2018 ISEP™

INTERNATIONAL SOLAR ENERGY PROVISIONS™

INCLUDES

- All solar energy-related provisions from the 2018 International Codes® and NFPA 70: 2017 NEC® National Electrical Code
- ICC 901/SRCC 100-2015: Solar Thermal Collector Standard
- ICC 900/SRCC 300-2015: Solar Thermal System Standard

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PREFACE

Introduction

The International Code Council develops model codes and standards used in the design, build and compliance process. The codes are founded on broad-based principles that make possible the use of new materials and new building designs. The *International Codes*® (I-Codes®) are chosen by most U.S. communities and many global markets for the design, construction and administration of safe, sustainable, affordable and resilient structures, including solar energy systems. As solar technologies have matured, become more cost effective and more mainstream, solar provisions have been featured throughout the I-Codes.

This 2018 *International Solar Energy Provisions*™ (ISEP™) brings together in one, easy-to-use format all solar energy provisions found throughout the 2018 I-Codes for both solar thermal and photovoltaic energy systems. These provisions are fully coordinated with those already in the I-Codes, including the *International Building Code*®, *International Energy Conservation Code*®, *International Fire Code*®, *International Mechanical Code*®, *International Plumbing Code*®, *International Residential Code*® and the *International Swimming Pool and Spa Code*®, thereby simplifying implementation. Adoption of the family of the 2018 I-Codes by a jurisdiction would include all of the provisions found in this document.

As electrical-related components and systems are a critical part of any solar energy system, those provisions of the *National Electrical Code*® (NEC®) (NFPA 70®) that are most directly related to solar energy systems have been extracted and reprinted in this 2018 *International Solar Energy Provisions*. These electrical provisions have been organized in specific coordinated sections such as definitions, solar water heating and photovoltaic systems, in much the same format as the ISEP chapters, so that the user can easily and conveniently locate and apply them. The *National Electrical Code* (NEC) provisions are copyrighted by and have been included with the permission and cooperation of the National Fire Protection Association. The NEC provisions in this 2018 *International Solar Energy Provisions* apply to both commercial and residential systems and are a part of the ISEP Commercial and ISEP Residential provisions. Readers should refer to NFPA's 2017 *Electrical Code Handbook* for the reasoning behind the NFPA 70, including NEC concepts, real-world examples and the background behind code revisions.

Modeled after the format of the *International Energy Conservation Code*® (IECC®), the commercial and residential sections are separate and distinct, each including administrative provisions, definitions, general regulations, and system-specific requirements for solar thermal (or solar heating and cooling) and photovoltaic system types. Provisions for typical water heaters and other heating or cooling systems have also been included because they may be used as backup or in hybrid solar systems.

In addition to the 2018 *International Solar Energy Provisions*, this document includes two standards from the Solar Rating & Certification Corporation (SRCC). These standards are referenced by the *International Residential Code* and have been reprinted, with permission, in their entirety. They include: ICC 901/SRCC 100–2015 *Solar Thermal Collector Standard* and ICC 900/SRCC 300–2015 *Solar Thermal System Standard*. Additional resources such as sample permitting forms and basic principles from the U.S. Department of Energy make the 2018 ISEP the most comprehensive document for solar energy provisions/standards in the nation.

Letter Designations

The 2018 ISEP is divided into two distinct parts: Part CS, Commercial Solar Energy; and Part RS, Residential Solar Energy. The section numbers in Part CS are preceded by capital letters CS (e.g., CS101.1) to indicate commercial provisions. Section numbers in Part RS are preceded by capital letters RS (e.g., RS101.1) to indicate residential provisions. In parentheses immediately following the ISEP section numbers are the code acronym and section number from the original *International Code* source, according to the following list:

(IBC): *International Building Code*;

(IECC): *International Energy Conservation Code*;

(IFC): *International Fire Code*;

(IMC): *International Mechanical Code*;

(IPC): *International Plumbing Code*;

(ISPSC): *International Swimming Pool and Spa Code*;

(R): *International Residential Code* – Building Provisions;

(M): *International Residential Code* – Mechanical Provisions;

(N): *International Residential Code* – Energy Provisions; and

(P): *International Residential Code* –Plumbing Provisions.

Format Designations

Because the ISEP provisions are a compilation, the original text often contains language referencing back to the source code itself. However, such provisions also apply to the ISEP as a whole. When the phrase [this code] or [this chapter] is shown in brackets, it denotes a reference to the ISEP as a collection of the same relevant code provisions.

Supporting, clarifying or contextual notes have been added throughout the document to aid in understanding. So as not to be confused with the code text, and for purposes of easy identification, these notes are shown directly under the section, indented and in an italicized font.

Italicized Terms

Selected words and terms defined in Chapter 2, Definitions, are italicized where they appear in code text and the Chapter 2 definition applies. Where such words and terms are not italicized, common-use definitions apply. The words and terms selected have code-specific definitions that the user should read carefully to facilitate better understanding of the code.

The 2018 ISEP Definitions chapters are not intended as all-inclusive lists of the italicized terms in the *International Codes*. Only those italicized terms directly related to solar energy systems have been included and defined in the 2018 ISEP chapters. Where terms are italicized and not defined herein, the definitions can be found in the corresponding source code document.

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ISEP—COMMERCIAL PROVISIONS

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CHAPTER 1 [CS]
SCOPE AND ADMINISTRATION

User note:

About this chapter: *Chapter 1 establishes the limits of applicability of the code and describes how the code is to be applied and enforced. Chapter 1 is in two parts: Part 1—Scope and Application and Part 2—Administration and Enforcement. Section 101 identifies what buildings, systems, appliances and equipment fall under its purview and references other I-Codes as applicable. Standards and codes are scoped to the extent referenced.*

PART 1—SCOPE AND APPLICATION

SECTION CS101 (IMC 101) GENERAL

CS101.1 (IMC 101.2) Scope. [This code] shall regulate the design, installation, maintenance, *alteration* and inspection of mechanical systems that are permanently installed and utilized to provide control of environmental conditions and related processes within buildings. [This code] shall also regulate those mechanical systems, system components, *equipment* and appliances specifically addressed herein. The installation of fuel gas distribution piping and *equipment*, fuel gas-fired appliances and fuel gas-fired *appliance* venting systems shall be regulated by the *International Fuel Gas Code*.

This collection of provisions imports code sections which address both Solar Thermal and Photovoltaic Solar Systems, and the structural, mechanical, plumbing, fire safety and energy conservation measures for each. Some are specific to Solar Systems and others to their auxiliary, or backup systems. The installation of Photovoltaic Solar Systems is also addressed in NFPA 70.

CS101.2 (IMC 101.3) Intent. The purpose of [this code] is to establish minimum standards to provide a reasonable level of safety, health, property protection and public welfare by regulating and controlling the design, construction, installation, quality of materials, location, operation and maintenance or use of mechanical systems.

In this collection of provisions from the 2015 I-Codes, Chapter 1 is taken from the International Mechanical Code; however, the application of this document is intended to apply to all of the code-regulated systems addressed herein, not just the mechanical systems.

SECTION CS102 (IMC 102) APPLICABILITY

CS102.1 (IMC 102.1) General. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall govern. Where, in a specific case, different sections of [this code] specify different materials, methods of construction or other requirements, the most restrictive shall govern.

CS102.2 (IMC 102.2) Existing installations. Except as otherwise provided for in [this chapter], a provision in [this code] shall not require the removal, *alteration* or abandonment of, nor prevent the continued utilization and maintenance of, a mechanical system lawfully in existence at the time of the adoption of [this code].

CS102.3 (IMC 102.3) Maintenance. Mechanical systems, both existing and new, and parts thereof shall be maintained in proper operating condition in accordance with the original design and in a safe and sanitary condition. Devices or safeguards that are required by [this code] shall be maintained in compliance with the edition of the code under which they were installed. The owner or the owner's authorized agent shall be responsible for maintenance of mechanical systems. To determine compliance with this provision, the code official shall have the authority to require a mechanical system to be reinspected.

The inspection for maintenance of HVAC systems shall be performed in accordance with ASHRAE/ACCA/ANSI Standard 180.

CS102.4 (IMC 102.4) Additions, alterations or repairs. Additions, alterations, renovations or repairs to a mechanical system shall conform to that required for a new mechanical system without requiring the existing mechanical system to comply with all of the requirements of [this code]. Additions, alterations or repairs shall not cause an existing mechanical system to become unsafe, hazardous or overloaded.

Minor additions, alterations, renovations and repairs to existing mechanical systems shall meet the provisions for new construction, unless such work is done in the same manner and arrangement as was in the existing system, is not hazardous and is *approved*.

CS102.5 (IMC 102.5) Change in occupancy. It shall be unlawful to make a change in the *occupancy* of any structure that will subject the structure to any special provision of [this code] applicable to the new *occupancy* without approval. The code official shall certify that such structure meets the intent of the provisions of law governing building construction for the proposed new *occupancy* and that such change of *occupancy* does not result in any hazard to the public health, safety or welfare.

CS102.6 (IMC 102.6) Historic buildings. The provisions of [this code] relating to the construction, *alteration*, repair, enlargement, restoration, relocation or moving of buildings or

structures shall not be mandatory for existing buildings or structures identified and classified by the state or local jurisdiction as historic buildings where such buildings or structures are judged by the code official to be safe and in the public interest of health, safety and welfare regarding any proposed construction, *alteration*, repair, enlargement, restoration, relocation or moving of buildings.

CS102.7 (IMC 102.7) Moved buildings. Except as determined by Section 102.2, mechanical systems that are a part of buildings or structures moved into or within the jurisdiction shall comply with the provisions of [this code] for new installations.

CS102.8 (IMC 102.8) Referenced codes and standards. The codes and standards referenced herein shall be those that are listed in Chapter 7 (IMC Chapter 15) and such codes and standards shall be considered as part of the requirements of [this code] to the prescribed extent of each such reference and as further regulated in Sections CS102.1.8.1 (IMC 102.8.1) and CS102.8.2 (IMC 102.8.2).

Exception: Where enforcement of a code provision would violate the conditions of the listing of the *equipment* or *appliance*, the conditions of the listing and the manufacturer's installation instructions shall apply.

CS102.8.1 (IMC 102.8.1) Conflicts. Where conflicts occur between provisions of [this code] and the referenced standards, the provisions of [this code] shall apply.

CS102.8.2 (IMC 102.8.2) Provisions in referenced codes and standards. Where the extent of the reference to a referenced code or standard includes subject matter that is within the scope of [this code], the provisions of [this code], as applicable, shall take precedence over the provisions in the referenced code or standard.

CS102.9 (IMC 102.9) Requirements not covered by [this code]. Requirements necessary for the strength, stability or proper operation of an existing or proposed mechanical system, or for the public safety, health and general welfare, not specifically covered by [this code], shall be determined by the code official.

CS102.10 (IMC 102.10) Other laws. The provisions of [this code] shall not be deemed to nullify any provisions of local, state or federal law.

CS102.11 (IMC 102.11) Application of references. Reference to chapter section numbers, or to provisions not specifically identified by number, shall be construed to refer to such chapter, section or provision of [this code].

PART 2—ADMINISTRATION AND ENFORCEMENT

SECTION CS103 (IMC 105) APPROVAL

CS103.1 (IMC 105.1) Modifications. Where there are practical difficulties involved in carrying out the provisions of [this code], the code official shall have the authority to grant modifications for individual cases upon application of the owner or owner's authorized agent, provided that the code official shall first find that special individual reason makes the strict letter of [this code] impractical and the modification is in compliance with the intent and purpose of [this code] and does not lessen health, life and fire safety requirements. The details of action granting modifications shall be recorded and entered in the files of the mechanical inspection department.

CS103.2 (IMC 105.2) Alternative materials, design and methods of construction and equipment. The provisions of [this code] are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by [this code], provided that any such alternative has been *approved*. An alternative material, design or method of construction shall be *approved* where the code official finds that the proposed design is satisfactory and complies with the intent of the provisions of [this code], and that the material, method or work offered is, for the purpose intended, not less than the equivalent of that prescribed in [this code] in quality, strength, effectiveness, fire resistance, durability and safety. Where the alternative material, design or method of construction is not *approved*, the *code official* shall respond in writing, stating the reasons why the alternative was not *approved*.

CS103.2.1 (IMC 105.2.1) Research reports. Supporting data, where necessary to assist in the approval of materials or assemblies not specifically provided for in [this code], shall consist of valid research reports from *approved* sources.

CS103.3 (IMC 105.3) Required testing. Where there is insufficient evidence of compliance with the provisions of [this code], or evidence that a material or method does not conform to the requirements of [this code], or in order to substantiate claims for alternative materials or methods, the code official shall have the authority to require tests as evidence of compliance to be made at no expense to the jurisdiction.

CS103.3.1 (IMC 105.3.1) Test methods. Test methods shall be as specified in [this code] or by other recognized test standards. In the absence of recognized and accepted test methods, the code official shall approve the testing procedures.

CS103.3.2 (IMC 105.3.2) Testing agency. Tests shall be performed by an *approved* agency.

CS103.3.3 (IMC 105.3.3) Test reports. Reports of tests shall be retained by the code official for the period required for retention of public records.

CS103.4 (IMC 105.4) Approved materials and equipment. Materials, *equipment* and devices *approved* by the code official shall be constructed and installed in accordance with such approval.

CS103.5 (IMC 105.5) Material, equipment and appliance reuse. Materials, *equipment*, appliances and devices shall not be reused unless such elements have been reconditioned, tested and placed in good and proper working condition and *approved*.

SECTION CS104 (IMC 106)
PERMITS

CS104.1 (IMC 106.1) Where required. An owner, owner's authorized agent or contractor who desires to erect, install, enlarge, alter, repair, remove, convert or replace a mechanical system, the installation of which is regulated by [this code], or to cause such work to be performed, shall first make application to the code official and obtain the required permit for the work.

Exception: Where *equipment* and *appliance* replacements or repairs must be performed in an emergency situation, the permit application shall be submitted within the next working business day of the department of mechanical inspection.

SECTION CS105 (IMC 107)
INSPECTIONS AND TESTING

CS105.1 (IMC 107.1) General. The code official is authorized to conduct such inspections as are deemed necessary to determine compliance with the provisions of [this code]. Construction or work for which a permit is required shall be subject to inspection by the code official, and such construction or work shall remain visible and able to be accessed for inspection purposes until *approved*. Approval as a result of an inspection shall not be construed to be an approval of a violation of the provisions of [this code] or of other ordinances of the jurisdiction. Inspections presuming to give authority to violate or cancel the provisions of [this code] or of other ordinances of the jurisdiction shall not be valid.

CS105.2 (IMC 107.2) Required inspections and testing. The code official, upon notification from the permit holder or the permit holder's agent, shall make the following inspections and other such inspections as necessary, and shall either release that portion of the construction or shall notify the permit holder or the permit holder's agent of violations that must be corrected. The holder of the permit shall be responsible for the scheduling of such inspections.

1. Underground inspection shall be made after trenches or ditches are excavated and bedded, piping installed, and before backfill is put in place. Where excavated soil contains rocks, broken concrete, frozen chunks and other rubble that would damage or break the piping or cause corrosive action, clean backfill shall be on the job site.
2. Rough-in inspection shall be made after the roof, framing, fireblocking and bracing are in place and all ducting and other components to be concealed are complete, and prior to the installation of wall or ceiling membranes.
3. Final inspection shall be made upon completion of the mechanical system.

Exception: Ground-source heat pump loop systems tested in accordance with Section 1210.10 shall be permitted to be backfilled prior to inspection.

The requirements of this section shall not be considered to prohibit the operation of any heating *equipment* or appliances installed to replace existing heating *equipment* or appliances serving an occupied portion of a structure provided that a request for inspection of such heating *equipment* or appliances has been filed with the department not more than 48 hours after such replacement work is completed, and before any portion of such *equipment* or appliances is concealed by any permanent portion of the structure.

CS105.2.1 (IMC 107.2.1) Other inspections. In addition to the inspections specified in Section CS105.2 (IMC 107.2), the code official is authorized to make or require other inspections of any construction work to ascertain compliance with the provisions of [this code] and other laws that are enforced.

CS105.2.2 (IMC 107.2.2) Inspection requests. It shall be the duty of the holder of the permit or their duly authorized agent to notify the code official when work is ready for inspection. It shall be the duty of the permit holder to provide access to and means for inspections of such work that are required by [this code].

CS105.2.3 (IMC 107.2.3) Approval required. Work shall not be done beyond the point indicated in each successive inspection without first obtaining the approval of the code official. The code official, upon notification, shall make the requested inspections and shall either indicate the portion of the construction that is satisfactory as completed, or notify the permit holder or his or her agent wherein the same fails to comply with [this code]. Any portions that do not comply shall be corrected and such portion shall not be covered or concealed until authorized by the code official.

CS105.2.4 (IMC 107.2.4) Approved inspection agencies. The code official is authorized to accept reports of *approved* agencies, provided that such agencies satisfy the requirements as to qualifications and reliability.

CS105.2.5 (IMC 107.2.5) Evaluation and follow-up inspection services. Prior to the approval of a prefabricated construction assembly having concealed mechanical work and the issuance of a mechanical permit, the code official shall require the submittal of an evaluation report on each prefabricated construction assembly, indicating the complete details of the mechanical system, including a description of the system and its components, the basis on which the system is being evaluated, test results and similar information, and other data as necessary for the code official to determine conformance to [this code].

CS105.2.5.1 (IMC 107.2.5.1) Evaluation service. The code official shall designate the evaluation service of an *approved* agency as the evaluation agency, and review such agency's evaluation report for adequacy and conformance to [this code].

CS105.2.5.2 (IMC 107.2.5.2) Follow-up inspection. Except where ready access is provided to mechanical systems, service *equipment* and accessories for complete inspection at the site without disassembly or dismantling, the code official shall conduct the in-plant inspections as frequently as necessary to ensure conformance to the *approved* evaluation report or shall designate an independent, *approved* inspection agency to

conduct such inspections. The inspection agency shall furnish the code official with the follow-up inspection manual and a report of inspections on request, and the mechanical system shall have an identifying label permanently affixed to the system indicating that factory inspections have been performed.

