

Chapter I

General

Article 100—Definitions

The *National Electrical Code* (NEC) contains a great number of definitions, which are very important for interpreting the *Code*. If you have any doubt as to the exact meaning of a general term, refer to Article 100 and verify that meaning. You will also find that the definitions in this section are arranged in two categories—“General” and “Over 600 Volts.”

But if you need the definition of a more specific term, you may have to find it in the article where it would be dealt with most directly. As you continue through the *Code*, you will find additional definitions scattered throughout other articles. These definitions are very specific to that article and are therefore included with that article and not in Article 100.

The following figures are useful in understanding the definitions. For a branch circuit, see Figure 100-1. For a multiwire branch circuit, see Figure 100-2. For an illustration of service drop, see Figure 100-3. Service-lateral and service-entrance equipment are illustrated in Figures 100-4 and 100-5, respectively.

Article 110—Requirements for Electrical Installations

Article 110 is by-passed in the study of the *Code* more often than any other article. It is short, but it is actually the foundation upon which the *Code* is written, as it contains provisions that are used throughout the entire *Code*.

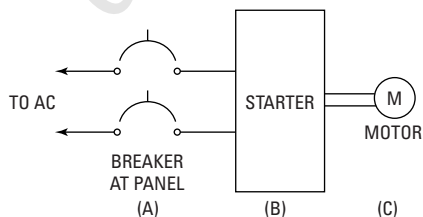


Figure 100-1 A motor circuit. The branch circuit extends from point A to point C.

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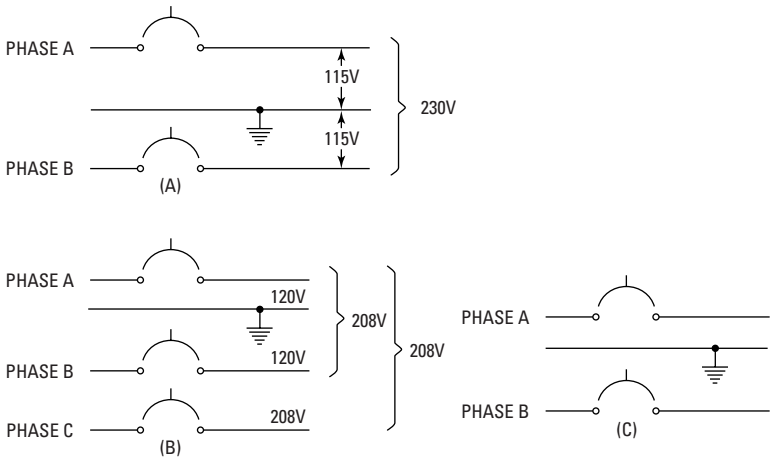


Figure 100-2 Variations of a multiwire branch circuit. Circuit C is not a multiwire branch circuit because it utilizes two wires from the same phase in conjunction with the neutral conductor.

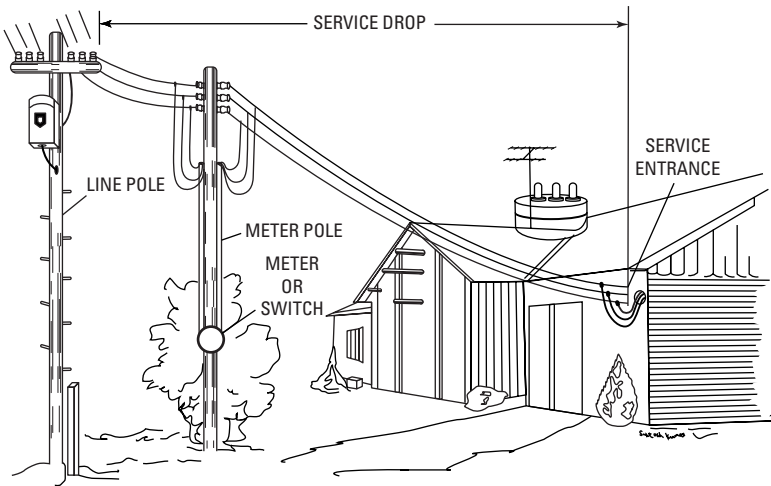


Figure 100-3 Illustrating the service drop attached to a building or other structure.

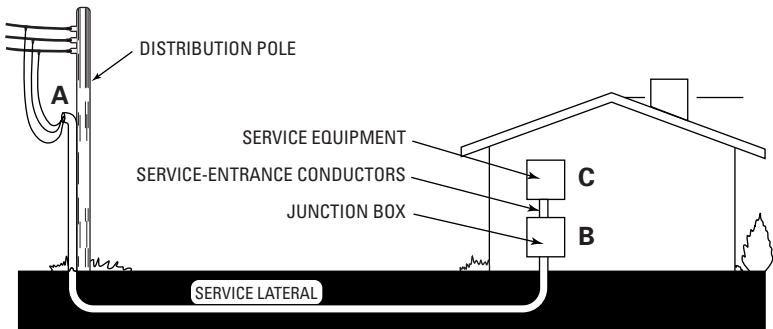


Figure 100-4 Illustrating the service lateral extending from point A to point B. The service entrance is from point B to point C.

