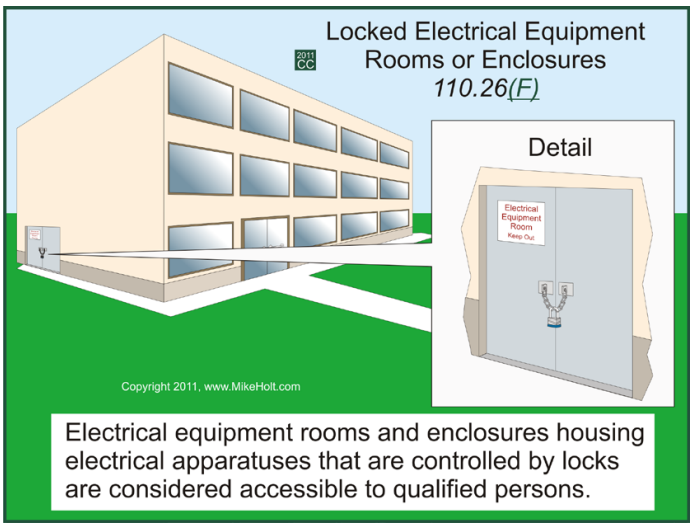


Figure 110–36

Notes