CS105.2.5.3 (IMC 107.2.5.3) Test and inspection records. Required test and inspection records shall be available to the code official at all times during the fabrication of the mechanical system and the erection of the building; or such records as the code official designates shall be filed.

CS105.3 (IMC 107.3) Testing. Mechanical systems shall be tested as required in [this code] and in accordance with Sections CS105.3.1 (IMC 107.3.1) through CS105.3.3 (IMC 107.3.3). Tests shall be made by the permit holder and observed by the code official.

Additional testing requirements of electrical systems can be found in NFPA 70.

CS105.3.1 (IMC 107.3.1) New, altered, extended or repaired systems. New mechanical systems and parts of existing systems, which have been altered, extended, renovated or repaired, shall be tested as prescribed herein to disclose leaks and defects.

CS105.3.2 (IMC 107.3.2) Apparatus, material and labor for tests. Apparatus, material and labor required for testing a mechanical system or part thereof shall be furnished by the permit holder.

CS105.3.3 (IMC 107.3.3) Reinspection and testing. Where any work or installation does not pass an initial test or inspection, the necessary corrections shall be made so as to achieve compliance with [this code]. The work or installation shall then be resubmitted to the code official for inspection and testing.

CS105.4 (IMC 107.4) Approval. After the prescribed tests and inspections indicate that the work complies in all respects with [this code], a notice of approval shall be issued by the code official.

CS105.4.1 (IMC 107.4.1) Revocation. The code official is authorized to, in writing, suspend or revoke a notice of approval issued under the provisions of [this code] wherever the notice is issued in error, on the basis of incorrect information supplied, or where it is determined that the building or structure, premise or portion thereof is in violation of any ordinance or regulation or any of the provisions of [this code].

CS105.5 (IMC 107.5) Temporary connection. The code official shall have the authority to authorize the temporary connection of a mechanical system to the sources of energy for the purpose of testing mechanical systems or for use under a temporary certificate of *occupancy*.

CS105.6 (IMC 107.6) Connection of service utilities. A person shall not make connections from a utility, source of energy, fuel or power to any building or system that is regulated by [this code] for which a permit is required, until authorized by the code official.

CHAPTER 2 [CS]

DEFINITIONS

User note:

About this chapter: *Codes, by their very nature, are technical documents. Every word, term and punctuation mark can add to or change the meaning of a technical requirement. It is necessary to maintain a consensus on the specific meaning of each term contained in the code. Chapter 2 performs this function by stating clearly what specific terms mean for the purposes of the code.*

SECTION CS201 (IMC 201) GENERAL

CS201.1 (IMC 201.1) Scope. Unless otherwise expressly stated, the following words and terms shall, for the purposes of [this code], have the meanings indicated in [this chapter].

Not all italicized terms in these provisions are defined in Chapter 2 [CS] of this document. Where terms are italicized and not defined herein, the definitions can be found in the I-Code that is the source of the section.

CS201.2 (IMC 201.2) Interchangeability. Words used in the present tense include the future; words in the masculine gender include the feminine and neuter; the singular number includes the plural and the plural, the singular.

CS201.3 (IMC 201.3) Terms defined in other codes. Where terms are not defined in [this code] and are defined in the *International Building Code*, *International Fire Code*, *International Fuel Gas Code* or the *International Plumbing Code*, such terms shall have meanings ascribed to them as in those codes.

The source of Section CS201 is the International Mechanical Code. It is also the primary source for the definitions in Section CS202.

CS201.4 (IMC 201.4) Terms not defined. Where terms are not defined through the methods authorized by this section, such terms shall have ordinarily accepted meanings such as the context implies.

SECTION CS202 (IMC 202) GENERAL DEFINITIONS

ACCESS (TO). (IMC) That which enables a device, *appliance* or *equipment* to be reached by ready access or by a means that first requires the removal or movement of a panel, door or similar obstruction [see also "Ready access (to)"].

AIR GAP (Water Distribution System). (IPC) The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet supplying water to a tank, plumbing fixture or other device and the *flood level rim* of the receptacle.

ALTERATION. (IMC) A change in a mechanical system that involves an extension, addition or change to the arrangement, type or purpose of the original installation.

APPLIANCE. (IMC) A device or apparatus that is manufactured and designed to utilize energy and for which [this code] provides specific requirements.

APPROVED. (IMC) Acceptable to the code official.

BATTERY SYSTEM, STATIONARY STORAGE. (IFC) A rechargeable energy storage system consisting of electrochemical storage batteries, battery chargers, controls and associated electrical equipment designed to provide electrical power to a building. The system is typically used to provide standby or emergency power, an uninterruptable power supply, load shedding, load sharing or similar capabilities.

BATTERY TYPES. (IFC)

Flow battery. A type of storage battery that includes chemical components dissolved in two different liquids. Ion exchange, which provides the flow of electrical current, occurs through the membrane while both liquids circulate in their respective spaces.

Lead-acid battery. A storage battery that is comprised of lead electrodes immersed in sulphuric acid electrolyte.

Lithium-ion battery. A storage battery with lithium ions serving as the charge carriers of the battery. The electrolyte is a polymer mixture of carbonates with an inorganic salt and can be in a liquid or a gelled polymer form. Lithiated metal oxide is typically a cathode and forms of carbon or graphite typically form the anode.

Nickel-cadmium (Ni-Cd) battery. An alkaline storage battery in which the positive active material is nickel oxide, the negative contains cadmium and the electrolyte is potassium hydroxide.

Preengineered stationary storage battery system. An energy storage system consisting of batteries, a battery management system, components and modules that are produced in a factory, designed to comprise the system when assembled on the job site.

Prepackaged stationary storage battery system. An energy storage system consisting of batteries, a battery management system, components and modules that is factory assembled and shipped as a complete unit for installation at the job site.

Sodium-beta storage battery. A storage battery, also referred to as a Na-beta battery or NBB, which uses a solid beta-alumina electrolyte membrane that selectively allows

sodium ion transport between a positive electrode such as metal halide and a negative sodium electrode.

Stationary storage battery. A group of electrochemical cells interconnected to supply a nominal voltage of DC power to a suitably connected electrical load, designed for service in a permanent location.

BUILDING-INTEGRATED PHOTOVOLTAIC (BIPV) PRODUCT. (IBC) A building product that incorporates photovoltaic modules and functions as a component of the building envelope.

BUILDING-INTEGRATED PHOTOVOLTAIC ROOF PANEL (BIPV ROOF PANEL). (IBC) A photovoltaic panel that functions as a component of the building envelope.

BTU. (IMC) Abbreviation for British thermal unit, which is the quantity of heat required to raise the temperature of 1 pound (454 g) of water 1ºF (0.56ºC) (1 Btu = 1055 J).

CAPACITOR ENERGY STORAGE SYSTEM. (IFC) A stationary, rechargeable energy storage system consisting of capacitors, chargers, controls and associated electrical equipment designed to provide electrical power to a building or facility. The system is typically used to provide standby or emergency power, an uninterruptable power supply, load shedding, load sharing or similar capabilities.

Preengineered capacitor energy storage system. A capacitor energy storage system consisting of capacitors, an energy management system, components and modules that are produced in a factory, designed to comprise the system when assembled on the job site.

Prepackaged capacitor energy storage system. A capacitor energy storage system consisting of capacitors, an energy management system, components and modules that is factory assembled and then shipped as a complete unit for installation at the job site.

CODE. (IMC) These regulations, subsequent amendments thereto, or any emergency rule or regulation that the administrative authority having jurisdiction has lawfully adopted.

CODE OFFICIAL. (IMC) The officer or other designated authority charged with the administration and enforcement of [this code], or a duly authorized representative.

DIRECT SOLAR SYSTEM. (IMC) A solar thermal system in which the gas or liquid in the solar collector loop is not separated from the load.

DRAIN-BACK SYSTEM. (IMC) A solar thermal system in which the fluid in the solar collector loop is gravity drained from the collector into a holding tank under prescribed circumstances.

DUCT. (IMC) A tube or conduit utilized for conveying air. The air passages of self-contained systems are not to be construed as air ducts.

DWELLING. (IMC) A building or portion thereof that contains not more than two *dwelling* units.

DWELLING UNIT. (IBC) A single unit providing complete, independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking and sanitation.

EQUIPMENT. (IMC) Piping, ducts, vents, control devices and other components of systems other than appliances that are permanently installed and integrated to provide control of environmental conditions for buildings. This definition shall also include other systems specifically regulated in [this code].

FLAMMABLE LIQUIDS. (IMC) Any liquid that has a flash point below 100ºF (38ºC), and has a vapor pressure not exceeding 40 psia (276 kPa) at 100ºF (38ºC). Flammable liquids shall be known as Class I liquids and shall be divided into the following classifications:

Class IA. Liquids having a flash point below 73ºF (23ºC) and having a *boiling point* below 100ºF (38ºC).

Class IB. Liquids having a *flash point* below 73ºF (23ºC) and a *boiling point* at or above 100ºF (38ºC).

Class IC. Liquids having a *flash point* at or above 73ºF (23ºC) and below 100ºF (38ºC).

FLAMMABLE VAPOR OR FUMES. (IMC) Mixtures of gases in air at concentrations equal to or greater than the LFL and less than or equal to the upper flammability limit (UFL).

FLASH POINT. (IMC) The minimum temperature corrected to a pressure of 14.7 psia (101 kPa) at which the application of a test flame causes the vapors of a portion of the sample to ignite under the conditions specified by the test procedures and apparatus. The flash point of a liquid shall be determined in accordance with ASTM D56, ASTM D93 or ASTM D3278.

HEAT EXCHANGER. (IMC) A device that transfers heat from one medium to another.

INDIRECT SOLAR SYSTEM. (IMC) A solar thermal system in which the gas or liquid in the solar collector loop circulates between the solar collector and a heat exchanger and such gas or liquid is not drained from the system or supplied to the load during normal operation.

LABELED. (IMC) *Equipment*, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, approved inspection agency or other organization concerned with product evaluation that maintains periodic inspection of the production of the above-labeled items and whose labeling indicates either that the *equipment*, material or product meets identified standards or has been tested and found suitable for a specified purpose.

LISTED. (IMC) *Equipment*, materials, products or services included in a list published by an organization acceptable to the code official and concerned with evaluation of products or services that maintains periodic inspection of production of *listed equipment* or materials or periodic evaluation of services and whose listing states either that the *equipment*, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

NO-FLOW CONDITION (SOLAR). (IMC) A condition where thermal energy is not transferred from a solar thermal collector by means of flow of a heat transfer fluid.

NONFOOD-GRADE FLUID. (IMC) Any fluid that is not designated as a food-grade fluid.

OCCUPANCY. (IMC) The purpose for which a building, or portion thereof, is utilized or occupied.

ON-SITE RENEWABLE ENERGY. (IECC) Energy derived from solar radiation, wind, waves, tides, landfill gas, biogas, biomass or the internal heat of the earth. The energy system providing on-site renewable energy shall be located on the project site.

PHOTOVOLTAIC MODULE. (IBC) A complete, environmentally protected unit consisting of solar cells, optics and other components, exclusive of tracker, designed to generate DC power when exposed to sunlight.

PHOTOVOLTAIC PANEL. (IBC) A collection of modules mechanically fastened together, wired and designed to provide a field-installable unit.

PHOTOVOLTAIC PANEL SYSTEM. (IBC) A system that incorporates discrete photovoltaic panels, that converts solar radiation into electricity, including rack support systems.

PHOTOVOLTAIC SHINGLES. (IBC) A *roof covering* resembling shingles that incorporates photovoltaic modules.

PRESSURE RELIEF DEVICE. (IMC) A pressure-actuated valve or rupture member designed to relieve excessive pressure automatically.

PRESSURE RELIEF VALVE. (IMC) A pressure-actuated valve held closed by a spring or other means and designed to relieve pressure automatically in excess of the device's setting.

PRESSURE VESSELS. (IMC) Closed containers, tanks or vessels that are designed to contain liquids or gases, or both, under pressure.

READY ACCESS (TO). (IMC) That which enables a device, *appliance* or *equipment* to be directly reached, without requiring the removal or movement of any panel, door or similar obstruction [see "Access (to)"].

SOLAR THERMAL SYSTEM. (IMC) A system that converts solar radiation to thermal energy for use in heating or cooling.

STATIONARY BATTERY ARRAY. (IFC) An arrangement of individual stationary storage batteries in close proximity to each other, mounted on storage racks or in modules, battery cabinets or other enclosures.

THIRD-PARTY CERTIFICATION AGENCY. (IMC) An *approved* agency operating a product or material certification system that incorporates initial product testing, assessment and surveillance of a manufacturer's quality control system.

THIRD-PARTY CERTIFIED. (IMC) Certification obtained by the manufacturer indicating that the function and performance characteristics of a product or material have been determined by testing and ongoing surveillance by an approved third-party certification agency. Assertion of certification is in the form of identification in accordance with the requirements of the third-party certification agency.

THIRD-PARTY TESTED. (IMC) Procedure by which an approved testing laboratory provides documentation that a product, material or system conforms to specified requirements.

WATER HEATER. (IMC) Any heating *appliance* or *equipment* that heats potable water and supplies such water to the potable hot water distribution system.

WATER OUTLET. (IPC) A discharge opening through which water is supplied to a fixture, into the atmosphere (except into an open tank that is part of the water supply system), to a boiler or heating system, or to any devices or equipment that require water to operate but which are not part of the plumbing system.

CHAPTER 3 [CS]
GENERAL REQUIREMENTS

User note:

About this chapter: *Chapter 3 contains broadly applicable requirements that are necessarily placed in an overarching "general" chapter. These general requirements would not be suitably located in any other chapter that is specific to unique subject matter. General requirements include those related to installation, access, location, testing, structural and clearances.*

SECTION CS301 (IMC 301)
GENERAL

CS301.1 (IMC 301.1) Scope. [This chapter] shall govern the approval and installation of all *equipment* and appliances that comprise parts of the building mechanical systems regulated by [this code] in accordance with Section CS101.1 (IMC 101.2).

CS301.2 (IMC 301.2) Energy utilization. Heating, ventilating and air-conditioning systems of all structures shall be designed and installed for efficient utilization of energy in accordance with the *International Energy Conservation Code*.

CS301.3 (IMC 301.3) Identification. Each length of pipe and tubing and each pipe fitting utilized in a mechanical system shall bear the identification of the manufacturer.

CS301.4 (IMC 301.4) Plastic pipe, fittings and components. Plastic pipe, fittings and components shall be *third-party certified* as conforming to NSF 14.

CS301.5 (IMC 301.5) Third-party testing and certification. Piping, tubing and fittings shall comply with the applicable referenced standards, specifications and performance criteria of [this code] and shall be identified in accordance with Section CS301.3 (IMC 301.3). Piping, tubing and fittings shall either be tested by an approved third-party testing agency or certified by an approved *third-party certification agency*.

CS301.6 (IMC 301.6) Fuel gas appliances and equipment. The approval and installation of fuel gas distribution piping and equipment, fuel gas-fired appliances and fuel gas-fired *appliance* venting systems shall be in accordance with the *International Fuel Gas Code*.

CS301.7 (IMC 301.7) Listed and labeled. Appliances regulated by [this code] shall be *listed* and *labeled* for the application in which they are installed and used, unless otherwise *approved* in accordance with Section CS103 (IMC 105).

CS301.8 (IMC 301.8) Labeling. Labeling shall be in accordance with the procedures set forth in Sections CS301.8.1 (IMC 301.8.1) through CS301.8.2.3 (IMC 301.8.2.3).

Additional labeling requirements of electrical systems can be found in NFPA 70.

CS301.8.1 (IMC 301.8.1) Testing. An *approved* agency shall test a representative sample of the mechanical *equipment* and appliances being *labeled* to the relevant standard or standards. The *approved* agency shall maintain a record of all of the tests performed. The record shall provide sufficient detail to verify compliance with the test standard.

CS301.8.2 (IMC 301.8.2) Inspection and identification. The *approved* agency shall periodically perform an inspection, which shall be in-plant if necessary, of the mechanical *equipment* and appliances to be *labeled*. The inspection shall verify that the *labeled* mechanical *equipment* and appliances are representative of the mechanical *equipment* and appliances tested.

CS301.8.2.1 (IMC 301.8.2.1) Independent. The agency to be *approved* shall be objective and competent. To confirm its objectivity, the agency shall disclose all possible conflicts of interest.

CS301.8.2.2 (IMC 301.8.2.2) Equipment. An *approved* agency shall have adequate equipment to perform all required tests. The *equipment* shall be periodically calibrated.

CS301.8.2.3 (IMC 301.8.2.3) Personnel. An approved agency shall employ experienced personnel educated in conducting, supervising and evaluating tests.

CS301.9 (IMC 301.9) Label information. A permanent factory-applied nameplate(s) shall be affixed to appliances on which shall appear in legible lettering, the manufacturer's name or trademark, the model number, serial number and the seal or mark of the *approved* agency. A label shall also include the following:

1. Electrical *equipment* and appliances: Electrical rating in volts, amperes and motor phase; identification of individual electrical components in volts, amperes or watts, motor phase; Btu/h (W) output; and required clearances.
2. Absorption units: Hourly rating in Btu/h (W); minimum hourly rating for units having step or automatic modulating controls; type of fuel; type of refrigerant; cooling capacity in Btu/h (W); and required clearances.
3. Fuel-burning units: Hourly rating in Btu/h (W); type of fuel *approved* for use with the *appliance*; and required clearances.
4. Electric comfort heating appliances: electric rating in volts, amperes and phase; Btu/h (W) output rating; individual marking for each electrical component in amperes or watts, volts and phase; and required clearances from combustibles.

CS301.10 (IMC 301.10) Electrical. Electrical wiring, controls and connections to equipment and appliances regulated by [this code] shall be in accordance with NFPA 70.

CS301.11 (IMC 301.11) Plumbing connections. Potable water supply and building drainage system connections to *equipment* and appliances regulated by [this code] shall be in accordance with the *International Plumbing Code*.