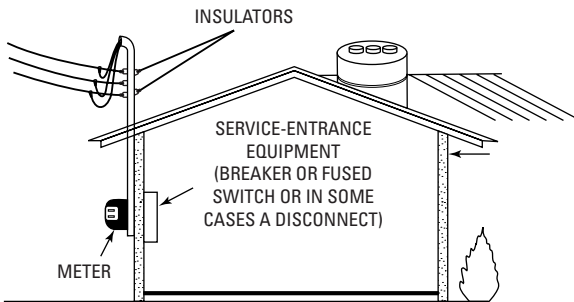


Figure 100-5 Showing the service-entrance equipment that will serve as the electrical disconnect supply.

I. General

110.2: Approval

See definition of *approved* under Article 100.

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

(A) Examination. Observe the following considerations for the evaluation of equipment:

- (1)** Wiring devices and equipment that are suitable for use must be provided with identification of the product and of the use intended—environmental application. The identification, in most cases, is by labeling or listing.

If the above information is not available, it becomes the responsibility of the authority having jurisdiction to decide the suitability of the equipment.

- (2) The wiring material and equipment must have their parts properly designed so that the enclosure will protect other equipment.
 - (3) Adequate splice-wire bending is required. The exact measurements are found in Tables 312.6(A) and (B) of the *NEC*.
 - (4) Electrical insulation may be checked.
 - (5) Heating effects must be taken into consideration on conductors. In Article 310 there are tables for reducing the ampacity of a conductor as ambient temperatures rise. The author finds that few are familiar with high-altitude rating of motors, which starts at 3500 feet above sea level. In higher altitudes the air is thinner and therefore has less cooling effect on the motor. For instance, a 5-horsepower motor at a high altitude can't be expected to carry as much load as the same 5-horsepower motor at sea level.
 - (6) The equipment must be designed for minimal arcing.
 - (7) The use of voltages and currents must be taken into consideration.
 - (8) Other factors that affect safety to persons that will have occasion to come in contact with this equipment must be considered.
- (B) **Installation and Use.** Labeling or listing will be effective only if the precautions noted on the installation and use instructions included with the labeling or listing service are followed. Alteration of equipment in the field voids any labeling or listing.

110.4: Voltages

The voltages referred to in the *Code* are the supply voltages, regardless of their source. The supply may be a battery, generator, transformer, rectifier, or a thermopile. When considering AC voltages, the voltage is the RMS voltage as explained in Article 100. There are really three general classifications of voltages in the *Code*—0 to 50 volts, 50 to 600 volts, and voltages that exceed 600 volts. Each is dealt with in separate parts of the *Code*. If wires having different

voltages are run in the same raceway, there are specific rules to be followed. See Section 300.3(C).

No electrical equipment may be connected to a circuit that has a voltage higher than the equipment's rating.

110.5: Conductors

Unless the material of which the conductor is made is specifically identified, it is assumed to be copper. Any other material of which a conductor may be made, such as aluminum, shall be identified as such.

Copper and aluminum conductors have different ampacities and are covered in Article 310. Copper-clad aluminum conductors have the same ampacity as aluminum conductors.

110.6: Conductor Sizes

In dealing with wire sizes, the *Code* always refers to the American Wire Gage (AWG). At one time, this was known as the B&S Gage. Sizes of conductors larger than 4/0 are measured in circular mils.

110.7: Insulation Integrity

All wiring shall be installed free of shorts and grounds. This does not cover purposefully-grounded conductors, as covered in Article 250.

Shorts or grounds may be located before energizing circuits by the use of a megohm-type tester (available from several manufacturers).

Conductors of the same circuit and in the same raceway must be insulated with the same type of material. Therefore, insulation-resistance tests on each conductor should produce similar values. A case in point: Six 500 kcmil THHN conductors in the same conduit read approximately 1500 megohms on four conductors, and in the vicinity of 300 megohms on the other two conductors. While 300 megohms would have been a good value, the difference in the readings indicated problems. The low-reading cables were pulled out, and it was found that the insulation had been cut in many places. With time and condensation moisture, a fault would have occurred.

110.8: Wiring Method

Only recognized and suitable wiring methods are included in the *Code*. Basically, Chapter 3 covers approved wiring methods; Chapters 5 through 8 cover specific conditions and occupancies.

110.9: Interrupting Rating

Interrupting capacity is far different from the rating of the amperes that are required by a load. We are faced with what is known as

fault currents. A fault current is the amount of current that might develop under a dead-short condition. This level of current is dependent upon the utility system supplying the current, the impedance of the system, and any fuses that may be up-line. At one time, this was not much of a problem, but with increased electrical usage and larger generating and distribution capacities, the problem of fault currents has increased. This is taken more into consideration now than in the past, and may become an increasingly important factor. If a piece of equipment is rated at X number of amperes, this does not necessarily mean that it can be disconnected under load or a fault condition without damage. Equipment is rated in carrying capacity as well as interrupting capacity. Sections 110.9 and 110.10 together require that all equipment be coordinated and protected from fault currents, not just from overcurrents. This requires the installer to get the cooperation of the utility company to verify available fault currents at the point of service.