CS301.12 (IMC 301.12) Fuel types. Fuel-fired appliances shall be designed for use with the type of fuel to which they will be connected and the altitude at which they are installed. Appliances that comprise parts of the building mechanical system shall not be converted for the usage of a different fuel, except where *approved* and converted in accordance with the manufacturer's instructions. The fuel input rate shall not be increased or decreased beyond the limit rating for the altitude at which the *appliance* is installed.

CS301.13 (IMC 301.13) Vibration isolation. Where vibration isolation of *equipment* and appliances is employed, an *approved* means of supplemental restraint shall be used to accomplish the support and restraint.

CS301.14 (IMC 301.14) Repair. Defective material or parts shall be replaced or repaired in such a manner so as to preserve the original approval or listing.

CS301.15 (IMC 301.15) Wind resistance. Mechanical *equipment*, appliances and supports that are exposed to wind shall be designed and installed to resist the wind pressures determined in accordance with the *International Building Code*.

CS301.16 (IMC 301.16) Flood hazard. For structures located in flood hazard areas, mechanical systems, equipment and appliances shall be located at or above the elevation required by Section 1612 of the *International Building Code* for utilities and attendant equipment.

Exception: Mechanical systems, equipment and appliances are permitted to be located below the elevation required by Section 1612 of the of the *International Building Code* for utilities and attendant equipment provided that they are designed and installed to prevent water from entering or accumulating within the components and to resist hydrostatic and hydrodynamic loads and stresses, including the effects of buoyancy, during the occurrence of flooding up to such elevation.

CS301.16.1 (IMC 301.16.1) Coastal high-hazard areas and coastal A zones. In coastal high-hazard areas and coastal A zones, mechanical systems and equipment shall not be mounted on or penetrate walls intended to break away under flood loads.

CS301.17 (IMC 301.17) Rodentproofing. Buildings or structures and the walls enclosing habitable or occupiable rooms and spaces in which persons live, sleep or work, or in which feed, food or foodstuffs are stored, prepared, processed, served or sold, shall be constructed to protect against the entrance of rodents in accordance with the *International Building Code*.

CS301.18 (IMC 301.18) Seismic resistance. Where earthquake loads are applicable in accordance with the *International Building Code*, mechanical system supports shall be designed and installed for the seismic forces in accordance with the *International Building Code*.

SECTION CS302 (IMC 302)
PROTECTION OF STRUCTURE

CS302.1 (IMC 302.1) Structural safety. The building or structure shall not be weakened by the installation of mechanical systems. Where floors, walls, ceilings or any other portion of the building or structure are required to be altered or replaced in the process of installing or repairing any system, the building or structure shall be left in a safe structural condition in accordance with the *International Building Code*.

CS302.2 (IMC 302.2) Penetrations of floor/ceiling assemblies and fire-resistance-rated assemblies. Penetrations of floor/ceiling assemblies and assemblies required to have a fire-resistance rating shall be protected in accordance with Chapter 7 of the *International Building Code*.

CS302.3 (IMC 302.3) Cutting, notching and boring in wood framing. The cutting, notching and boring of wood framing members shall comply with Sections CS302.3.1 (IMC 302.3.1) through CS302.3.4 (IMC 302.3.4).

CS302.3.1 (IMC 302.3.1) Joist notching. Notches on the ends of joists shall not exceed one-fourth the joist depth. Holes bored in joists shall not be within 2 inches (51 mm) of the top or bottom of the joist, and the diameter of any such hole shall not exceed one-third the depth of the joist. Notches in the top or bottom of joists shall not exceed one-sixth the depth and shall not be located in the middle third of the span.

CS302.3.2 (IMC 302.3.2) Stud cutting and notching. In exterior walls and bearing partitions, a wood stud shall not be cut or notched in excess of 25 percent of its depth. In nonbearing partitions that do not support loads other than the weight of the partition, a stud shall not be cut or notched in excess of 40 percent of its depth.

CS302.3.3 (IMC 302.3.3) Bored holes. The diameter of bored holes in wood studs shall not exceed 40 percent of the stud depth. The diameter of bored holes in wood studs shall not exceed 60 percent of the stud depth in nonbearing partitions. The diameter of bored holes in wood studs shall not exceed 60 percent of the stud depth in any wall where each stud is doubled, provided that not more than two such successive doubled studs are so bored. The edge of the bored hole shall be not closer than $^{5}/_{8}$ inch (15.9 mm) to the edge of the stud. Bored holes shall be not located at the same section of stud as a cut or notch.

CS302.3.4 (IMC 302.3.4) Engineered wood products. Cuts, notches and holes bored in trusses, structural composite lumber, structural glue-laminated members and I-joists are prohibited except where permitted by the manufacturer's recommendations or where the effects of such alterations are specifically considered in the design of the member by a registered design professional.

CS302.4 (IMC 302.4) Alterations to trusses. Truss members and components shall not be cut, drilled, notched, spliced or otherwise altered in any way without written concurrence and approval of a *registered design professional*.

Alterations resulting in the addition of loads to any member, such as HVAC *equipment* and water heaters, shall not be permitted without verification that the truss is capable of supporting such additional loading.

CS302.5 (IMC 302.5) Cutting, notching and boring in steel framing. The cutting, notching and boring of steel framing members shall comply with Sections CS302.5.1 (IMC 302.5.1) through CS302.5.3 (IMC 302.5.3).

CS302.5.1 (IMC 302.5.1) Cutting, notching and boring holes in structural steel framing. The cutting, notching and boring of holes in structural steel framing members shall be as prescribed by the *registered design professional*.

CS302.5.2 (IMC 302.5.2) Cutting, notching and boring holes in cold-formed steel framing. Flanges and lips of load-bearing cold-formed steel framing members shall not be cut or notched. Holes in webs of load-bearing cold-formed steel framing members shall be permitted along the centerline of the web of the framing member and shall not exceed the dimensional limitations, penetration spacing or minimum hole edge distance as prescribed by the *registered design professional*. Cutting, notching and boring holes of steel floor/roof decking shall be as prescribed by the *registered design professional*.

CS302.5.3 (IMC 302.5.3) Cutting, notching and boring holes in nonstructural cold-formed steel wall framing. Flanges and lips of nonstructural cold-formed steel wall studs shall not be cut or notched. Holes in webs of nonstructural cold-formed steel wall studs shall be permitted along the centerline of the web of the framing member, shall not exceed $1^1/_2$ inches (38 mm) in width or 4 inches (102 mm) in length, and shall not be spaced less than 24 inches (610 mm) center to center from another hole or less than 10 inches (254 mm) from the bearing end.

SECTION CS303 (IMC 303)
EQUIPMENT AND APPLIANCE LOCATION

CS303.1 (IMC 303.1) General. *Equipment* and appliances shall be located as required by this section, specific requirements elsewhere in [this code] and the conditions of the *equipment* and *appliance* listing.

This collection of provisions imports code sections which address both Solar Thermal and Photovoltaic Solar Systems, and the structural, mechanical, plumbing, fire safety and energy conservation measures for each. Some are specific to Solar Systems and others to their auxiliary, or backup systems. The installation of Photovoltaic Solar Systems is also addressed in NFPA 70.

CS303.2 (IMC 303.2) Hazardous locations. Appliances shall not be located in a *hazardous location* unless *listed* and *approved* for the specific installation.

CS303.3 (IMC 303.4) Protection from damage. Appliances shall not be installed in a location where subject to mechanical damage unless protected by *approved* barriers.

CS303.4 (IMC 303.6) Outdoor locations. Appliances installed in other than indoor locations shall be *listed* and *labeled* for outdoor installation.

CS303.5 (IMC 303.7) Pit locations. Appliances installed in pits or excavations shall not come in direct contact with the surrounding soil and shall be installed not less than 3 inches (76 mm) above the pit floor. The sides of the pit or excavation shall be held back not less than 12 inches (305 mm) from the *appliance*. Where the depth exceeds 12 inches (305 mm) below adjoining grade, the walls of the pit or excavation shall be lined with concrete or masonry. Such concrete or masonry shall extend not less than 4 inches (102 mm) above adjoining grade and shall have sufficient lateral load-bearing capacity to resist collapse. Excavation on the control side of the appliance shall extend not less than 30 inches (762 mm) horizontally. The *appliance* shall be protected from flooding in an *approved* manner.

CS303.6 (IMC 303.8) Elevator shafts. Mechanical systems shall not be located in an elevator shaft.

SECTION CS304 (IMC 304)
INSTALLATION

CS304.1 (IMC 304.1) General. *Equipment* and appliances shall be installed as required by the terms of their approval, in accordance with the conditions of the listing, the manufacturer's installation instructions and [this code]. Manufacturer's installation instructions shall be available on the job site at the time of inspection.

CS304.2 (IMC 304.2) Conflicts. Where conflicts between [this code] and the conditions of listing or the manufacturer's installation instructions occur, the provisions of [this code] shall apply.

Exception: Where a code provision is less restrictive than the conditions of the listing of the *equipment* or *appliance* or the manufacturer's installation instructions, the conditions of the listing and the manufacturer's installation instructions shall apply.

CS304.3 (IMC 304.3) Elevation of ignition source. Equipment and appliances having an *ignition source* and located in hazardous locations and public garages, private garages, repair garages, automotive motor fuel-dispensing facilities and parking garages shall be elevated such that the source of ignition is not less than 18 inches (457 mm) above the floor surface on which the *equipment* or *appliance* rests. For the purpose of this section, rooms or spaces that are not part of the living space of a *dwelling unit* and that communicate directly with a private garage through openings shall be considered to be part of the private garage.

Exception: Elevation of the ignition source is not required for appliances that are listed as flammable vapor ignition resistant.

CS304.3.1 (IMC 304.3.1) Parking garages. Connection of a parking garage with any room in which there is a fuel-fired *appliance* shall be by means of a vestibule providing a two-doorway separation, except that a single door is permitted where the sources of ignition in the *appliance* are

elevated in accordance with Section CS304.3 (IMC 304.3).

Exception: This section shall not apply to *appliance* installations complying with Section CS304.5 (IMC 304.6).

CS304.4 (IMC 304.4) Prohibited equipment and appliance location. Equipment and appliances having an *ignition source* shall not be installed in Group H occupancies or control areas where open use, handling or dispensing of combustible, flammable or explosive materials occurs.

CS304.5 (IMC 304.6) Public garages. Appliances located in public garages, motor fueling-dispensing facilities, repair garages or other areas frequented by motor vehicles, shall be installed not less than 8 feet (2438 mm) above the floor. Where motor vehicles are capable of passing under an *appliance*, the *appliance* shall be installed at the clearances required by the *appliance* manufacturer and not less than 1 foot (305 mm) higher than the tallest vehicle garage door opening.

Exception: The requirements of this section shall not apply where the appliances are protected from motor vehicle impact and installed in accordance with Section CS304.3 (IMC 304.3) and NFPA 30A.

CS304.6 (IMC 304.7) Private garages. Appliances located in private garages and carports shall be installed with a minimum clearance of 6 feet (1829 mm) above the floor.

Exception: The requirements of this section shall not apply where the appliances are protected from motor vehicle impact and installed in accordance with Section CS304.3 (IMC 304.3).

CS304.7 (IMC 304.8) Construction and protection. Boiler rooms and furnace rooms shall be protected as required by the *International Building Code*.

CS304.8 (IMC 304.9) Clearances to combustible construction. Heat-producing *equipment* and *appliances* shall be installed to maintain the required *clearances* to combustible construction as specified in the listing and manufacturer's instructions. Such clearances shall be reduced only in accordance with Section (IMC 308). *Clearances* to combustibles shall include such considerations as door swing, drawer pull, overhead projections or shelving and window swing, shutters, coverings and drapes. Devices such as doorstops or limits, closers, drapery ties or guards shall not be used to provide the required *clearances*.

CS304.9 (IMC 304.10) Clearances from grade. Equipment and *appliances* installed at grade level shall be supported on a level concrete slab or other *approved* material extending not less than 3 inches (76 mm) above adjoining grade or shall be suspended not less than 6 inches (152 mm) above adjoining grade. Such support shall be in accordance with the manufacturer's installation instructions.

CS304.10 (IMC 304.11) Guards. Guards shall be provided where various components that require service and roof hatch openings are located within 10 feet (3048 mm) of a roof edge or open side of a walking surface and such edge or open side is located more than 30 inches (762 mm) above the floor, roof, or grade below. The guard shall extend not less than 30 inches (762 mm) beyond each end of components that require service. The top of the guard shall be located not less than 42 inches (1067 mm) above the elevated surface adjacent to the guard. The guard shall be constructed so as to prevent the passage of a 21-inch-diameter (533 mm) sphere and shall comply with the loading requirements for guards specified in the *International Building Code*.

Exception: Guards are not required where permanent fall arrest/restraint anchorage connector devices that comply with ANSI/ASSE Z 359.1 are installed.

CS304.11 (IMC 304.12) Area served. Appliances serving different areas of a building other than where they are installed shall be permanently marked in an *approved* manner that uniquely identifies the *appliance* and the area it serves.

SECTION CS305 (IMC 305)
PIPING SUPPORT

CS305.1 (IMC 305.1) General. Mechanical system piping shall be supported in accordance with this section.

CS305.2 (IMC 305.2) Materials. Pipe hangers and supports shall have sufficient strength to withstand all anticipated static and specified dynamic loading conditions associated with the intended use. Pipe hangers and supports that are in direct contact with piping shall be of *approved* materials that are compatible with the piping and that will not promote galvanic action.

CS305.3 (IMC 305.3) Structural attachment. Hangers and anchors shall be attached to the building construction in an *approved* manner.

CS305.4 (IMC 305.4) Interval of support. Piping shall be supported at distances not exceeding the spacing specified in Table CS305.4 (IMC Table 305.4), or in accordance with ANSI/MSS SP-58.

CS305.5 (IMC 305.5) Protection against physical damage. In concealed locations where piping, other than cast-iron or steel, is installed through holes or notches in studs, joists, rafters or similar members less than $1^1/_2$ inches (38 mm) from the nearest edge of the member, the pipe shall be protected by shield plates. Protective steel shield plates having a minimum thickness of 0.0575 inch (1.463 mm) (No. 16 gage) shall cover the area of the pipe where the member is notched or bored, and shall extend not less than 2 inches (51 mm) above sole plates and below top plates.

SECTION CS306 (IMC 306)
ACCESS AND SERVICE SPACE

CS306.1 (IMC 306.1) Access. Appliances, controls devices, heat exchangers and HVAC system components that utilize energy shall be accessible for inspection, service, repair and replacement without disabling the function of a fire-resistance-rated assembly or removing permanent construction, other appliances, venting systems or any other piping or ducts not connected to the *appliance* being inspected, serviced, repaired or replaced. A level working space not less than 30 inches deep and 30 inches wide (762 mm by 762 mm) shall

TABLE CS305.4 (IMC 305.4)
PIPING SUPPORT SPACING[a]

PIPING MATERIAL	MAXIMUM HORIZONTAL SPACING (feet)	MAXIMUM VERTICAL SPACING (feet)
ABS pipe	4	10[c]
Aluminum pipe and tubing	10	15
Cast-iron pipe[b]	5	15
Copper or copper-alloy pipe	12	10
Copper or copper-alloy tubing	8	10
CPVC pipe or tubing, 1 inch and smaller	3	10[c]
CPVC pipe or tubing, $1^1/_4$ inches and larger	4	10[c]
Lead pipe	Continuous	4
PB pipe or tubing	$2^2/_3$ (32 inches)	4
PE-RT 1 inch and smaller	$2^2/_3$ (32 inches)	10[c]
PE-RT $1^1/_4$ inches and larger	4	10[c]
PEX tubing 1 inch and smaller	$2^2/_3$ (32 inches)	10[c]
PEX tubing $1^1/_4$ inches and larger	4	10[c]
Polypropylene (PP) pipe or tubing, 1 inch and smaller	$2^2/_3$ (32 inches)	10[c]
Polypropylene (PP) pipe or tubing, $1^1/_4$ inches and larger	4	10[c]
PVC pipe	4	10[c]
Steel tubing	8	10
Steel pipe	12	15

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. See Section CS301.18 (IMC 301.18).

b. The maximum horizontal spacing of cast-iron pipe hangers shall be increased to 10 feet where 10-foot lengths of pipe are installed.

c. Mid-story guide.

be provided in front of the control side to service an *appliance*.

CS306.2 (IMC 306.2) Appliances in rooms. Rooms containing appliances shall be provided with a door and an unobstructed passageway measuring not less than 36 inches (914 mm) wide and 80 inches (2032 mm) high.

Exception: Within a *dwelling unit*, appliances installed in a compartment, alcove, basement or similar space shall be accessed by an opening or door and an unobstructed passageway measuring not less than 24 inches (610 mm) wide and large enough to allow removal of the largest *appliance* in the space, provided that a level service space of not less than 30 inches (762 mm) deep and the height of the *appliance*, but not less than 30 inches (762 mm), is present at the front or service side of the *appliance* with the door open.

CS306.3 (IMC 306.3) Appliances in attics. Attics containing appliances shall be provided with an opening and unobstructed passageway large enough to allow removal of the largest *appliance*. The passageway shall be not less than 30 inches (762 mm) high and 22 inches (559 mm) wide and not more than 20 feet (6096 mm) in length measured along the centerline of the passageway from the opening to the *appliance*. The passageway shall have continuous solid flooring not less than 24 inches (610 mm) wide. A level service space not less than 30 inches (762 mm) deep and 30 inches (762 mm) wide shall be present at the front or service side of the appliance. The clear access opening dimensions shall be not less than 20 inches by 30 inches (508 mm by 762 mm), and large enough to allow removal of the largest *appliance*.

Exceptions:

1. The passageway and level service space are not required where the *appliance* is capable of being serviced and removed through the required opening.
2. Where the passageway is unobstructed and not less than 6 feet (1829 mm) high and 22 inches (559 mm) wide for its entire length, the passageway shall be not greater than 50 feet (15 250 mm) in length.