110.10: Circuit Impedance and Other Characteristics

The fault currents are limited only by the capacity of the electrical supply, the impedance of the supplying circuits, and the wiring. As an example, the fault current will be much larger in circuits supplied from a large-capacity transformer supplying a heavily loaded city block than the fault current from a transformer serving a 5-horsepower irrigation pump in a rural area. The impedance of the supply to the 5-horsepower motor will be high in comparison to the impedance of the supply to the city block.

It is necessary to understand all coordinate fault currents, circuit impedances, and component short-circuit withstanding ratings. Fuse and breaker manufacturers have available easy-to-understand literature on fault currents and impedances, making it simple to check whether the equipment will withstand available fault currents.

It is also necessary to consider equipment that is connected to these circuits. In many cases, a wiring fault could spread its damage to these devices. This must be prevented. It is also important to understand that the requirements of the *Code*, especially in this section, will provide for a minimum level of safety; they don't guarantee that the equipment will not be damaged. Even with appropriately sized fault protection, damage to the equipment is possible, albeit without causing damage to other equipment or persons.

110.11: Deteriorating Agent

Environmental factors, such as wetness, dampness, fumes, vapors, gases, liquids, temperatures, and any other deteriorating effects, must also be noted; conductors and equipment used must be

approved for the specific conditions of operation. The inspection authority is often faced with the responsibility of deciding in which category the installation belongs; it most certainly is beyond the scope of the *Code* to define and specify for every possible condition that will have to be met. The *NFPA National Fire Codes* will be of great value in this respect.

Protection shall be given to equipment, such as control equipment, utilization equipment, and busways, during construction if this equipment is approved for dry locations only. It shouldn't be permanently damaged by weather during the building construction. Section 300.6 further discusses protection from corrosion.

110.12: Mechanical Execution of Work

Electrical installers are required to install all electrical systems in a neat and workmanlike manner. Thus, the *Code* specifies that not just materials are important, but that workmanship is also extremely important.

This "neat and workmanlike manner" rule is actually one of the broadest in the *Code*. It can be applied to conduit bending, the trimming of panels, or to almost any aspect of an installation of electrical wiring. This gives the authorities having jurisdiction some discretion; they can invoke rulings based upon workmanship, which can be interpreted many ways. In actual practice, this rule can be applied either well or poorly, but is probably necessary. As expansive as the *Code* document is, human action is far more expansive, and no rule-book could address every possibility. This rule gives an inspector some latitude. The author has never seen it used in an overtly malicious fashion, though that does remain a possibility.

- (A) Unused Openings.** All openings in boxes, equipment, or enclosures of any kind must be effectively closed and must provide protection equal to that of the equipment or enclosure itself.
- (B) Subsurface Enclosures.** Conductors in underground enclosures (such as manholes) must be racked. This is necessary to provide for safe and easy access.
- (C) Integrity of Electrical Equipment and Connections.** All parts of electrical equipment must be kept free of paint, plaster, cleaners, and any other type of foreign material. This has long been a problem on construction sites, where plaster and paint end up in electrical panels and other items. All such contamination must be avoided.

110.13: Mounting and Cooling of Equipment

- (A) **Mounting.** Mounting of equipment is an item directly related to workmanship. Wooden plugs driven into holes in masonry, plaster, concrete, and so on, will shrink and rot, thereby allowing the equipment to become loose. Thus, only approved methods of mounting and special anchoring devices may be used.
- (B) **Cooling.** Electricity produces heat. Electrical equipment must be installed in such a way that circulation of air and convection methods of cooling are not hindered. Mounting equipment too close to walls, ceilings, floors, or other items will interfere with the electric equipment's designed means of cooling. Ventilation openings in the electric equipment must be kept free to permit natural circulation.

One should also watch the amount of total space in the room where the equipment is mounted. If it is inadequate to permit a low enough ambient temperature, means must be taken to permit the lowering of high ambient temperatures by natural or other means.

110.14: Electrical Connections

Because values of electrolysis (chemical decomposition caused by an electrical current) vary among metals, and because we are using copper or aluminum conductors, copper, being the more noble on the electrolysis series, will corrode the aluminum away. Therefore, you must be sure when making splices or terminations that the lugs or connectors are listed for the purpose for which you are using them. When using solder fluxes or inhibitors, make sure they are listed for the job you are doing. Wherever values for tightening torques are given, they must be adhered to.

The author has found very little available information on torquing values. Therefore, it might be appropriate to insert some torquing values in this book. Many breakdowns and possible fires might result from not adhering to proper torquing values, so Tables 110-1 through 110-3 are presented as guidelines for tightening connections. It might also be mentioned that dies on compression tools do wear, and to avoid breakdowns, the Biddle Co.'s Ducter can prevent this problem, as it will read down to one-half millionth of an ohm. This instrument has been invaluable to the author.

You will find additional torquing pressures in mechanical engineering handbooks. Loose connections can be a hazard, causing breakdowns and possibly fires. If the authority having jurisdiction so wishes, it may require torquing tests during inspections.