CS306.3.1 (IMC 306.3.1) Electrical requirements. A luminaire controlled by a switch located at the required passageway opening and a receptacle outlet shall be provided at or near the *appliance* location in accordance with NFPA 70.

CS306.4 (IMC 306.4) Appliances under floors. Underfloor spaces containing appliances shall be provided with an access opening and unobstructed passageway large enough to remove the largest *appliance*. The passageway shall be not less than 30 inches (762 mm) high and 22 inches (559 mm) wide, nor more than 20 feet (6096 mm) in length measured along the centerline of the passageway from the opening to the *appliance*. A level service space not less than 30 inches (762 mm) deep and 30 inches (762 mm) wide shall be present at the front or service side of the *appliance*. If the depth of the passageway or the service space exceeds 12 inches (305 mm) below the adjoining grade, the walls of the passageway shall be lined with concrete or masonry. Such concrete or masonry shall extend not less than 4 inches (102 mm) above the adjoining grade and shall have sufficient lateral-bearing capacity to resist collapse. The clear access opening dimensions shall be not less than 22 inches by 30 inches (559 mm by 762 mm), and large enough to allow removal of the largest *appliance*.

Exceptions:

1. The passageway is not required where the level service space is present when the access is open and the *appliance* is capable of being serviced and removed through the required opening.
2. Where the passageway is unobstructed and not less than 6 feet high (1929 mm) and 22 inches (559 mm) wide for its entire length, the passageway shall not be limited in length.

CS306.4.1 (IMC 306.4.1) Electrical requirements. A luminaire controlled by a switch located at the required passageway opening and a receptacle outlet shall be provided at or near the *appliance* location in accordance with NFPA 70.

CS306.5 (IMC 306.5) Equipment and appliances on roofs or elevated structures. Where *equipment* requiring access or appliances are located on an elevated structure or the roof of a building such that personnel will have to climb higher than 16 feet (4877 mm) above grade to access such equipment or appliances, an interior or exterior means of access shall be provided. Such access shall not require climbing over obstructions greater than 30 inches (762 mm) in height or walking on roofs having a slope greater than 4 units vertical in 12 units horizontal (33-percent slope). Such access shall not require the use of portable ladders. Where access involves climbing over parapet walls, the height shall be measured to the top of the parapet wall.

Permanent ladders installed to provide the required access shall comply with the following minimum design criteria:

1. The side railing shall extend above the parapet or roof edge not less than 30 inches (762 mm).
2. Ladders shall have rung spacing not to exceed 14 inches (356 mm) on center. The uppermost rung shall be not greater than 24 inches (610 mm) below the upper edge of the roof hatch, roof or parapet, as applicable.
3. Ladders shall have a toe spacing not less than 6 inches (152 mm) deep.
4. There shall be not less than 18 inches (457 mm) between rails.
5. Rungs shall have a diameter not less than 0.75-inch (19.1 mm) and be capable of withstanding a 300-pound (136 kg) load.
6. Ladders over 30 feet (9144 mm) in height shall be provided with offset sections and landings capable of withstanding 100 pounds per square foot (488 kg/m^2). Landing dimensions shall be not less than 18 inches (457 mm) and not less than the width of the ladder served. A guard rail shall be provided on all open sides of the landing.
7. Climbing clearance. The distance from the centerline of the rungs to the nearest permanent object on the climbing side of the ladder shall be not less than 30 inches (762 mm) measured perpendicular to the rungs. This distance shall be maintained from the point of ladder access to the bottom of the roof hatch. A minimum clear width of 15 inches (381 mm) shall be provided on both sides of the ladder measured from the midpoint of and parallel with the rungs except where cages or wells are installed.
8. Landing required. The ladder shall be provided with a clear and unobstructed bottom landing area having a minimum dimension of 30 inches (762 mm) by 30 inches (762 mm) centered in front of the ladder.
9. Ladders shall be protected against corrosion by *approved* means.
10. Access to ladders shall be provided at all times.

Catwalks installed to provide the required access shall be not less than 24 inches (610 mm) wide and shall have railings as required for service platforms.

Exception: This section shall not apply to Group R-3 occupancies.

CS306.5.1 (IMC 306.5.1) Sloped roofs. Where appliances, *equipment*, fans or other components that require service are installed on a roof having a slope of three units vertical in 12 units horizontal (25-percent slope) or greater and having an edge more than 30 inches (762 mm) above grade at such edge, a level platform shall be provided on each side of the *appliance* or *equipment* to which access is required for service, repair or maintenance. The platform shall be not less than 30 inches (762 mm) in any dimension and shall be provided with guards. The guards shall extend not less than 42 inches (1067 mm) above the platform, shall be constructed so as to prevent the passage of a 21-inch-diameter (533 mm) sphere and shall comply with the loading requirements for guards specified in the *International Building Code*. Access shall not require walking on roofs having a slope greater than four units vertical in 12 units horizontal (33-percent slope). Where access involves obstructions greater than 30 inches (762 mm) in height, such obstructions shall be provided with ladders installed in accordance with Section CS306.5 (IMC 306.5) or stairways installed in accordance with the requirements specified in the *International Building Code* in the path of travel to and from appliances, fans or *equipment* requiring service.

CS306.5.2 (IMC 306.5.2) Electrical requirements. A receptacle outlet shall be provided at or near the *equipment* location in accordance with NFPA 70.

SECTION CS307 (IMC 307)
CONDENSATE DISPOSAL

CS307.1 (IMC 307.1) Fuel-burning appliances. Liquid *combustion* by-products of condensing appliances shall be collected and discharged to an *approved* plumbing fixture or disposal area in accordance with the manufacturer's installation instructions. Condensate piping shall be of *approved* corrosion-resistant material and shall not be smaller than the drain connection on the appliance. Such piping shall maintain a minimum horizontal slope in the direction of discharge of not less than one-eighth unit vertical in 12 units horizontal (1-percent slope).

CS307.2 (IMC 307.2) Evaporators and cooling coils. Condensate drain systems shall be provided for *equipment* and appliances containing evaporators or cooling coils. Condensate drain systems shall be designed, constructed and installed in accordance with Sections (IMC 307.2.1) through (IMC 307.2.5).

Some of the auxiliary and backup equipment and appliances for Solar Thermal Systems are condensing, or produce liquid byproducts. The disposal of those liquid byproducts is covered

in the manufacturer's installation instructions and in Section 307 of the International Mechanical Code.

SECTION CS308 (IMC 309)
TEMPERATURE CONTROL

CS308.1 (IMC 309.1) Space-heating systems. Interior spaces intended for human occupancy shall be provided with active or passive space-heating systems capable of maintaining an indoor temperature of not less than 68°F (20°C) at a point 3 feet (914 mm) above floor on the design heating day. The installation of portable space heaters shall not be used to achieve compliance with this section.

Exceptions:

1. Interior spaces where the primary purpose is not associated with human comfort.
2. Group F, H, S and U occupancies.

SECTION CS309 (IMC 312)
HEATING AND COOLING LOAD CALCULATIONS

CS309.1 (IMC 312.1) Load calculations. Heating and cooling system design loads for the purpose of sizing systems, appliances and *equipment* shall be determined in accordance with the procedures described in the ASHRAE/ACCA Standard 183. Alternatively, design loads shall be determined by an *approved* equivalent computation procedure, using the design parameters specified in Chapter 3 [CE] of the *International Energy Conservation Code*.

SECTION CS310 (IFC 317)
ROOFTOP GARDENS AND LANDSCAPED ROOFS

CS310.1 (IFC 317.1) General. Rooftop gardens and landscaped roofs shall be installed and maintained in accordance with Sections (IFC 317.2) through (IFC 317.5) and Section CS502 (IBC 1505) and (IBC Section 1507.16).

CS310.2 (IFC 317.3) Rooftop structure and equipment clearance. For all vegetated roofing systems abutting combustible vertical surfaces, a Class A-rated roof system complying with ASTM E108 or UL 790 shall be achieved for a minimum 6-foot-wide (1829 mm) continuous border placed around rooftop structures and all rooftop equipment including, but not limited to, mechanical and machine rooms, penthouses, skylights, roof vents, solar panels, antenna supports and building service equipment.

SECTION CS311 (IBC 2606)
LIGHT-TRANSMITTING PLASTICS

CS311.1 (IBC 2606.1) General. The provisions of this section and Sections (IBC 2607) through (IBC 2611) shall govern the quality and methods of application of light-transmitting plastics for use as light-transmitting materials in buildings and structures. Foam plastics shall comply with Section (IBC 2603). Light-transmitting plastic materials that meet the other code requirements for walls and roofs shall be permitted to be used in accordance with the other applicable chapters of [the code].

CS311.2 (IBC 2606.12) Solar collectors. Light-transmitting plastic covers on solar collectors having noncombustible sides and bottoms shall be permitted on buildings not over three *stories above grade plane* or 9,000 square feet (836.1 m^2) in total floor area, provided that the light-transmitting plastic cover does not exceed 33.33 percent of the roof area for CC1 materials or 25 percent of the roof area for CC2 materials.

Exception: Light-transmitting plastic covers having a thickness of 0.010 inch (0.3 mm) or less shall be permitted to be of any plastic material provided that the area of the solar collectors does not exceed 33.33 percent of the roof area.

SECTION CS312 (ISPSC 316)
SWIMMING POOL AND SPA HEATERS

CS312.1 (ISPSC 316.1) General. The provisions of this section apply to heaters for pools and spas.

Exception: Portable *residential* spas and portable *residential* exercise spas.

CS312.2 (ISPSC 316.2) Listed and labeled. Heaters and hot water storage tanks shall be listed and labeled in accordance with the applicable standard listed in Table CS312.2 (ISPSC Table 316.2).

CS312.3 (ISPSC 316.4) Installation. Heaters shall be installed in accordance with the manufacturer's specifications and the *International Fuel Gas Code*, *International Mechanical Code*, *International Energy Conservation Code*, NFPA 70 or *International Residential Code*, as applicable in accordance with Section (ISPSC 102.7.1). Solar thermal water heaters shall be installed in accordance with Section CS312.4 (ISPSC 316.6).

CS312.3.1 (ISPSC 316.4.1) Temperature. A means shall be provided to monitor water temperature.

CS312.3.2 (ISPSC 316.4.2) Access prohibited. For public pools and spas, public access to controls shall be prohibited.

TABLE CS312.2 (ISPSC TABLE 316.2)
WATER HEATERS

DEVICE	STANDARD
Electric water heater	UL 1261, UL 1563 or CSA C22.2 No. 218.1
Gas-fired water heater	ANSI Z21.56/CSA 4.7a
Heat exchanger	AHRI 400
Heat pump water heater	UL 1995, AHRI 1160, CSA C22.2 No. 236

CS312.4 (ISPSC 316.6) Solar thermal water heaters. Solar thermal heaters utilized for pools and spas shall comply with Sections CS312.4.1 (ISPSC 316.6.1) through CS312.4.2 (ISPSC 316.6.2).

CS312.4.1 (ISPSC 316.6.1) Installation. Solar thermal water heaters shall be installed in accordance with the *International Mechanical Code* or *International Residential Code*, as applicable in accordance with Section (ISPSC 102.7.1).

CS312.4.2 (ISPSC 316.6.2) Collectors and panels. Solar thermal collectors and panels shall be *listed* and *labeled* in accordance with ICC 901/SRCC 100 or ICC 900/SRCC 300. Collectors and panels shall be permanently marked with the manufacturer's name, model number, and serial number. Such markings shall be located on each collector in a position that is readily viewable after installation of the collector or panel.

CHAPTER 4 [CS]

SOLAR THERMAL AND AUXILIARY SYSTEMS

User note:

About this chapter: *Chapter 4 addresses solar thermal systems, not photovoltaic systems. The provisions are intended to protect property and life from the hazards associated with high-temperature liquids, pressurized systems and toxic fluids. There are also provisions to protect the building structure and the solar thermal system components from damage.*

PART 1—SOLAR THERMAL SYSTEMS

SECTION CS401 (IMC 1401) GENERAL

CS401.1 (IMC 1401.1) Scope. [This chapter] shall govern the design, construction, installation, alteration and repair of solar thermal systems, *equipment* and appliances intended to utilize solar energy for space heating or cooling, domestic hot water heating, swimming pool heating or process heating.

This collection of provisions imports code sections which address Solar Thermal Systems and the structural, mechanical, plumbing, fire safety and energy conservation measures for them. Some are specific to the Solar Thermal portion and others to their auxiliary, or backup systems. These have been separated into Part 1 and Part 2 of this chapter.

CS401.2 (IMC 1401.2) Potable water supply. Potable water supplies to solar systems shall be protected against contamination in accordance with the *International Plumbing Code*.

Exception: Where all solar system piping is a part of the potable water distribution system, in accordance with the requirements of the *International Plumbing Code*, and all components of the piping system are *listed* for potable water use, cross-connection protection measures shall not be required.

CS401.3 (IMC 1401.3) Heat exchangers. Heat exchangers used in domestic water-heating systems shall be *approved* for the intended use. The system shall have adequate protection to ensure that the potability of the water supply and distribution system is properly safeguarded.

CS401.4 (IMC 1401.4) Solar thermal equipment and appliances. Solar thermal *equipment* and appliances shall conform to the requirements of [this chapter] and ICC 900/SRCC 300. Solar thermal systems shall be listed and labeled in accordance with ICC 900/SRCC 300 and shall be installed in accordance with the manufacturer's instructions and ICC 900/SRCC 300.

CS401.4.1 (IMC 1401.4.1) Collectors and panels. Solar thermal collectors and panels shall be listed and labeled in accordance with ICC 901/SRCC 100.

SECTION CS402 (IMC 1402) DESIGN AND INSTALLATION

CS402.1 (IMC 1402.1) General. The design and installation of solar thermal systems shall comply with Sections CS402.1 (IMC 1402.1) through CS402.8 (IMC 1402.8). Solar thermal systems shall be listed and labeled in accordance with ICC 900/SRCC 300 and shall be installed in accordance with the manufacturer's instructions and ICC 900/SRCC 300.

CS402.2 (IMC 1402.2) Access. Access shall be provided to solar thermal equipment for maintenance. Solar thermal systems and appurtenances shall not obstruct or interfere with the operation of any doors, windows or other building components requiring operation or access. Roof-mounted solar thermal equipment shall not obstruct or interfere with the operation of roof-mounted equipment, appliances, chimneys, roof hatches, smoke vents, skylights and other roof penetrations and openings.

CS402.3 (IMC 1402.3) Pressure and temperature. Solar thermal system components containing pressurized fluids shall be protected against pressures and temperatures exceeding design limitations with pressure and temperature relief valves or pressure relief valves. System components shall have a working pressure rating of not less than the setting of the pressure relief device.

CS402.3.1 (IMC 1402.3.1) Relief device. Each section of the system in which excessive pressures are capable of developing shall have a relief device located so that a section cannot be valved off or otherwise isolated from a relief device. Relief valves shall comply with the requirements of Section CS410.6 (IMC 1006.6). For indirect solar systems, pressure relief valves in solar loops shall also comply with ICC 900/SRCC 300.

CS402.3.2 (IMC 1402.3.2) Vacuum. System components that might be subjected to a vacuum while in operation or during shutdown shall be designed to withstand such vacuum or shall be protected with vacuum relief valves.

CS402.4 (IMC 1402.4) Protection from freezing. System components shall be protected from damage by freezing of heat transfer liquids at the lowest ambient temperatures that will be encountered during the operation of the system. Freeze protection shall be provided in accordance with ICC 900/SRCC 300. Drain-back systems shall be installed in com-

pliance with Section CS402.4.1 (IMC 1402.4.1) and systems utilizing freeze-protection valves shall comply with Section CS402.4.2 (IMC 1402.4.2).

CS402.4.1 (IMC 1402.4.1) Drain-back systems. Drain-back systems shall be designed and installed to allow for manual gravity draining of fluids from areas subject to freezing to locations not subject to freezing, and air filling of the components and piping. Such piping and components shall maintain a horizontal slope in the direction of flow of not less than one-fourth unit vertical in 12 units horizontal (2-percent slope). Piping and components subject to manual gravity draining shall permit subsequent air filling upon drainage and air storage or venting upon refilling.

CS402.4.2 (IMC 1402.4.2) Freeze-protection valves. Freeze-protection valves shall discharge in a manner that does not create a hazard or structural damage.

CS402.5 (IMC 1402.5) Protection of potable water. Where a solar thermal system heats potable water to supply a potable hot water distribution or any other type of heating system, the solar thermal system shall be in accordance with Sections CS402.5.1 (IMC 1402.5.1) through CS402.5.3 (IMC 1402.5.3) as applicable.

CS402.5.1 (IMC 1402.5.1) Indirect systems. Water supplies of any type shall not be connected to the solar heating loop of an indirect solar thermal hot water heating system. This requirement shall not prohibit the presence of inlets or outlets on the solar heating loop for the purposes of servicing the fluid in the solar heating loop.

CS402.5.2 (IMC 1402.5.2) Direct systems for potable water distribution systems. Where a solar thermal system directly heats potable water for a potable water distribution system, the pipe, fittings, valves and other components that are in contact with the potable water in the system shall comply with the requirements of the *International Plumbing Code*.

CS402.5.3 (IMC 1402.5.3) Direct systems for other than potable water distribution systems. Where a solar thermal system directly heats water for a system other than a potable water distribution system, a potable water supply connected to such system shall be protected against backflow in accordance with the *International Plumbing Code.*

CS402.6 (IMC 1402.6) Protection of equipment. Solar thermal *equipment* exposed to vehicular traffic shall be installed not less than 6 feet (1829 mm) above the finished floor.

Exception: This section shall not apply where the *equipment* is protected from motor vehicle impact.

CS402.7 (IMC 1402.7) Protection of structure. In the process of installing or repairing any part of a solar thermal system, the building or structure shall be left in a safe structural condition in accordance with Sections CS302 (IMC 302), CS402.7.1 (IMC 1402.7.1) and CS402.7.2 (IMC 1402.7.2).

CS402.7.1 (IMC 1402.7.1) Controlling condensation. Where attics or structural spaces are part of a passive solar system, ventilation of such spaces, as required by Section (IMC 406), is not required where other *approved* means of controlling condensation are provided.

CS402.7.2 (IMC 1402.7.2) Penetrations. Roof and wall penetrations shall be flashed and sealed to prevent entry of water, rodents and insects in accordance with Section CS302 (IMC 302).

CS402.8 (IMC 1402.8) Equipment. The solar thermal system shall be equipped in accordance with the requirements of Sections CS402.8.1 (IMC 1402.8.1) through CS402.8.5.3 (IMC 1402.8.5.3).

CS402.8.1 (IMC 1402.8.1) Collectors and panels. Solar collectors and panels shall comply with Sections CS402.8.1.1 (IMC 1402.8.1.1) through CS402.8.1.4 (IMC 1402.8.1.4).

CS402.8.1.1 (IMC 1402.8.1.1) Design. Solar thermal collectors and panels shall be listed and labeled in accordance with ICC 901/SRCC 100.

CS402.8.1.2 (IMC 1402.8.1.2) Rooftop-mounted solar thermal collectors and systems. The roof shall be constructed to support the loads imposed by roof-mounted solar collectors. Where mounted on or above the roof covering, the collector array and supporting construction shall be constructed of noncombustible materials or fire-retardant-treated wood conforming to the *International Building Code* to the extent required for the type of roof construction of the building to which the collectors are accessory.

CS402.8.1.3 (IMC 1402.8.1.3) Collectors as roof covering. Roof-mounted solar collectors that also serve as a roof covering shall conform to the requirements for roof coverings in accordance with the *International Building Code*.

Exception: The use of plastic solar collector covers shall be limited to those *approved* light-transmitting plastics meeting the requirements for plastic roof panels in Section 2609 of the *International Building Code*.

CS402.8.1.4 (IMC 1402.8.1.4) Collector sensors. Collector sensor installation, sensor location and the protection of exposed sensor wires from degradation shall be in accordance with ICC 900/SRCC 300, NFPA 70 and the collector manufacturer's instructions.

CS402.8.2 (IMC 1402.8.2) Ducts. Ducts utilized in solar heating and cooling systems shall be constructed and installed in accordance with (IMC) Chapter 6.

CS402.8.2.1 (IMC 1402.8.2.1) Filtering. Air transported to occupied spaces through dust-producing materials by means other than natural convection shall be filtered before entering the occupied space in accordance with Section (IMC 605).

CS402.8.3 (IMC 1402.8.3) Piping. Potable piping shall be installed in accordance with the *International Plumbing Code*. Hydronic piping shall be installed in accordance with (IMC) Chapter 10 of [this code]. Mechanical system piping shall be supported in accordance with Section CS305 (IMC 305).

CS402.8.3.1 (IMC 1402.8.3.1) Piping insulation. Piping shall be insulated in accordance with the requirements of the *International Energy Conservation Code*. Exterior insulation shall be protected from degradation. The entire solar loop shall be insulated. Where split-style insulation is used, the seam shall be sealed. Fittings shall be fully insulated. Insulation shall comply with Section (IMC 1204.1).

Exceptions:

1. Those portions of the piping that are used to help prevent the system from overheating shall not be required to be insulated.
2. Those portions of piping that are exposed to solar radiation, made of the same material as the solar collector absorber plate and covered in the same manner as the solar collector absorber, or that are used to collect additional solar energy, shall not be required to be insulated.
3. Piping in solar thermal systems using unglazed solar collectors to heat a swimming pool shall not be required to be insulated.

CS402.8.4 (IMC 1402.8.4) Heat exchangers. Heat exchangers used in domestic water-heating systems shall be approved for the intended use. The system shall have adequate protection to ensure that the potability of the water supply and distribution system is properly safeguarded.

CS402.8.4.1 (IMC 1402.8.4.1) Double-wall heat exchangers. Heat exchangers utilizing a non-food-grade fluid shall be separated from the potable water by double-wall construction. An air gap open to the atmosphere shall be provided between the two walls. The discharge location from the double-wall heat exchanger shall be visible.

CS402.8.4.2 (IMC 1402.8.4.2) Single-wall heat exchangers. Food-grade fluids shall be used as the heat transfer fluid in single-wall heat exchangers.

CS402.8.5 (IMC 1402.8.5) Water heaters and hot water storage tanks. Auxiliary water heaters, boilers and water storage tanks associated with solar thermal systems shall comply with (IMC) Chapter 10 and ICC 900/SRCC 300.

CS402.8.5.1 (IMC 1402.8.5.1) Hot water storage tank insulation. Hot water storage tanks shall be insulated and such insulation shall have an *R*-value of not less than R-12.5.

CS402.8.5.2 (IMC 1402.8.5.2) Outdoor locations. Storage tanks and heating equipment installed in outdoor locations shall be designed for outdoor installation.

CS402.8.5.3 (IMC 1402.8.5.3) Storage tank sensors. Storage tank sensors shall comply with ICC 900/SRCC 300.

CS402.8.6 (IMC 1402.8.6) Solar loop. Solar loops shall be in accordance with Sections CS402.8.6.1 (IMC 1402.8.6.1) and CS402.8.6.2 (IMC 1402.8.6.2).

CS402.8.6.1 (IMC 1402.8.6.1) Solar loop isolation. Valves shall be installed to allow the solar loop to be isolated from the remainder of the system.

CS402.8.6.2 (IMC 1402.8.6.2) Drain and fill valve caps. Drain caps shall be installed on drain and fill valves.

CS402.8.7 (IMC 1402.8.7) Expansion tanks. Liquid single-phase solar energy systems shall be equipped with expansion tanks sized in accordance with Section CS403 (IMC 1009), except that additional expansion tank acceptance volume equal to the total volume of liquid contained in the installed solar collectors and piping above the collectors shall be included.

SECTION CS403 (IMC 1403)
HEAT TRANSFER FLUIDS

CS403.1 (IMC 1403.1) Flash point. The flash point of the actual heat transfer fluid utilized in a solar system shall be not less than 50°F (28°C) above the design maximum nonoperating (no-flow) temperature of the fluid attained in the collector.

CS403.2 (IMC 1403.2) Heat transfer fluids. Heat transfer gases and liquids shall be rated to withstand the system's maximum design temperature under operating conditions without degradation. Heat transfer fluids shall be in accordance with ICC 900/SRCC 300.

CS403.3 (IMC 1403.3) Food-grade additives. Any food-grade fluid used as a heat transfer fluid containing additives shall be third-party listed by an approved agency to the appropriate section of the Code of Federal Regulations, Title 21, Food and Drugs, Chapter 1, Food and Drug Administration, Parts 174–186.

CS403.4 (IMC 1403.4) Toxicity. The use of toxic fluids shall comply with Title 15 of the Federal Hazardous Substances Act and Chapter 60 of the *International Fire Code*.

CS403.5 (IMC 1403.5) Flammable gases and liquids. A flammable liquid or gas shall not be utilized as a heat transfer fluid. The flash point of liquids used in occupancies classified in Group H or F shall not be lower unless *approved*.

SECTION CS404 (IMC 1404)
LABELING

CS404.1 (IMC 1404.1) Collectors. Factory-built collectors shall bear a label showing the manufacturer's name and address, model number and serial number.

CS404.2 (IMC 1404.2) Water storage tanks. Pressurized water storage tanks shall bear a label showing the manufacturer's name and address, model number, serial number, storage unit maximum and minimum allowable operating temperatures, and storage unit maximum and minimum allowable operating pressures. The label shall clarify that these specifications apply only to the water storage tanks.

CS404.3 (IMC 1404.3) Fluid safety labeling. Drain and fill valves shall be labeled with a description and warning that identifies the fluid in that loop as "Potable Water," "Food-

Grade Fluid," "Non-Food-Grade Fluid" or "Toxic." Labeling shall also be provided that reads as follows: "Fluid could be discharged at high temperature or pressure or both. Unauthorized alterations to this system could result in a health hazard or a hazardous condition."

CS404.4 (IMC 1404.4) Heat exchangers. Heat exchangers shall be labeled to indicate the heat exchanger type with one of the following:

1. "Single-wall without leak protection."
2. "Double-wall without leak protection."
3. "Double-wall with leak protection."

PART 2 – AUXILIARY AND BACKUP THERMAL SYSTEMS

SECTION CS405 (IMC 1002) WATER HEATERS

CS405.1 (IMC 1002.1) General. Potable water heaters and hot water storage tanks shall be listed and labeled and installed in accordance with the manufacturer's instructions, the *International Plumbing Code* and [this code]. Water heaters shall be capable of being removed without first removing a permanent portion of the building structure. The potable water connections and relief valves for all water heaters shall conform to the requirements of the *International Plumbing Code*. Domestic electric water heaters shall comply with UL 174 or UL 1453. Commercial electric water heaters shall comply with UL 1453. Oil-fired water heaters shall comply with UL 732. Solid-fuel-fired water heaters shall comply with UL 2523. Solar thermal water heating systems shall comply with (IMC) Chapter 14 and ICC 900/SRCC 300.

Chapter 14 of the International Mechanical Code is included in Part 1 of this chapter.

CS405.2 (IMC 1002.2) Water heaters utilized for space heating. Water heaters utilized both to supply potable hot water and provide hot water for space-heating applications shall be *listed* and *labeled* for such applications by the manufacturer and shall be installed in accordance with the manufacturer's instructions and the *International Plumbing Code*.

CS405.2.1 (IMC 1002.2.1) Sizing. Water heaters utilized for both potable water heating and space-heating applications shall be sized to prevent the space-heating load from diminishing the required potable water-heating capacity.

CS405.2.2 (IMC 1002.2.2) Temperature limitation. Where a combination potable water-heating and space-heating system requires water for space heating at temperatures higher than 140°F (60°C), a temperature-actuated mixing valve that conforms to ASSE 1017 shall be provided to temper the water supplied to the potable hot water distribution system to a temperature of 140°F (60°C) or less.

CS405.3 (IMC 1002.3) Supplemental water-heating devices. Potable waterheating devices that utilize refrigerant-to-water heat exchangers shall be *approved* and installed in accordance with the *International Plumbing Code* and the manufacturer's instructions.

SECTION CS406 (IPC 502) INSTALLATION

CS406.1 (IPC 502.1) General. Water heaters shall be installed in accordance with the manufacturer's instructions. Oil-fired water heaters shall conform to the requirements of [this code] and the *International Mechanical Code*. Electric water heaters shall conform to the requirements of [this code] and provisions of NFPA 70. Gas-fired water heaters shall conform to the requirements of the *International Fuel Gas Code*. Solar thermal water heating systems shall conform to the requirements of the *International Mechanical Code* and ICC 900/SRCC 300.

CS406.2 (IPC 601.2) Solar energy utilization. Solar energy systems used for heating potable water or using an independent medium for heating potable water shall comply with the applicable requirements of [this code]. The use of solar energy shall not compromise the requirements for cross connection or protection of the potable water supply system required by [this code].

SECTION CS407 (IMC 1003) PRESSURE VESSELS

CS407.1 (IMC 1003.1) General. All pressure vessels, unless otherwise approved, shall be constructed and certified in accordance with the ASME *Boiler and Pressure Vessel Code*, and shall be installed in accordance with the manufacturer's instructions and nationally recognized standards. Directly fired pressure vessels shall meet the requirements of Section CS408 (IMC 1004).

CS407.2 (IMC 1003.2) Piping. All piping materials, fittings, joints, connections and devices associated with systems utilized in conjunction with pressure vessels shall be designed for the specific application and shall be *approved*.

CS407.3 (IMC 1003.3) Welding. Welding on pressure vessels shall be performed by an R-Stamp holder in accordance with the *National Board Inspection Code*, *Part 3* or in accordance with an approved standard.

SECTION CS408 (IMC 1004) BOILERS

CS408.1 (IMC 1004.1) Standards. Boilers shall be designed, constructed and certified in accordance with the ASME *Boiler and Pressure Vessel Code*, Section I or IV. Controls and safety devices for boilers with fuel input ratings of 12,500,000 Btu/hr (3,662,500 W) or less shall meet the requirements of ASME CSD-1. Controls and safety devices for boilers with inputs greater than 12,500,000 Btu/hr (3,662,500 W) shall meet the requirements of NFPA 85. Packaged oil-fired boilers shall be listed and labeled in accordance with UL 726. Packaged electric boilers shall be listed

and labeled in accordance with UL 834. Solid-fuel-fired boilers shall be listed and labeled in accordance with UL 2523.

CS408.2 (IMC 1004.2) Installation. In addition to the requirements of [this code], the installation of boilers shall conform to the manufacturer's instructions. Operating instructions of a permanent type shall be attached to the boiler. Boilers shall have all controls set, adjusted and tested by the installer. The manufacturer's rating data and the nameplate shall be attached to the boiler.

CS408.3 (IMC 1004.3) Working clearance. Clearances shall be maintained around boilers, generators, heaters, tanks and related *equipment* and appliances so as to permit inspection, servicing, repair, replacement and visibility of all gauges. Where boilers are installed or replaced, clearance shall be provided to allow access for inspection, maintenance and repair. Passageways around all sides of boilers shall have an unobstructed width of not less than 18 inches (457 mm), unless otherwise *approved*.

CS408.3.1 (IMC 1004.3.1) Top clearance. Clearances from the tops of boilers to the ceiling or other overhead obstruction shall be in accordance with Table CS408.3.1 (IMC Table 1004.3.1).

CS408.4 (IMC 1004.4) Mounting. *Equipment* shall be set or mounted on a level base capable of supporting and distributing the weight contained thereon. Boilers, tanks and *equipment* shall be secured in accordance with the manufacturer's installation instructions.

CS408.5 (IMC 1004.5) Floors. Boilers shall be mounted on floors of noncombustible construction, unless *listed* for mounting on combustible flooring.

CS408.6 (IMC 1004.6) Boiler rooms and enclosures. Boiler rooms and enclosures and access thereto shall comply with the *International Building Code* and (IMC) Chapter 3 of [this code]. Boiler rooms shall be equipped with a floor drain or other *approved* means for disposing of liquid waste.

CS408.7 (IMC 1004.7) Operating adjustments and instructions. Hot water and steam boilers shall have all operating and safety controls set and operationally tested by the installing contractor. A complete control diagram and boiler operating instructions shall be furnished by the installer for each installation.

SECTION CS409 (IMC 1005) BOILER CONNECTIONS

CS409.1 (IMC 1005.1) Valves. Every boiler or modular boiler shall have a shutoff valve in the supply and return piping. For multiple boiler or multiple modular boiler installations, each boiler or modular boiler shall have individual shutoff valves in the supply and return piping.

Exception: Shutoff valves are not required in a system having a single low-pressure steam boiler.

CS409.2 (IMC 1005.2) Potable water supply. The water supply to all boilers shall be connected in accordance with the *International Plumbing Code*.

TABLE CS408.3.1 (IMC TABLE 1004.3.1)
BOILER TOP CLEARANCES

BOILER TYPE	MINIMUM CLEARANCES FROM TOP OF BOILER TO CEILING OR OTHER OVERHEAD OBSTRUCTION (feet)
All boilers with manholes on top of the boiler except where a greater clearance is required in this table.	3
All boilers without manholes on top of the boiler except high-pressure steam boilers and where a greater clearance is required in this table.	2
High-pressure steam boilers with steam generating capacity not exceeding 5,000 pounds per hour.	3
High-pressure steam boilers with steam generating capacity exceeding 5,000 pounds per hour.	7
High-pressure steam boilers having heating surface not exceeding 1,000 square feet.	3
High-pressure steam boilers having heating surface in excess of 1,000 square feet.	7
High-pressure steam boilers with input not exceeding 5,000,000 Btu/h.	3
High-pressure steam boilers with input in excess of 5,000,000 Btu/h.	7
Steam-heating boilers and hot water-heating boilers with input exceeding 5,000,000 Btu/h.	3
Steam-heating boilers exceeding 5,000 pounds of steam per hour.	3
Steam-heating boilers and hot water-heating boilers having heating surface exceeding 1,000 square feet.	3

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2,
1 pound per hour = 0.4536 kg/h, 1 Btu/hr = 0.293 W.

SECTION CS410 (IMC 1006) SAFETY AND PRESSURE RELIEF VALVES AND CONTROLS

CS410.1 (IMC 1006.1) Safety valves for steam boilers. Steam boilers shall be protected with a safety valve.

CS410.2 (IMC 1006.2) Safety relief valves for hot water boilers. Hot water boilers shall be protected with a safety relief valve.

CS410.3 (IMC 1006.3) Pressure relief for pressure vessels. Pressure vessels shall be protected with a pressure relief valve or pressure-limiting device as required by the manufacturer's installation instructions for the pressure vessel.

CS410.4 (IMC 1006.4) Approval of safety and safety relief valves. Safety and safety relief valves shall be *listed* and *labeled*, and shall have a minimum rated capacity for the *equipment* or appliances served. Safety and safety relief valves shall be set at not greater than the nameplate pressure rating of the boiler or pressure vessel.

CS410.5 (IMC 1006.5) Installation. Safety or relief valves shall be installed directly into the safety or relief valve opening on the boiler or pressure vessel. Valves shall not be located on either side of a safety or relief valve connection. The relief valve shall discharge by gravity.

CS410.6 (IMC 1006.6) Safety and relief valve discharge. Safety and relief valve discharge pipes shall be of rigid pipe that is *approved* for the temperature of the system. Highpressure-steam safety valves shall be vented to the outside of the structure. The discharge piping serving pressure relief valves, temperature relief valves and combinations of such valves shall:

1. Not be directly connected to the drainage system.
2. Discharge through an air break located in the same room as the appliance.
3. Not be smaller than the diameter of the outlet of the valve served and shall discharge full size to the air break.
4. Serve a single relief device and shall not connect to piping serving any other relief device or equipment.
5. Discharge to the floor, to the pan serving the boiler or storage tank, to a waste receptor or to the outdoors.
6. Discharge in a manner that does not cause personal injury or structural damage.
7. Discharge to a termination point that is readily observable by the building occupants.
8. Not be trapped.
9. Be installed so as to flow by gravity.
10. Not terminate more than 6 inches (152 mm) above the floor or waste receptor.
11. Not have a threaded connection at the end of such piping.
12. Not have valves or tee fittings.
13. Be constructed of those materials listed in Section 605.4 of the *International Plumbing Code* or materials tested, rated and approved for such use in accordance with ASME A112.4.1.