Table I 10.1 Tightening Torque in Pound-Feet Screw Fit

Wire Size, AWG	Driver	Bolt	Other
18–16	1.67	6.25	4.2
14–8	1.67	6.25	6.125
6–4	3.0	12.5	8.0
3–1	3.2	21.00	10.40
0–2/0	4.22	29	12.5
AWG 200 kcmil	—	37.5	17.0
250–300	—	50.0	21.0
400	—	62.5	21.0
500	—	62.5	25.0
600–750	—	75.0	25.0
800–1000	—	83.25	33.0
1250–2000	—	83.26	42.0

Table I 10.2 Screws

Screw Size, Inches Across Hex Flats	Torque, Pound-Feet
$\frac{1}{8}$	4.2
$\frac{5}{32}$	8.3
$\frac{3}{16}$	15
$\frac{7}{32}$	23.25
$\frac{1}{4}$	42

Table I 10.3 Bolts

Size	Duronze	Steel	Aluminum
Standard, Unlubricated			
$\frac{3}{8}$	20	15	16
$\frac{1}{2}$	40	25	35
$\frac{5}{8}$	70	50	50
$\frac{3}{4}$	100	90	70
Standard, Lubricated			
$\frac{3}{8}$	15	10	13
$\frac{1}{2}$	30	20	25
$\frac{5}{8}$	50	40	40

(A) Terminals. Connections to terminals must ensure a good electrical and mechanical contact without injury to the conductors; connection must be by approved pressure connectors, solder lugs, or splices to flexible wires. The exception to the regulation is that No. 10 or smaller stranded conductors can be connected by means of clamps or screws with terminal plates having upturned lugs (Figure 110-1). Terminals for more than one conductor must be of the approved type for this purpose. When permitted to place a wire under a terminal screw, wrap it in such a direction that when you tighten the screw, the wire will not be squeezed out from under the head of the screw. On the smaller sizes of conductors, especially cord conductors, it is best to twist the conductor strands and apply some solder to them.

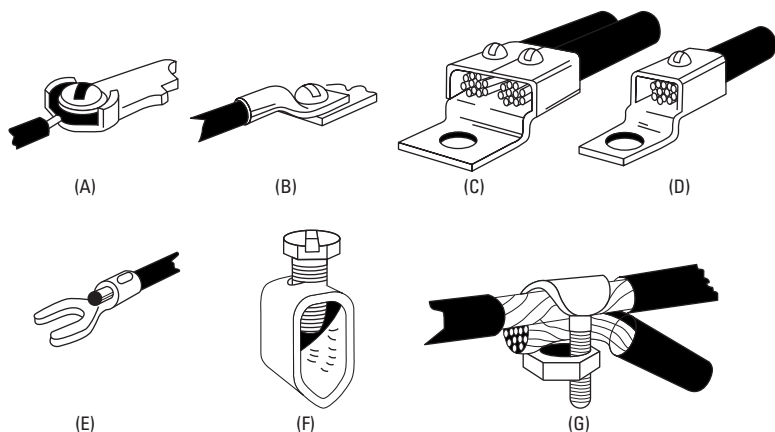


Figure 110-1 Various types of approved pressure connectors.
 (A) Terminal plate; (B) Soldered lug; (C) Double pressure-type lug;
 (D) Single pressure-type lug; (E) Open-end crimp-type lug; (F) Pressure-type connector; (G) Split-bolt clamp.

Compression-type connections are extremely good if the proper compression tool is used and it is in good shape. No. 10 or smaller conductors can be used for screws, studs, or nuts that have upturned lugs or equal design to keep the wire connection in place.

Any terminal or lug intended for use with aluminum must be so marked.

- (B) Splices.** Splices in wires are permissible in the proper places. When making a splice, the wires must be clean and a good electrical and mechanical connection must be made. The wires may then be soldered, provided a suitable solder and flux are used. The soldering temperature should be carefully controlled, because a cold solder joint is of no value; also, if the wires become too hot, the heat will damage the insulation. Remember that soldering is not permitted on conductors used for grounding. Approved connectors may also be used for splices, making sure the wires are clean and free from corrosion. After splicing, insulation at least equivalent to that on the wire must be applied to the splice. In general, this applies to all splices, but on high-voltage splicing, the specifications supplied with the high-voltage cables should be followed. When wire connectors are to be used on splices directly buried in the ground, they must be made with a type that is listed for that use.

This is extremely important. Many electrical connections fail because they are improperly made. Many troubles have been due to electrolysis between different metals, that is, the more-noble metal depleting the less-noble metal. Also, the oxidation of aluminum conductors (and this oxidation occurs practically instantly) creates a layer that has a very high resistance.

Another problem is the coefficient of expansion of different metals, creeping, and the difference in deformation of different metals. Be certain that you use connectors approved for use with this new product.

Inhibitors for use with aluminum are very important. Don't rely on the inhibitor alone, but thoroughly brush the aluminum conductor to remove the oxide film, and then immediately apply the inhibitor to prevent the recurrence of the oxide film.