CS410.7 (IMC 1006.7) Boiler safety devices. Boilers shall be equipped with controls and limit devices as required by the manufacturer's installation instructions and the conditions of the listing.

CS410.8 (IMC 1006.8) Electrical requirements. The power supply to the electrical control system shall be from a two-wire branch circuit that has a grounded conductor, or from an isolation transformer with a two-wire secondary. Where an isolation transformer is provided, one conductor of the secondary winding shall be grounded. Control voltage shall not exceed 150 volts nominal, line to line. Control and limit devices shall interrupt the ungrounded side of the circuit. A means of manually disconnecting the control circuit shall be provided and controls shall be arranged so that when deenergized, the burner shall be inoperative. Such disconnecting means shall be capable of being locked in the off position and shall be provided with ready access.

SECTION CS411 (IMC 1007)
BOILER LOW-WATER CUTOFF

CS411.1 (IMC 1007.1) General. Steam and hot water boilers shall be protected with a low-water cutoff control.

Exception: A low-water cutoff is not required for coil-type and water-tube-type boilers that require forced circulation of water through the boiler and that are protected with a flow sensing control.

CS411.2 (IMC 1007.2) Operation. Low-water cutoff controls and flow sensing controls required by Section CS411.1 (IMC 1007.1) shall automatically stop the *combustion* operation of the *appliance* when the water level drops below the lowest safe water level as established by the manufacturer or when water circulation stops, respectively.

SECTION CS412 (IMC 1008)
BOTTOM BLOWOFF VALVE

CS412.1 (IMC 1008.1) General. Steam boilers shall be equipped with bottom blowoff valve(s). The valve(s) shall be installed in the opening provided on the boiler. The minimum size of the valve(s) and associated piping shall be the size specified by the boiler manufacturer or the size of the boiler blowoff-valve opening. Where the maximum allowable working pressure of the boiler exceeds 100 psig (689 kPa), two bottom blowoff valves shall be provided consisting of either two slow-opening valves in series or one quick-opening valve and one slowopening valve in series, with the quick-opening valve installed closest to the boiler.

CS412.2 (IMC 1008.2) Discharge. Blowoff valves shall discharge to a safe place of disposal. Where discharging to the drainage system, the installation shall conform to the *International Plumbing Code*.

SECTION CS413 (IMC 1009)
HOT WATER BOILER EXPANSION TANK

CS413.1 (IMC 1009.1) Where required. An expansion tank shall be installed in every hot water system. For multiple boiler installations, not less than one expansion tank is required. Expansion tanks shall be of the closed or open type. Tanks shall be rated for the pressure of the hot water system.

Exception: Expansion tanks shall not be required in the collector loop of drain-back systems.

CS413.2 (IMC 1009.2) Closed-type expansion tanks. Closed-type expansion tanks shall be installed in accordance with the manufacturer's instructions. Expansion tanks for systems designed to have an operating pressure in excess of 30 psi (207 kPa) shall be constructed and certified in accordance with the ASME *Boiler and Pressure Vessel Code*. The size of the tank shall be based on the capacity of the hot-water-heating system. The minimum size of the tank shall be

determined in accordance with the following equation where all necessary information is known:

(Equation 4-1)
(IMC Equation 10-1)

$$V_t = \frac{(0.00041T - 0.0466)V_s}{\left(\frac{P_a}{P_f}\right) - \left(\frac{P_a}{P_o}\right)}$$

For SI:

$$V_t = \frac{(0.000738T - 0.03348)V_s}{\left(\frac{P_a}{P_f}\right) - \left(\frac{P_a}{P_o}\right)}$$

where:

V_t = Minimum volume of tanks (gallons) (L).

V_s = Volume of system, not including expansion tanks (gallons) (L).

T = Average operating temperature (ºF) (ºC).

P_a = Atmospheric pressure (psi) (kPa).

P_f = Fill pressure (psi) (kPa).

P_o = Maximum operating pressure (psi) (kPa).

Where all necessary information is not known, the minimum size of the tank shall be determined from Table CS413.2 (IMC Table 1009.2).

TABLE CS413.2 (IMC TABLE 1009.2)
CLOSED-TYPE EXPANSION TANK SIZING

SYSTEM VOLUME IN GALLONS	TANK CAPACITIES IN GALLONS	
	Pressurized Diaphragm Type	Nonpressurized Type
100	9	15
200	17	30
300	25	45
400	33	60
500	42	75
1,000	83	150
2,000	165	300

For SI: 1 gallon = 3.795 L.

CS413.3 (IMC 1009.3) Open-type expansion tanks. Open-type expansion tanks shall be located not less than 4 feet (1219 mm) above the highest heating element. The tank shall be adequately sized for the hot water system. An overflow with a minimum diameter of 1 inch (25 mm) shall be installed at the top of the tank. The overflow shall discharge to the drainage system in accordance with the *International Plumbing Code*.

SECTION CS414 (IMC 1010) GAUGES

CS414.1 (IMC 1010.1) Hot water boiler gauges. Every hot water boiler shall have a pressure gauge and a temperature gauge, or a combination pressure and temperature gauge. The gauges shall indicate the temperature and pressure within the normal range of the system's operation.

CS414.2 (IMC 1010.2) Steam boiler gauges. Every steam boiler shall have a water-gauge glass and a pressure gauge. The pressure gauge shall indicate the pressure within the normal range of the system's operation.

CS414.2.1 (IMC 1010.2.1) Water-gauge glass. The gauge glass shall be installed so that the midpoint is at the normal boiler water level.

SECTION CS415 (IMC 1011) TESTS

CS415.1 (IMC 1011.1) Tests. Upon completion of the assembly and installation of boilers and pressure vessels, acceptance tests shall be conducted in accordance with the requirements of the ASME *Boiler and Pressure Vessel Code* or the manufacturer's requirements, and such tests shall be approved. A copy of all test documents along with all manufacturer's data reports required by the ASME *Boiler and Pressure Vessel Code* shall be submitted to the code official.

CS415.2 (IMC 1011.2) Test gauges. An indicating test gauge shall be connected directly to the boiler or pressure vessel where it is visible to the operator throughout the duration of the test. The pressure gauge scale shall be graduated over a range of not less than one and one-half times and not greater than four times the maximum test pressure. Gauges utilized for testing shall be calibrated and certified by the test operator.

CHAPTER 5 [CS]
PHOTOVOLTAIC SYSTEMS

User note:

About this chapter: *The source code for section numbers in parenthesis is the 2018 International Building Code®, except where the International Fire Code® has been denoted. Chapter 5 is specific to photovoltaic solar systems and equipment. Solar thermal systems are not addressed in this chapter. This chapter covers solar modules and shingles, system design, and roof access and pathways.*

SECTION CS501 (IBC 1501) GENERAL

CS501.1 (IBC 1501.1) Scope. The provisions of [this chapter] shall govern the design, materials, construction and quality of roof assemblies, and rooftop structures.

This collection of provisions imports code sections which address Photovoltaic Solar Systems, and the structural, fire safety and energy conservation measures for them. These are specific to Solar Systems. Additional information can be found in the source code documents. The installation of Photovoltaic Solar Systems is also addressed in NFPA 70.

SECTION CS502 (IBC 1505) FIRE CLASSIFICATION

CS502.1 (IBC 1505.1) General. Roof assemblies shall be divided into the classes defined in this section. Class A, B and C roof assemblies and roof coverings required to be listed by this section shall be tested in accordance with ASTM E108 or UL 790. In addition, *fire-retardant-treated wood* roof coverings shall be tested in accordance with ASTM D2898. The minimum roof coverings installed on buildings shall comply with Table CS502.1 (IBC 1505.1) based on the type of construction of the building.

Exception: Skylights and sloped glazing that comply with (IBC) Chapter 24 or Section (IBC 2610).

TABLE CS502.1 (IBC TABLE 1505.1)[a, b] MINIMUM ROOF COVERING CLASSIFICATION FOR TYPES OF CONSTRUCTION

IA	IB	IIA	IIB	IIIA	IIIB	IV	VA	VB
B	B	B	C[c]	B	C[c]	B	B	C[c]

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2.

a. Unless otherwise required in accordance with the *International Wildland-Urban Interface Code* or due to the location of the building within a fire district in accordance with (IBC) Appendix D.

b. Nonclassified roof coverings shall be permitted on buildings of Group R-3 and Group U occupancies, where there is a minimum fire-separation distance of 6 feet measured from the leading edge of the roof.

c. Buildings that are not more than two stories above grade plane and having not more than 6,000 square feet of projected roof area and where there is a minimum 10-foot fire-separation distance from the leading edge of the roof to a lot line on all sides of the building, except for street fronts or public ways, shall be permitted to have roofs of No. 1 cedar or redwood shakes and No. 1 shingles constructed in accordance with Section (IBC 1505.7).

CS502.2 (IBC 1505.2) Class A roof assemblies. Class A roof assemblies are those that are effective against severe fire test exposure. Class A roof assemblies and roof coverings shall be *listed* and identified as Class A by an *approved* testing agency. Class A roof assemblies shall be permitted for use in buildings or structures of all types of construction.

Exceptions:

1. Class A roof assemblies include those with coverings of brick, masonry or an exposed concrete roof deck.
2. Class A roof assemblies also include ferrous or copper shingles or sheets, metal sheets and shingles, clay or concrete roof tile or slate installed on noncombustible decks or ferrous, copper or metal sheets installed without a roof deck on noncombustible framing.
3. Class A roof assemblies include minimum 16 ounce per square foot (0.0416 kg/m^2) copper sheets installed over combustible decks.
4. Class A roof assemblies include slate installed over ASTM D226, Type II underlayment over combustible decks.

CS502.3 (IBC 1505.3) Class B roof assemblies. Class B roof assemblies are those that are effective against moderate fire-test exposure. Class B roof assemblies and roof coverings shall be *listed* and identified as Class B by an *approved* testing agency.

CS502.4 (IBC 1505.4) Class C roof assemblies. Class C roof assemblies are those that are effective against light fire-test exposure. Class C roof assemblies and roof coverings shall be *listed* and identified as Class C by an *approved* testing agency.

CS502.5 (IBC 1505.5) Nonclassified roofing. Nonclassified roofing is *approved* material that is not *listed* as a Class A, B or C roof covering.

CS502.6 (IBC 1505.8) Building-integrated photovoltaic products. *Building-integrated photovoltaic products* installed as the roof covering shall be tested, *listed* and *labeled* for fire classification in accordance with Section CS502.1 (IBC 1505.1).

CS502.7 (IBC 1505.9) Rooftop mounted photovoltaic panel systems. Rooftop rack-mounted *photovoltaic panel systems* shall be tested, *listed* and identified with a fire classi-

fication in accordance with UL 1703 and UL 2703. The fire classification shall comply with Table CS502.1 (IBC Table 1505.1) based on the type of construction of the building.

SECTION CS503 (IBC 1507)
REQUIREMENTS FOR ROOF COVERINGS

CS503.1 (IBC 1507.1) Scope. Roof coverings shall be applied in accordance with the applicable provisions of this section and the manufacturer's installation instructions.

CS503.1.1 (IBC 1507.1.1) Underlayment. Underlayment for asphalt shingles, clay and concrete tile, metal roof shingles, mineral-surfaced roll roofing, slate and slate-type shingles, wood shingles, wood shakes, metal roof panels and photovoltaic shingles shall conform to the applicable standards listed in [this chapter]. Underlayment materials required to comply with ASTM D226, D1970, D4869 and D6757 shall bear a label indicating compliance with the standard designation and, if applicable, type classification indicated in Table CS503.1.1(1) [IBC Table 1507.1.1(1)]. Underlayment shall be applied in accordance with Table CS506.1.1(2) [IBC Table 1507.1.1(2)]. Underlayment shall be attached in accordance with Table CS506.1.1(3) [IBC Table 1507.1.1(3)].

Exceptions:

1. As an alternative, self-adhering polymer modified bitumen underlayment complying with ASTM D1970 and installed in accordance with the manufacturer's installation instructions for the deck material, roof ventilation configuration and climate exposure for the roof covering to be installed shall be permitted.
2. As an alternative, a minimum 4-inch-wide (102 mm) strip of self-adhering polymer modified bitumen membrane complying with ASTM D1970 and installed in accordance with the manufacturer's installation instructions for the deck material shall be applied over all joints in the roof decking. An approved underlayment for the applicable roof covering for design wind speeds less than 120 mph (54 m/s) shall be applied over the 4-inch-wide (102 mm) membrane strips.
3. As an alternative, two layers of underlayment complying with ASTM D226 Type II or ASTM D4869 Type IV shall be permitted to be installed as follows: Apply a 19-inch (483 mm) strip of underlayment parallel with the eave. Starting at the eave, apply 36-inch-wide (914 mm) strips of underlayment felt, overlapping successive sheets 19 inches (483 mm). The underlayment shall be attached with corrosion-resistant fasteners in a grid pattern of 12 inches (305 mm) between side laps with a 6-inch (152 mm) spacing at side and end laps. End laps shall be 4 inches (102 mm) and shall be offset by 6 feet (1829 mm). Underlayment shall be attached using metal or plastic cap nails with a nominal cap diameter of not less than 1 inch (25.4 mm). Metal caps shall have a thickness of not less than 32-gage sheet metal. Power-driven metal

TABLE CS503.1.1(1) [IBC 1507.1.1(1)]
UNDERLAYMENT TYPES

ROOF COVERING	SECTION	MAXIMUM BASIC DESIGN WIND SPEED, V< 140 MPH	MAXIMUM BASIC DESIGN WIND SPEED, V ≥ 140 MPH
Asphalt shingles	1507.2	ASTM D226 Type I or II ASTM D4869 Type I, II, III or IV ASTM D6757	ASTM D226 Type II ASTM D4869 Type IV ASTM D6757
Clay and concrete tiles	1507.3	ASTM D226 Type II ASTM D2626 Type I ASTM D6380 Class M mineral surfaced roll roofing	ASTM D226 Type II ASTM D2626 Type I ASTM D6380 Class M mineral surfaced roll roofing
Metal panels	1507.4	Manufacturer's instructions	ASTM D226 Type II ASTM D4869 Type IV
Metal roof shingles	1507.5	ASTM D226 Type I or II ASTM D4869 Type I, II, III or IV	ASTM D226 Type II ASTM D4869 Type IV
Mineral-surfaced roll roofing	1507.6	ASTM D226 Type I or II ASTM D4869 Type I, II, III or IV	ASTM D226 Type II ASTM D4869 Type IV
Slate shingles	1507.7	ASTM D226 Type II ASTM D4869 Type III or IV	ASTM D226 Type II ASTM D4869 Type IV
Wood shingles	1507.8	ASTM D226 Type I or II ASTM D4869 Type I, II, III or IV	ASTM D226 Type II ASTM D4869 Type IV
Wood shakes	1507.9	ASTM D226 Type I or II ASTM D4869 Type I, II, III or IV	ASTM D226 Type II ASTM D4869 Type IV
Photovoltaic shingles	CS503.2 (IBC 1507.17)	ASTM D226 Type I or II ASTM D4869 Type I, II, III or IV ASTM D6757	ASTM D226 Type II ASTM D4869 Type IV ASTM D6757

caps shall have a thickness of not less than 0.010 inch (mm). Thickness of the outside edge of plastic caps shall be not less than 0.035 inch (mm). The cap nail shank shall be not less than 0.083 inch for ring shank cap nails and 0.091 inch (mm) for smooth shank cap nails. The cap nail shank shall have a length sufficient to penetrate through the roof sheathing or not less than $^3/_4$ inch (19.1 mm) into the roof sheathing.

4. Structural metal panels that do not require a substrate or underlayment.

TABLE CS503.1.1(2) [IBC 1507.1.1(2)]
UNDERLAYMENT APPLICATION

ROOF COVERING	SECTION	MAXIMUM BASIC DESIGN WIND SPEED, V < 140 MPH	MAXIMUM BASIC DESIGN WIND SPEED, $V \geq$ 140 MPH
Asphalt shingles	1507.2	For roof slopes from two units vertical in 12 units horizontal (2:12), up to four units vertical in 12 units horizontal (4:12), underlayment shall be two layers applied as follows: Apply a 19-inch strip of underlayment felt parallel to and starting at the eaves. Starting at the eave, apply 36-inch-wide sheets of underlayment, overlapping successive sheets 19 inches. End laps shall be 4 inches and shall be offset by 6 feet. Distortions in the underlayment shall not interfere with the ability of the shingles to seal. For roof slopes of four units vertical in 12 units horizontal (4:12) or greater, underlayment shall be one layer applied as follows: Underlayment shall be applied shingle fashion, parallel to and starting from the eave and lapped 2 inches, Distortions in the underlayment shall not interfere with the ability of the shingles to seal. End laps shall be 4 inches and shall be offset by 6 feet.	Same as Maximum Basic Design Wind Speed, V < 140 mph except all laps shall be not less than 4 inches
Clay and concrete tile	1507.3	For roof slopes from two and one-half units vertical in 12 units horizontal ($2^1/_2$:12), up to four units vertical in 12 units horizontal (4:12), underlayment shall be not fewer than two layers applied as follows: Starting at the eave, a 19-inch strip of underlayment shall be applied parallel with the eave. Starting at the eave, a 36-inch-wide strip of underlayment felt shall be applied, overlapping successive sheets 19 inches. End laps shall be 4 inches and shall be offset by 6 feet. For roof slopes of four units vertical in 12 units horizontal (4:12) or greater, underlayment shall be one layer applied as follows: Underlayment shall be applied shingle fashion, parallel to and starting from the eave and lapped 2 inches. End laps shall be 4 inches and shall be offset by 6 feet.	Same as Maximum Basic Design Wind Speed, V < 140 mph except all laps shall be not less than 4 inches
Metal roof panels	1507.4	Apply in accordance with the manufacturer's installation instructions	For roof slopes from two units vertical in 12 units horizontal (2:12), up to four units vertical in 12 units horizontal (4:12), underlayment shall be two layers applied as follows: Apply a 19-inch strip of underlayment felt parallel to and starting at the eaves. Starting at the eave, apply 36-inch-wide sheets of underlayment, overlapping successive sheets 19 inches. End laps shall be 4 inches and shall be offset by 6 feet. For roof slopes of four units vertical in 12 units horizontal (4:12) or greater, underlayment shall be one layer applied as follows: Underlayment shall be applied shingle fashion, parallel to and starting from the eave and lapped 4 inches. End laps shall be 4 inches and shall be offset by 6 feet.
Metal roof shingles	1507.5		
Mineral-surfaced roll roofing	1507.6		
Slate shingles	1507.7		
Wood shakes	1507.8		
Wood shingles	1507.9		
Photovoltaic shingles	CS503.2 (IBC 1507.17)	For roof slopes from three units vertical in 12 units horizontal (3:12), up to four units vertical in 12 units horizontal (4:12), underlayment shall be two layers applied as follows: Apply a 19-inch strip of underlayment felt parallel to and starting at the eaves. Starting at the eave, apply 36-inch-wide sheets of underlayment, overlapping successive sheets 19 inches. End laps shall be 4 inches and shall be offset by 6 feet. Distortions in the underlayment shall not interfere with the ability of the shingles to seal. For roof slopes of four units vertical in 12 units horizontal (4:12) or greater, underlayment shall be one layer applied as follows: Underlayment shall be applied shingle fashion, parallel to and starting from the eave and lapped 2 inches. Distortions in the underlayment shall not interfere with the ability of the shingles to seal. End laps shall be 4 inches and shall be offset by 6 feet.	Same as Maximum Basic Design Wind Speed, V < 140 mph except all laps shall be not less than 4 inches

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm; 1 mile per hour = 0.447 m/s.