- (C) Temperature Limitations.** The general principle of temperature limitations is that the operating temperatures of all circuit components (conductors, terminals, and equipment) must be coordinated so that no component is operated above its temperature rating. This section provides temperature limits for the termination of conductors. Terminations for circuits that are rated 100 amps or less and that use conductors from #14 through (and including) #1 are limited to 60°C. Conductors that have higher temperature ratings (such as the most common THHN conductors) can be used for these circuits, but the

ampacity of such conductors must be determined by the “60°C” columns of Tables 310-16 through 310-19.

If the termination devices for the circuits mentioned above are listed for operation at higher temperatures, the conductors may also have their ampacity calculated at the higher temperatures.

Terminations for circuits that are rated over 100 amps, and that use conductors larger than No. 1, are limited to 75°C. Conductors that have higher temperature ratings (such as the most common THHN conductors) can be used for these circuits, but the ampacity of such conductors must be determined by the “75°C” columns of Tables 310-16 through 310-19.

Separately installed pressure connectors (such as a wire nut used between the termination points) must have temperature ratings equal to the temperature at which the conductor’s ampacity was calculated. For example, if you are calculating the ampacity of a No. 8 conductor at 75°C, any splicing connector (such as a wire nut) that you use on those conductors must have a temperature rating of at least 75°C.

Design type B, C, D, or E motors are permitted to be terminated with conductors rated 75°C or higher, so long as the ampacity of the conductors will not heat them beyond 75°C. Remember in these situations that the supply source for the conductors must also be rated for the conductors.

II. 600 Volts, Nominal or Less

110.26: Working Space about Electric Equipment (600 Volts, Nominal or Less, to Ground)

Adequate space for safety must be maintained for easy maintenance of equipment. When equipment is located in locked rooms, it may still be considered accessible if the room is accessible to qualified personnel.

- (A) Working Clearances.** For working clearances, refer to Table 110.26(A)(1) in the *NEC*. Where enclosures are installed on each side of a workspace (whether or not either has live exposed parts), the amount of clear distance must be determined by Condition 3 in Table 110.26(A)(1).

In addition, the free space in front of electrical equipment must be at least 30 inches (762 mm) wide. This clear space must continue from the floor to the height specified in Section

110.26(E). Doors or panels on all electrical equipment must be capable of opening to at least a 90-degree angle. No equipment is permitted to extend more than 6 inches in front of another piece of equipment; for example, a large transformer may not be placed in front of a panelboard, even when the top of the transformer is lower than the bottom of the panel.

Condition 1: In this portion, insulated wire or bus bars are not considered live parts. If there are any exposed energized parts and parts that are grounded on the opposite side of the working space, or if there are exposed live parts on both sides of the equipment, suitable insulating materials must be installed for protection of only the live parts described above.

From this, we might conclude that a panel of this kind that will have to be worked on from time to time falls under Condition 1, and give a minimum 3 feet of clearance. This will also apply to bus bars and conductors.

Condition 2: In Condition 1, the panel was used as an example, but since the panel is usually contained in a metal enclosure, we must also look at Condition 2, which we find might be used under certain conditions.

Condition 3: Condition 1 might be an electrical closet, where panels are on two walls, in which case 3- and 4-foot conditions would prevail.

Exception

(a) If there are no renewable or replaceable parts on the back side of switchboards or motor control centers, and all parts of the unit are accessible from its front, working space is not required.

(b) The inspection authority has the right to make exceptions for smaller spaces where it seems appropriate. These judgments are applicable if the particular arrangement of the installation shows that it will provide sufficient accessibility or if no insulated parts carry more than 30 volts RMS, 42 volts peak, or 60 volts DC.

Concrete, brick, or tile walls should very definitely be considered grounds.

(c) Condition 2 working clearances are permitted between pieces of dead-front equipment that are located across an aisle from each other. However, this applies only in cases where written procedures ensure that pieces of equipment located across from one another will never be open at the same time. Also, this must be done in areas that are accessible to authorized personnel only.

- (B) **Clear Spaces.** Clear spaces required around equipment can't be used for storage. If live parts are exposed, they must be guarded.
- (C) **Access and Entrance to Working Space.** This portion is very important for persons working in the area discussed above. There shall be at least one entrance that is large enough to give adequate working space to the electrical equipment therein. Where switchboards and control panels are located with a rating of 1200 amperes or more and are 6 feet or more in width, it is required that one entrance be at least 24 inches in width and 6.5 feet in height at each end. Thus, in cases such as this, at least two entrances are required.

Exception

- (a) This allows for a continuous unobstructed way of exit wherever switchboards or panelboards are located.
- (b) Only one entrance is required if the working space around the various pieces of equipment in the room is doubled.

- (D) **Illumination.** The equipment described in this article must be provided with a source of illumination.
- (E) **Headroom.** The minimum ceiling height above the various pieces of equipment covered in this article is 6½ feet (1.98 m), except for residential service equipment or panelboards in existing dwellings rated 200 amps or less. (The requirements for equipment operating at higher voltages are given in Article 490.)
- (F) **Dedicated Equipment Space.** Motor control centers and other equipment covered by Article 408 must be located in dedicated and protected spaces. An exception is made for control wiring that must be located adjacent to or near specific pieces of equipment.