TABLE CS503.1.1(3) [IBC 1507.1.1(3)]
UNDERLAYMENT ATTACHMENT

ROOF COVERING	SECTION	MAXIMUM BASIC DESIGN WIND SPEED, V < 140 MPH	MAXIMUM BASIC DESIGN WIND SPEED, $V \geq$ 140 MPH
Asphalt shingles	1507.2	Fastened sufficiently to hold in place	The underlayment shall be attached with corrosion-resistant fasteners in a grid pattern of 12 inches between side laps with a 6-inch spacing at side and end laps. Underlayment shall be attached using metal or plastic cap nails or cap staples with a nominal cap diameter of not less than 1 inch. Metal caps shall have a thickness of not less than 32-gage (0.0134 inch) sheet metal. Power-driven metal caps shall have a minimum thickness of 0.010 inch. Minimum thickness of the outside edge of plastic caps shall be 0.035 inch. The cap nail shank shall be not less than 0.083 inch for ring shank cap nails and 0.091 inch for smooth shank cap nails. Staples shall be not less than 21 gage (0.032 inch). The cap nail shank and cap staple legs shall have a length sufficient to penetrate through the roof sheathing or not less than $^3/_4$ inch into the roof sheathing.
Clay and concrete tile	1507.3		
Photovoltaic shingles	CS503.2 (IBC 1507.17)		
Metal roof panels	1507.4	Manufacturer's installation instructions	The underlayment shall be attached with corrosion-resistant fasteners in a grid pattern of 12 inches between side laps with a 6-inch spacing at side and end laps. Underlayment shall be attached using metal or plastic cap nails or cap staples with a nominal cap diameter of not less than 1 inch. Metal caps shall have a thickness of not less than 32-gage sheet metal. Power-driven metal caps shall have a minimum thickness of 0.010 inch. Minimum thickness of the outside edge of plastic caps shall be 0.035 inch. The cap nail shank shall be not less than 0.083 inch for ring shank cap nails and 0.091 inch for smooth shank cap nails. Staples shall be not less than 21 gage. The cap nail shank and cap staple legs shall have a length sufficient to penetrate through the roof sheathing or not less than $^3/_4$ inch into the roof sheathing.
Metal roof shingles	1507.5		
Mineral-surfaced roll roofing	1507.6		
Slate shingles	1507.7		
Wood shingles	1507.8		
Wood shakes	1507.9		

For SI: 1 inch = 25.4 mm; 1 mile per hour = 0.447 m/s.

CS503.2 (IBC 1507.17) Photovoltaic shingles. The installation of *photovoltaic shingles* shall comply with the provisions of this section.

CS503.2.1 (IBC 1507.17.1) Deck requirements. *Photovoltaic shingles* shall be applied to a solid or closely fitted deck, except where the shingles are specifically designed to be applied over spaced sheathing.

CS503.2.2 (IBC 1507.17.2) Deck slope. *Photovoltaic shingles* shall be installed on roof slopes of not less than two units vertical in 12 units horizontal (2:12).

CS503.2.3 (IBC 1507.17.3) Underlayment. Underlayment shall comply with Section CS503.1.1 (IBC 1507.1.1).

CS503.2.4 (IBC 1507.17.4) Ice barrier. Where required, ice barriers shall comply with Section CS503.1.1 (IBC 1507.1.1).

CS503.2.5 (IBC 1507.17.5) Fasteners. Fasteners for *photovoltaic shingles* shall be galvanized, stainless steel, aluminum or copper roofing nails, minimum 12-gage [0.105 inch (2.67 mm)] shank with a minimum $^3/_8$-inch-diameter (9.5 mm) head, of a length to penetrate through the roofing materials and a minimum of $^3/_4$ inch (19.1 mm) into the roof sheathing. Where the roof sheathing is less than $^3/_4$ inch (19.1 mm) thick, the nails shall penetrate through the sheathing. Fasteners shall comply with ASTM F1667.

CS503.2.6 (IBC 1507.17.6) Material standards. *Photovoltaic shingles* shall be *listed* and labeled in accordance with UL 1703.

CS503.2.7 (IBC 1507.17.7) Attachment. *Photovoltaic shingles* shall be attached in accordance with the manufacturer's installation instructions.

CS503.2.8 (IBC 1507.17.8) Wind resistance. *Photovoltaic shingles* shall be tested in accordance with procedures and acceptance criteria in ASTM D3161. *Photovoltaic shingles* shall comply with the classification requirements of Table (IBC 1504.1.1) for the appropriate maximum nominal design wind speed. *Photovoltaic shingle* packaging shall bear a *label* to indicate compliance with the procedures in ASTM D3161 and the required classification from Table (IBC 1504.1.1).

CS503.3 (IBC 1507.18) Building-integrated photovoltaic roof panels. The installation of building-integrated photovoltaic (BIPV) roof panels shall comply with the provisions of this section.

CS503.3.1 (IBC 1507.18.1) Deck requirements. BIPV roof panels shall be applied to a solid or closely fitted deck, except where the roof covering is specifically designed to be applied over spaced sheathing.

CS503.3.2 (IBC 1507.18.2) Deck slope. BIPV roof panels shall be used only on roof slopes of two units vertical in 12 units (2:12) or greater.

CS503.3.3 (IBC 1507.18.3) Underlayment. Underlayment shall comply with ASTM D226, ASTM D4869 or ASTM D6757.

CS503.3.4 (IBC 1507.18.4) Underlayment application. Underlayment shall be applied shingle fashion, parallel to and starting from the eave, lapped 2 inches (51 mm) and fastened sufficiently to hold in place.

CS503.3.4.1 (IBC 1507.18.4.1) High-wind attachment. Underlayment applied in areas subject to high winds [V_{asd} greater than 110 mph (49 m/s) as determined in accordance with Section (IBC 1609.3.1)] shall be applied in accordance with the manufacturer's instructions. Fasteners shall be applied along the overlap at not more than 36 inches (914 mm) on center. Underlayment installed where V_{asd} is not less than 120 mph (54 m/s) shall comply with ASTM D226, Type III, ASTM D4869, Type IV or ASTM D6757. The underlayment shall be attached in a grid pattern of 12 inches (305 mm) between side laps with a 6-inch (152 mm) spacing at the side laps. The underlayment shall be applied in accordance with Section (IBC 1507.2.8) except all laps shall be not less than 4 inches (102 mm). Underlayment shall be attached using cap nails or cap staples. Caps shall be metal or plastic with a nominal head diameter of not less than 1 inch (25.4 mm). Metal caps shall have a thickness of not less than 0.010 inch (0.25 mm). Power-driven metal caps shall have a thickness of not less than 0.010 inch (0.25 mm). Thickness of the outside edge of plastic caps shall be not less than 0.035 inch (0.89 mm). The cap nail shank shall be not less than 0.083 inch (2.11 mm) for ring shank cap nails and 0.091 inch (2.31 mm) for smooth shank cap nails. Staple gage shall be not less than 21 gage [0.0.2 inch (0.81 mm)]. Cap nail shank and cap staple legs shall have a length sufficient to penetrate through-the-roof sheathing or not less than $^3/_4$ inch (19.1 mm) into the roof sheathing.

Exception: As an alternative, adhered underlayment complying with ASTM D1970 shall be permitted.

CS503.3.4.2 (IBC 1507.18.4.2) Ice barrier. In areas where there has been a history of ice forming along the eaves causing a back-up of water, an ice barrier consisting of not fewer than two layers of underlayment cemented together or of a self-adhering polymer/modified bitumen sheet shall be used instead of normal underlayment and extend from the lowest edges of all roof surfaces to a point not less than 24 inches (610 mm) inside the exterior wall line of the building.

Exception: Detached accessory structures that do not contain conditioned floor area.

CS503.3.5 (IBC 1507.18.5) Material standards. BIPV roof panels shall be listed and labeled in accordance with UL 1703.

CS503.3.6 (IBC 1507.18.6) Attachment. BIPV roof panels shall be attached in accordance with the manufacturer's installation instructions.

CS503.3.7 (IBC 1507.18.7) Wind resistance. BIPV roof panels shall be tested in accordance with UL 1897. BIPV roof panel packaging shall bear a label to indicate compliance with UL 1897.

SECTION CS504 (IBC 1510) ROOFTOP STRUCTURES

CS504.1 (IBC 1510.1) General. The provisions of this section shall govern the construction of rooftop structures.

CS504.2 (IBC 1510.7) Photovoltaic panels and modules. Rooftop-mounted *photovoltaic panels* and *modules* shall be designed in accordance with this section.

CS504.2.1 (IBC 1510.7.2) Fire classification. Rooftop-mounted *photovoltaic panels* and *modules* shall have the fire classification in accordance with Section CS502.7 (IBC 1505.9).

CS504.2.2 (IBC 1510.7.4) Photovoltaic panels and modules. Rooftop-mounted *photovoltaic panels* and *modules* shall be *listed* and labeled in accordance with UL 1703 and shall be installed in accordance with the manufacturer's instructions.

SECTION CS505 (IBC 1512) PHOTOVOLTAIC PANELS AND MODULES

CS505.1 (IBC 1512.1) Photovoltaic panels and modules. *Photovoltaic panels* and *modules* installed upon a roof or as an integral part of a roof assembly shall comply with the requirements of [this code] and the *International Fire Code*.

SECTION CS506 (IBC 1603) CONSTRUCTION DOCUMENTS

CS506.1 (IBC 1603.1) General. *Construction documents* shall show the size, section and relative locations of structural members with floor levels, column centers and offsets dimensioned. The design loads and other information pertinent to the structural design required by Sections (IBC 1603.1.1) through (IBC 1603.1.9) shall be indicated on the *construction documents*.

CS506.1.1 (IBC 1603.1.8) Special loads. Special loads that are applicable to the design of the building, structure or portions thereof, including but not limited to the loads of machinery or equipment, and that are greater than specified floor and roof loads shall be specified by their descriptions and locations.

CS506.1.1.1 (IBC 1603.1.8.1) Photovoltaic panel systems. The dead load of rooftop-mounted *photovoltaic panel systems*, including rack support systems, shall be indicated on the construction documents.

SECTION CS507 (IBC 1607) LIVE LOADS

CS507.1 (IBC 1607.1) General. Live loads are those loads defined in (IBC) Chapter 2 of [this code].

CS507.1.1 (IBC 1607.13.5) Photovoltaic panel systems. Roof structures that provide support for *photovoltaic panel*

systems shall be designed in accordance with Sections CS507.1.1.1 (IBC 1607.13.5.1) through CS507.1.1.4 (IBC 1607.13.5.4), as applicable.

CS507.1.1.1 (IBC 1607.13.5.1) Roof live load. Roof structures that support photovoltaic panel systems shall be designed to resist each of the following conditions:

1. Applicable uniform and concentrated roof loads with the photovoltaic panel system dead loads.

   Exception: Roof live loads need not be applied to the area covered by the photovoltaic panels where the clear space between the panels and the roof surface is 24 inches (610 mm) or less.

2. Applicable uniform and concentrated roof loads without the photovoltaic panel system present.

CS507.1.1.2 (IBC 1607.13.5.2) Photovoltaic panels or modules. The structure of a roof that supports solar photovoltaic panels or modules shall be designed to accommodate the full solar photovoltaic panels or modules and ballast dead load, including concentrated loads from support frames in combination with the loads from Section CS507.1.1.1 (IBC 1607.13.5.1) and other applicable loads. Where applicable, snow drift loads created by the photovoltaic panels or modules shall be included.

CS507.1.1.2.1 (IBC 1607.13.5.2.1) Photovoltaic panels installed on open grid roof structures. Structures with open grid framing and without a roof deck or sheathing supporting photovoltaic panel systems shall be designed to support the uniform and concentrated roof live loads specified in Section CS507.1.1.1 (IBC 1607.13.5.1), except that the uniform roof live load shall be permitted to be reduced to 12 psf (0.57 kN/m^2).

CS507.1.1.3 (IBC 1607.13.5.3) Photovoltaic panels or modules installed as an independent structure. Solar photovoltaic panels or modules that are independent structures and do not have accessible/occupied space underneath are not required to accommodate a roof photovoltaic live load, provided the area under the structure is restricted to keep the public away. All other loads and combinations in accordance with Section (IBC 1605) shall be accommodated.

Solar photovoltaic panels or modules that are designed to be the roof, span to structural supports and have accessible/occupied space underneath shall have the panels or modules and all supporting structures designed to support a roof photovoltaic live load, as defined in Section CS507.1.1.1 (IBC 1607.13.5.1) in combination with other applicable loads. Solar photovoltaic panels or modules in this application are not permitted to be classified as "not accessible" in accordance with Section CS507.1.1.1 (IBC 1607.13.5.1).

CS507.1.1.4 (IBC 1607.13.5.4) Ballasted photovoltaic panel systems. Roof structures that provide support for ballasted *photovoltaic panel systems* shall be designed, or analyzed, in accordance with Section (IBC 1604.4); checked in accordance with Section (IBC 1604.3.6) for deflections; and checked in accordance with Section (IBC 1611) for ponding.

SECTION CS508 (IBC 1613) EARTHQUAKE LOADS

CS508.1 (IBC 1613.1) Scope. Every structure, and portion thereof, including nonstructural components that are permanently attached to structures and their supports and attachments, shall be designed and constructed to resist the effects of earthquake motions in accordance with Chapters 11, 12, 13, 15, 17 and 18 of ASCE 7, as applicable. The *seismic design category* for a structure is permitted to be determined in accordance with Section CS508 (IBC 1613) or ASCE 7.

CS508.2 (IBC 1613.3) Ballasted photovoltaic panel systems. Ballasted, roof-mounted *photovoltaic panel systems* need not be rigidly attached to the roof or supporting structure. Ballasted nonpenetrating systems shall be designed and installed only on roofs with slopes not more than one unit vertical in 12 units horizontal. Ballasted nonpenetrating systems shall be designed to resist sliding and uplift resulting from lateral and vertical forces as required by Section (IBC 1605), using a coefficient of friction determined by acceptable engineering principles. In structures assigned to *Seismic Design Category* C, D, E or F, ballasted nonpenetrating systems shall be designed to accommodate seismic displacement determined by nonlinear response-history analysis or other approved analysis or shake-table testing, using input motions consistent with ASCE 7 lateral and vertical seismic forces for nonstructural components on roofs.

SECTION CS509 (IBC Chapter 31) SPECIAL CONSTRUCTION

CS509.1 (IBC 3101.1) Scope. The provisions of [this chapter] shall govern special building construction including membrane structures, temporary structures, *pedestrian walkways* and tunnels, automatic *vehicular gates*, *awnings* and *canopies*, *marquees*, signs, towers, antennas, relocatable buildings, swimming pool enclosures and safety devices, and solar energy systems.

SECTION CS510 (IBC 3111) SOLAR ENERGY SYSTEMS

CS510.1 (IBC 3111.1) General. Solar energy systems shall comply with the requirements of [this section].

CS510.1.1 (IBC 3111.1.1) Wind resistance. Rooftop-mounted photovoltaic panels and modules and solar thermal collectors shall be designed in accordance with Section (IBC 1609).

CS510.1.2 (IBC 3111.1.2) Roof live load. Roof structures that provide support for solar energy systems shall be

designed in accordance with Section CS507.1.1 (IBC 1607.13.5).

CS510.2 (IBC 3111.2) Solar thermal systems. Solar thermal systems shall be designed and installed in accordance with Section CS311.2 (IBC 2606.12), the *International Plumbing Code*, the *International Mechanical Code* and the *International Fire Code*.

CS510.2.1 (IBC 3111.2.1) Equipment. Solar thermal systems and components shall be *listed* and *labeled* in accordance with ICC 900/SRCC 300 and ICC 901/SRCC 100.

CS510.3 (IBC 3111.3) Photovoltaic solar energy systems. Photovoltaic solar energy systems shall be designed and installed in accordance with this section, the *International Fire Code*, NFPA 70 and the manufacturer's installation instructions.

CS510.3.1 (IBC 3111.3.1) Equipment. Photovoltaic panels and modules shall be *listed* and *labeled* in accordance with UL 1703. Inverters shall be *listed* and *labeled* in accordance with UL 1741. Systems connected to the utility grid shall use inverters *listed* for utility interaction.