For indoor locations, this dedicated space is required to be equal to the width and depth of the equipment from the floor up to a 6-foot level, or up to a structural ceiling if it is lower than 6 feet. (Suspended ceilings are not considered to be structural ceilings.) No piping or nonelectrical equipment may be located in this space. Sprinkler systems may be installed for these spaces so long as they are fitted with drip pans or other suitable protection.

Equipment located outdoors must be installed in enclosures that are adequate to the conditions, and must be protected

from vehicles and accidental contact by unqualified persons. No other equipment is permitted in the dedicated space.

110.27: Guarding of Live Parts

This section applies to parts supplied with 600 volts or less.

- (A) Live Parts Guarded Against Accidental Contact.** This section covers the guarding or protecting of live parts of electrical equipment that are operated at 50 volts or more, so as to prevent accidental contact with them. Approved cabinets or enclosures shall be used, according to the requirements in other portions of the *Code*. The following are the means by which this shall be accomplished:
- (1)** Many references are made to only qualified persons having access to rooms, vaults, and so on. It is recommended that the reader refer to Article 100 and review the definition of qualified persons.
 - (2)** So that only qualified persons may have access to live parts, suitable partitions or screens must be installed to keep away unqualified persons. Openings to live parts shall be of such a size that unqualified persons will be kept from accidentally contacting live parts. Again, qualified persons are mentioned. Their safety is thought of in making the equipment accessible without obstruction and in giving attention to the contact of conducting materials such as conduit or pipes.
 - (3)** Balconies, galleries, or platforms must have sufficient elevations and be arranged such that unqualified persons have no access to live parts.
 - (4)** Any live parts of equipment that are elevated a minimum of 8 feet or more above the floor or other accessible places are considered accessible to qualified persons only.
- (B) Prevent Physical Damage.** Many times electrical equipment is located in a work area where the activity around it might damage the equipment. In such a case, the enclosures or guards shall be of such strength as to prevent any damage to the electrical equipment.
- (C) Warning Signs.** Warning signs shall be posted at entrances to rooms or other guarded locations giving warning that only

qualified personnel are permitted to enter. Although not specifically covered here, posting of dangers that might exist in any situation is always good safety practice.

Motors are covered in Sections 430.132 and 420.133, and parts supplied with over 600 volts are covered in Section 110.34.

110.18: Arcing Parts

Making and breaking of contacts usually causes sparking or arcing. Also, the white-hot filament of a lightbulb broken while in operation takes a little time to cool. Any parts that normally cause arcing or sparking are to be enclosed unless they are isolated or separated from combustible material. Lightbulbs are mentioned, but additional information is given in the articles covering hazardous areas, along with the specific requirements for switches, outlets, and other devices in hazardous locations.

Hazardous areas are covered in Sections 500 through 517.

110.19: Light and Power from Railway Conductors

It is not permissible to connect any circuits for light or power to any trolley wires that use a ground return signal.

The exceptions to this include car houses or any other freight station, and so on, that operate with electric railways.

110.21: Marking

All electrical equipment must be marked, showing the manufacturer's name and the electrical characteristics.

110.22: Identification of Disconnecting Means

It is essential that disconnecting means for appliances, motors, feeders, and branch circuits be properly identified as to what the disconnect serves. If overcurrent devices that have a series combination rating are used, they must be clearly marked to that effect. Such markings must be legible and durable. Panels usually have a card with the circuit numbers marked, which should be filled out in its entirety as a permanent record. This is one of the most frequent violations of the *Code*.

III. Over 600 Volts, Nominal

110.30: General

Since 1975, additions have been made at the end of various articles of the *Code* to cover over 600 volts, nominal. It is the intent that conductors and equipment used on volts higher than 600 volts, nominal, comply with this article and with all applicable articles. It

is not intended that provisions of this article apply to equipment on the supply-side of the service conductors.

110.31: Enclosure for Electrical Installations

Areas where access is controlled by lock-and-key or other approved means, shall be considered accessible to qualified persons only. Examples of these areas include vault installations, room or closet installations, and areas surrounded by walls, screens, or fences.

The design and construction of enclosures shall be suitable to the nature and degree of hazard involved.

Any wall or fence less than 7 feet in height is not considered as preventing access. A 7-foot fence or wall is considered to be adequate. Fences or walls of lower height must have additional protection to the 7-foot limit. A fence made of no less than 6 feet of fence fabric and a 1-foot or greater extension, using three or more strands of barbed wire, is acceptable.

(A) Fire Resistivity of Electrical Vaults. Walls, roofs, floors, and doorways of vaults containing conductors operating at 600 volts or more must be fire-rated for a minimum of three hours. Equipment must also be marked with warning signs. Openings in equipment must be designed so that foreign objects inserted through such openings are deflected away from energized parts.

(B) Indoor Installations.

(1) In Places Accessible to Unqualified Persons. This section covers indoor installations to which unqualified persons might have access. The equipment shall be made with metal enclosures or a vault that is accessible only by lock and key.

Unit substations and any pull boxes or other means of connection associated with the equipment must be permanently marked with caution signs. Dry-type transformers must be ventilated so that they have openings in the equipment, but they shall be designed in such a manner that foreign objects inserted through the ventilating holes will have something to deflect them from the live parts.

(2) In Places Accessible to Qualified Persons Only. Section 110.34 and Article 490, Part III, are to be used for compliance when indoor electrical installations are considered accessible to qualified persons.

(C) Outdoor Installations.

- (1) In Places Accessible to Unqualified Persons.** Article 225 covers outdoor installations that are accessible to unqualified persons.

The *National Electrical Safety Code (ANSI) C2-2002* covers the clearance of conductors that are over 600 volts, nominal.

- (2) In Places Accessible to Qualified Persons Only.** Section 110.34 and Article 490, Part III, cover places of outdoor electrical installations where exposed live parts may be accessible to qualified persons. These sections deal with voltages over 600, nominal, and need not be repeated here.

- (D) Enclosed Equipment Accessible to Unqualified Persons.** Where equipment requires ventilation or other openings, the design of the equipment shall be such that foreign objects that might be inserted into ventilating openings will be deflected so as not to contact any live parts. Any such equipment that is in a position where it may be physically damaged from passing traffic must be protected by a suitable guard. Sometimes metal-enclosed equipment has to be located outdoors, where it might be damaged by the general public. If so, the design of such equipment shall be such that any exposed bolts, nuts, and so forth can't easily be removed by the public, and if such electrical equipment is located outdoors and is less than 8 feet from floor or ground, any doors or covers shall be hinged and capable of being locked. Manhole covers weighing more than 100 pounds need not be locked.

110.32: Work Space about Equipment

There shall be sufficient clear space around high-voltage equipment to permit ready and safe operation of such equipment.

If any energized parts are exposed, they shouldn't be less than 6½ feet measured vertically from any floor or platform, or less than 3 feet wide, measured parallel to the equipment. In all cases the width shouldn't be less than the space required for doors or hinge panels to open to a position of at least 90 degrees.

110.33: Entrance and Access to Work Space

- (A) Entrance.** The requirements for the entrance are to be not less than 6½ feet and not less than 2 feet in width. Adequate space

must be provided for access to the working space around electrical equipment. If the switchboard or controller panels are more than 6 feet wide, entrance at each end will be required for both panelboards.

When only one entry is provided, it must be so located that the distance from switchboard to panelboard meets the minimum requirements for distance away from the equipment given in Table 110.34(A).

If bare or insulated parts of more than 600 volts, nominal, are located adjacent to such entrances, there must be suitable means taken to guard them.

- (B) **Access.** When electric equipment is installed on platforms, balconies, mezzanine floors, or in attic or roof rooms or spaces, there must be permanent ladders or stairways installed for access. There is an OSHA regulation that requires ladders to extend 3 feet above the location to which they give access.

110.34: Work Space and Guarding

- (A) **Working Space.** The minimum clear working space in front of electric equipment such as switchboards, control panels, switches, circuit breakers, transformers, motor controllers, relays, and similar equipment shouldn't be less than specified in Table 110.34(A) in the *NEC*, unless otherwise specified in the *Code*. Distances shall be measured from the live parts if such are exposed, or from the enclosure front or opening if such are enclosed.
 - (1) Insulated wire or insulated bus bars that are not supplied with over 300 volts shouldn't be considered live parts. If live parts are exposed on any one side and the parts on the other side are grounded in the working space, or if suitable guards made of wood or other insulating materials are in place, then the live parts shall be considered suitably protected.
 - (2) This section describes condition number two of Table 110.34(A). Note that masonry surfaces must be considered grounded surfaces.
 - (3) Describes condition number three of Table 110.34(A).

Exception

The deenergized parts are to be worked from the back on enclosed equipment. The required workspace is 30 inches nominal. If dead-front

switchboards or control assemblies are in use, there are no fuses or breakers or adjustable parts on the back, and all connections are accessible from places other than the back, then the above 30-inch requirement will apply.

- (B) Separation from Low-Voltage Equipment.** When there is any low-voltage equipment in a vault, room or enclosure, such as switches, cutouts, or other equipment that operates at 600 volts, nominal or less, all exposed live parts or exposed wiring that operate at more than 600 volts, nominal, must be separated effectively from the low-voltage equipment and wiring by suitable partitions, screens, or fences.

Many utility companies will not permit low voltage in transformer vaults with high voltage, with the exception of low-voltage buses. This does not include lighting or other low voltage that might be required in the operation of the high-voltage equipment.

Exception

When 600 volts or less for switches or other equipment services only equipment within the high-voltage room, vault, or enclosure, such equipment in use in conjunction therewith at a voltage of 600 or less, nominal may be installed in the room that is accessible to qualified persons only.

- (C) Locked Rooms or Enclosures.** When there are live parts or exposed conductors that operate at over 600 volts, nominal, the entrances to any such building must be locked. There is an exception: Such locked entrances must be under the observation of qualified persons at all times. Permanent and conspicuous caution signs are to be installed where the voltage exceeds 600 volts, nominal, and must include the message “WARNING—HIGH VOLTAGE—KEEP OUT.”
- (D) Illumination.** Adequate illumination must be provided to illuminate the high-voltage area properly for safe working, and the fixtures must be installed so that there will be no danger to anyone changing bulbs or working on the illumination system. All lighting outlets in these areas must be arranged so that no one making repairs or changing lamps will be exposed to live parts.
- (E) Elevation of Unguarded Live Parts.** See Table 110.34(E) for elevation of unguarded live parts.

- (F) Protection of Service Equipment, Metal-Enclosed Power Switchgear, and Industrial Control Assemblies.** Any pipes or ducts that are not related to the electrical installation and that require periodic maintenance, or whose malfunction would endanger the operation of the electrical system, must not be located in the vicinity of service equipment, metal-enclosed power switchgear, or industrial control assemblies. Protection must be provided where necessary to prevent damage from condensation, leaks, or breaks in foreign systems. If the pipes are installed for the protection of electrical equipment, they shouldn't be considered foreign objects.

110.36: Circuit Conductors

Circuit conductors may be installed in raceways, cable trays, as metal-clad cable, bare-wire cable, and buses, or as Type MV cables or conductors, as provided in Sections 300.39, 300.40, and 300.50. When bare live conductors are installed, they must conform to Section 490.24.

In the installation of conductors that carry high voltage, the sizing of bare conductors must be done with consideration for corona effects.

Insulators, their mountings, and conductor attachments, when used as supports for single conductors and bus bars, must be capable of safely withstanding the magnetic forces that will result between two or more conductors in the event of a fault current being imposed on them. The magnetic forces tend to push the conductors apart. The magnitude of the force depends upon the amount of short-circuit current involved, the spacing, and so on.

If open runs of lead-sheathed cables are used, they must be protected from physical damage and electrolysis of the sheath.

110.40: Temperature Limitations at Terminations

Conductors operating at over 600 volts are permitted to be terminated based upon a 90°C temperature rating and ampacity. See Sections 310.67 through 310.86 for the ratings of specific conductors.

IV. Tunnel Installations Over 600 Volts, Nominal

110.51: General

- (A) Covered.** This part applies to installation and use of high-voltage distribution and utilization power equipment that is portable and mobile, such as substations, cars, trailers, mobile

shovels, draglines, hoists, drills, dredges, compressors, pumps, conveyors, underground excavators, and so on.

- (B) **Other Articles.** The requirements of this part shall be in addition to other articles, such as Articles 100 through 710 of the *Code*. Grounding requires special attention; see Article 250.
- (C) **Protection Against Physical Damage.** All conductors and cables used in tunnels must be located so that they are above the tunnel floor, and they must be thoroughly located and guarded so that they will not be subject to physical damage.

110.52: Overcurrent Protection

Article 430 covers the protection of motor-operated equipment from overcurrent. Transformers must be protected as covered in Article 450.

110.53: Conductors

Conductors installed in tunnels for high voltage may be installed (1) as in metal conduit or other metal raceways; (2) in Type MC cable; or (3) if approved, in other types of cable. Cables that are multiconductor, if approved for the service, may be a portable type supplying mobile equipment.

110.54: Bonding and Equipment-Grounding Conductors

Great care must be exercised when bonding or equipment-grounding, for personnel safety.

- (A) **Grounding and Bonding.** Nonenergized metal parts of the electrical equipment, and metal raceways, and the cable sheath are required to be effectively grounded and bonded to all metal rails and pipes, not only at the portal, but at intervals not exceeding 1000 feet throughout the tunnel.

This is very important, as the best grounds will no doubt be encountered outside the tunnel, and thus extra paths are provided to this point.

- (B) **Equipment-Grounding Conductor.** Inside the metal raceway, or inside the multiconductor cable jacket, an equipment-grounding conductor must be run with the circuit conductors. This equipment-grounding conductor can be insulated or bare.

110.55: Transformers, Switches, and Electrical Equipment

It is required that all transformers, switches, motor controllers, motors, rectifiers, and other equipment installed below ground be protected from physical damage by location or guarding.

110.56: Energized Parts

Any bare terminals or electrical equipment, including transformers, switches, motor controllers, and so on are to be enclosed to protect persons from accidental contact.

110.57: Ventilation Control Systems

When ventilation equipment is used, it shall be installed such that the ventilation may be reversed because during the summer, air will probably be going out of the tunnel, and in the winter, going into the tunnel.

110.58: Disconnecting Means

A switching device that conforms to the requirements of Articles 430 and 450 must be installed at each transformer or motor location for the purpose of disconnecting the transformer or motor. This switching device shall open all ungrounded conductors at the same time. A disconnect switch for a transformer must be rated no less than the ampacity of the transformer supply conductors.

110.59: Enclosures

Any enclosure used in a tunnel shall be drip-proof or submersible, as may be required by environmental conditions. Neither switch nor contactor enclosures are permitted to be used as junction boxes or raceways for conductors feeding through or tapping off at those locations to other switches, unless specially designed equipment is provided that is adequate for the purpose.