CS510.3.2 (IBC 3111.3.2) Fire classification. Rooftop-mounted photovoltaic systems shall have a fire classification in accordance with Section CS502.7 (IBC 1505.9). Building-integrated photovoltaic systems shall have a fire classification in accordance with Section CS502.6 (IBC 1505.8).

CS510.3.3 (IBC 3111.3.3) Building-integrated photovoltaic systems. Building-integrated photovoltaic systems that serve as roof coverings shall be designed and installed in accordance with Section CS503.3 (IBC 1507.18).

CS510.3.4 (IBC 3111.3.4) Access and pathways. Roof access, pathways and spacing requirements shall be provided in accordance with Section CS512 (IFC 1204) of the *International Fire Code*.

CS510.3.5 (IBC 3111.3.5) Ground-mounted photovoltaic systems. Ground-mounted photovoltaic systems shall be designed and installed in accordance with (IBC) Chapter 16 and the *International Fire Code.*

CS510.3.5.1 (IBC 3111.3.5.1) Fire separation distances. Ground-mounted photovoltaic systems shall be subject to the fire separation distance requirements determined by the local jurisdiction.

SECTION CS511 (IFC 503)
FIRE APPARATUS ACCESS ROADS

CS511.1 (IFC 503.1) Where required. Fire apparatus access roads shall be provided and maintained in accordance with Sections CS511.1.1 (IFC 503.1.1) through (IFC 503.1.3).

CS511.1.1 (IFC 503.1.1) Buildings and facilities. *Approved* fire apparatus access roads shall be provided for every facility, building or portion of a building hereafter constructed or moved into or within the jurisdiction. The fire apparatus access road shall comply with the requirements of this section and shall extend to within 150 feet (45 720 mm) of all portions of the facility and all portions of the *exterior walls* of the first story of the building as measured by an *approved* route around the exterior of the building or facility.

Exceptions:

1. The *fire code official* is authorized to increase the dimension of 150 feet (45 720 mm) where any of the following conditions occur:
   1.1. The building is equipped throughout with an *approved automatic sprinkler system* installed in accordance with Section (IFC 903.3.1.1, IFC 903.3.1.2 or IFC 903.3.1.3).
   1.2. Fire apparatus access roads cannot be installed because of location on property, topography, waterways, nonnegotiable grades or other similar conditions, and an *approved* alternative means of fire protection is provided.
   1.3. There are not more than two Group R-3 or Group U occupancies.
2. Where approved by the *fire code official*, fire apparatus access roads shall be permitted to be exempted or modified for solar photovoltaic power generation facilities.

SECTION CS512 (IFC 1204)
SOLAR PHOTOVOLTAIC POWER SYSTEMS

CS512.1 (IFC 1204.1) General. Solar photovoltaic systems shall be installed in accordance with Sections CS512.2 (IFC 1204.2) through CS512.5 (IFC 1204.5), and the *International Building Code* or *International Residential Code*. The electrical portion of solar PV systems shall be installed in accordance with NFPA 70.

CS512.2 (IFC 1204.2) Access and pathways. Roof access, pathways, and spacing requirements shall be provided in accordance with Sections CS512.2.1 (IFC 1204.2.1) through CS512.3.3 (IFC 1204.3.3). Pathways shall be over areas capable of supporting fire fighters accessing the roof. Pathways shall be located in areas with minimal obstructions, such as vent pipes, conduit or mechanical equipment.

Exceptions:

1. Detached, nonhabitable Group U structures including, but not limited to, detached garages serving Group R-3 buildings, parking shade structures, carports, solar trellises and similar structures.
2. Roof access, pathways and spacing requirements need not be provided where the *fire code official* has determined that rooftop operations will not be employed.

CS512.2.1 (IFC 1204.2.1) Solar photovoltaic systems for Group R-3 buildings. Solar photovoltaic systems for Group R-3 buildings shall comply with Sections

CS512.2.1.1 (IFC 1204.2.1.1) through CS512.2.1.3 (IFC 1204.2.1.3).

Exceptions:

1. These requirements shall not apply to structures designed and constructed in accordance with the *International Residential Code*.
2. These requirements shall not apply to roofs with slopes of 2 units vertical in 12 units horizontal or less.

CS512.2.1.1 (IFC 1204.2.1.1) Pathways to ridge. Not fewer than two 36-inch-wide (914 mm) pathways on separate roof planes, from lowest roof edge to ridge, shall be provided on all buildings. Not fewer than one pathway shall be provided on the street or driveway side of the roof. For each roof plane with a photovoltaic array, not fewer than one 36-inch-wide (914 mm) pathway from lowest roof edge to ridge shall be provided on the same roof plane as the photovoltaic array, on an adjacent roof plane or straddling the same and adjacent roof planes.

CS512.2.1.2 (IFC 1204.2.1.2) Setbacks at ridge. For photovoltaic arrays occupying 33 percent or less of the plan view total roof area, a setback of not less than 18 inches (457 mm) wide is required on both sides of a horizontal ridge. For photovoltaic arrays occupying more than 33 percent of the plan view total roof area, a setback of not less than 36 inches (457 mm) wide is required on both sides of a horizontal ridge.

CS512.2.1.3 (IFC 1204.2.1.3) Alternative setbacks at ridge. Where an automatic sprinkler system is installed within the dwelling in accordance with Section (IFC 903.3.1.3), setbacks at the ridge shall conform to one of the following:

1. For photovoltaic arrays occupying 66 percent or less of the plan view total roof area, a setback of not less than 18 inches (457 mm) wide is required on both sides of a horizontal ridge.
2. For photovoltaic arrays occupying more than 66 percent of the plan view total roof area, a setback of not less than 36 inches (914 mm) wide is required on both sides of a horizontal ridge.

CS512.2.2 (IFC 1204.2.2) Emergency escape and rescue openings. Panels and modules installed on Group R-3 buildings shall not be placed on the portion of a roof that is below an emergency escape and rescue opening. A pathway of not less than 36 inches (914 mm) wide shall be provided to the emergency escape and rescue opening.

CS512.3 (IFC 1204.3) Other than Group R-3 buildings. Access to systems for buildings, other than those containing Group R-3 occupancies, shall be provided in accordance with Sections CS512.3.1 (IFC 1204.3.1) through CS512.3.3 (IFC 1204.3.3).

Exception: Where it is determined by the *fire code official* that the roof configuration is similar to that of a Group R-3 occupancy, the residential access and ventilation requirements in Sections CS512.2.1.1 (IFC 1204.2.1.1) through CS512.2.1.3 (IFC 1204.2.1.3) are a suitable alternative.

CS512.3.1 (IFC 1204.3.1) Perimeter pathways. There shall be a minimum 6-foot-wide (1829 mm) clear perimeter around the edges of the roof.

Exception: Where either axis of the building is 250 feet (76 200 mm) or less, the clear perimeter around the edges of the roof shall be permitted to be reduced to a minimum width of 4 feet (1219 mm).

CS512.3.2 (IFC 1204.3.2) Interior pathways. Interior pathways shall be provided between array sections to meet the following requirements:

1. Pathways shall be provided at intervals not greater than 150 feet (45 720 mm) throughout the length and width of the roof.
2. A pathway not less than 4 feet (1219 mm) wide in a straight line to roof standpipes or ventilation hatches.
3. A pathway not less than 4 feet (1219 mm) wide around roof access hatches, with not fewer than one such pathway to a parapet or roof edge.

CS512.3.3 (IFC 1204.3.3) Smoke ventilation. The solar installation shall be designed to meet the following requirements:

1. Where nongravity-operated smoke and heat vents occur, a pathway not less than 4 feet (1219 mm) wide shall be provided bordering all sides.
2. Smoke ventilation options between array sections shall be one of the following:
   - 2.1. A pathway not less than 8 feet (2438 mm) wide.
   - 2.2. Where gravity-operated dropout smoke and heat vents occur, a pathway not less than 4 feet (1219 mm) wide on not fewer than one side.
   - 2.3. A pathway not less than 4 feet (1219 mm) wide bordering 4-foot by 8-foot (1219 mm by 2438 mm) venting cutouts every 20 feet (6096 mm) on alternating sides of the pathway.

CS512.4 (IFC 1204.4) Ground-mounted photovoltaic panel systems. Ground-mounted photovoltaic panel systems shall comply with Section CS512.1 (IFC 1204.1) and this section. Setback requirements shall not apply to ground-mounted, free-standing photovoltaic arrays. A clear, brush-free area of 10 feet (3048 mm) shall be required for ground-mounted photovoltaic arrays.

CS512.5 (IFC 1204.5) Buildings with rapid shutdown. Buildings with rapid shutdown solar photovoltaic systems shall have permanent labels in accordance with Sections CS512.5.1 (IFC 1204.5.1) through CS512.5.3 (IFC 1204.5.3).

CS512.5.1 (IFC 1204.5.1) Rapid shutdown type. The type of solar photovoltaic system rapid shutdown shall be labeled with one of the following:

1. For solar photovoltaic systems that shut down the array and the conductors leaving the array, a label shall be provided. The first two lines of the label shall be uppercase characters with a minimum height of $^{3}/_{8}$ inch (10 mm) in black on a yellow

background. The remaining characters shall be uppercase with a minimum height of $^3/_{16}$ inch (5 mm) in black on a white background. The label shall be in accordance with Figure CS512.5.1(1) [IFC Figure 1204.5.1(1)] and state the following:

SOLAR PV SYSTEM EQUIPPED WITH RAPID SHUTDOWN. TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUT DOWN PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY.

2. For photovoltaic systems that only shut down conductors leaving the array, a label shall be provided. The first two lines of the label shall be uppercase characters with a minimum height of $^3/_8$ inch (10 mm) in white on a red background and the remaining characters shall be capitalized with a minimum height of $^3/_{16}$ inch (5 mm) in black on a white background. The label shall be in accordance with Figure CS512.5.1(2) [IFC Figure 1204.5.1(2)] and state the following:

THIS SOLAR PV SYSTEM EQUIPPED WITH RAPID SHUTDOWN. TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUT DOWN CONDUCTORS OUTSIDE THE ARRAY. CONDUCTORS WITHIN ARRAY REMAIN ENERGIZED IN SUNLIGHT.

CS512.5.1.1 (IFC 1204.5.1.1) Diagram. The labels in Section CS512.5.1 (IFC 1204.5.1) shall include a simple diagram of a building with a roof. Diagram sections in red signify sections of the solar photovoltaic system that are not shut down when the rapid shutdown switch is turned off.

CS512.5.1.2 (IFC 1204.5.1.2) Location. The rapid shutdown label in Section CS512.5.1 (IFC 1204.5.1) shall be located not greater than 3 feet (914 mm) from the service disconnecting means to which the photovoltaic systems are connected, and shall indicate the location of all identified rapid shutdown switches if not at the same location.

CS512.5.2 (IFC 1204.5.2) Buildings with more than one rapid shutdown type. Solar photovoltaic systems that contain rapid shutdown in accordance with both Items 1 and 2 of Section CS512.5.1 (IFC 1204.5.1) or solar photovoltaic systems where only portions of the systems on the building contain rapid shutdown, shall provide a detailed plan view diagram of the roof showing each different photovoltaic system and a dotted line around areas that remain energized after the rapid shutdown switch is operated.

CS512.5.3 (IFC 1204.5.3) Rapid shutdown switch. A rapid shutdown switch shall have a label located not greater than 3 feet (914 mm) from the switch that states the following:

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

SECTION CS513 (IFC 1206) ELECTRICAL ENERGY STORAGE SYSTEMS

CS513.1 (IFC 1206.1) Scope. The provisions in this section are applicable to energy storage systems designed to provide electrical power to a building or facility. These systems are used to provide standby or emergency power, an uninterruptable power supply, load shedding, load sharing or similar capabilities.

CS513.2 (IFC 1206.2) Stationary storage battery systems. Stationary storage battery systems having capacities exceeding the values shown in Table CS513.2 (IFC Table 1206.2)

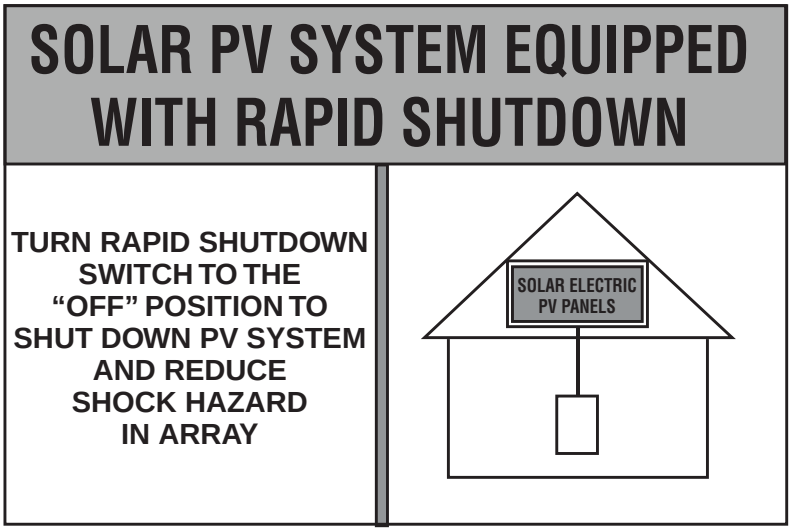

FIGURE CS512.5.1(1) [IFC 1204.5.1(1)]
LABEL FOR SOLAR PV SYSTEMS THAT REDUCE SHOCK HAZARD WITHIN ARRAY AND SHUT DOWN CONDUCTORS LEAVING ARRAY

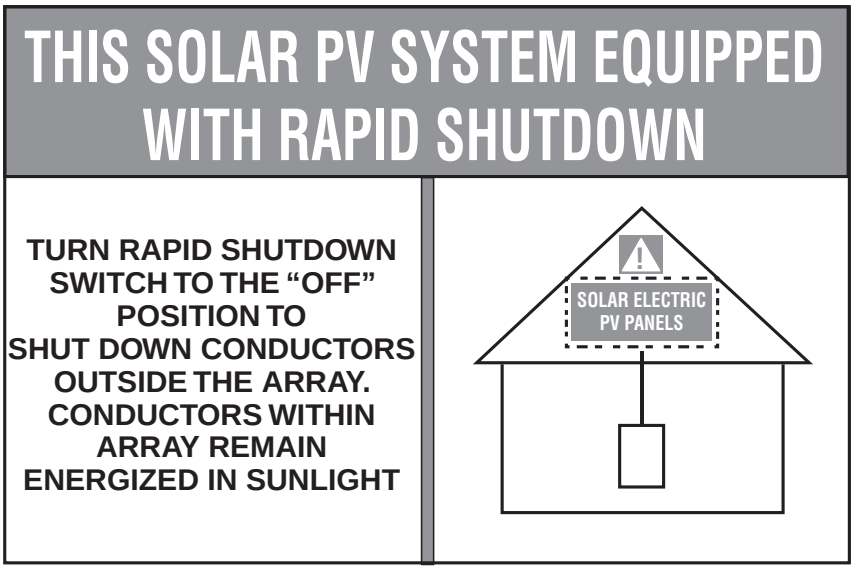

FIGURE CS512.5.1(2) [IFC 1204.5.1(2)]
LABEL FOR SOLAR PV SYSTEMS THAT ONLY SHUT DOWN CONDUCTORS LEAVING THE ARRAY

shall comply with Sections CS513.2.1 (IFC 1206.2.1) through CS513.2.12.6 (IFC 1206.2.12.6), as applicable.

CS513.2.1 (IFC 1206.2.1) Permits. Permits shall be obtained for the installation and operation of stationary storage battery systems in accordance with Section (IFC 105.7.2).

CS513.2.2 (IFC 1206.2.2) Construction documents. The following information shall be provided with the permit application:

1. Location and layout diagram of the room in which the stationary storage battery system is to be installed.
2. Details on hourly fire-resistance-rated assemblies provided.
3. Quantities and types of storage batteries and battery systems.
4. Manufacturer's specifications, ratings and listings of storage batteries and battery systems.
5. Details on energy management systems.
6. Location and content of signage.
7. Details on fire-extinguishing, smoke detection and ventilation systems.
8. Rack storage arrangement, including seismic support criteria.

CS513.2.3 (IFC 1206.2.3) Hazard mitigation analysis. A failure modes and effects analysis (FMEA) or other approved hazard mitigation analysis shall be provided in accordance with Section (IFC 104.7.2) under any of the following conditions:

1. Battery technologies not specifically identified in Table CS513.2 (IFC Table 1206.2) are provided.
2. More than one stationary storage battery technology is provided in a room or indoor area where there is a potential for adverse interaction between technologies.
3. Where allowed as a basis for increasing maximum allowable quantities in accordance with Section CS513.2.9 (IFC 1206.2.9).

CS513.2.3.1 (IFC 1206.2.3.1) Fault condition. The hazard mitigation analysis shall evaluate the consequences of the following failure modes, and others deemed necessary by the *fire code official*. Only single-failure modes shall be considered.

1. Thermal runaway condition in a single-battery storage rack, module or array.
2. Failure of any energy management system.
3. Failure of any required ventilation system.
4. Voltage surges on the primary electric supply.
5. Short circuits on the load side of the stationary battery storage system.
6. Failure of the smoke detection, fire-extinguishing or gas detection system.
7. Spill neutralization not being provided or failure of the secondary containment system.

CS513.2.3.2 (IFC 1206.2.3.2) Analysis approval. The *fire code official* is authorized to approve the hazardous mitigation analysis provided that the hazard mitigation analysis demonstrates all of the following:

1. Fires or explosions will be contained within unoccupied battery storage rooms for the minimum duration of the fire-resistance-rated walls identified in Table 509.1 of the *International Building Code*.
2. Fires and explosions in battery cabinets in occupied work centers will be detected in time to allow occupants within the room to evacuate safely.

3. Toxic and highly toxic gases released during fires and other fault conditions shall not reach concentrations in excess of Immediately Dangerous to Life or Health (IDLH) levels in the building or adjacent means of egress routes during the time deemed necessary to evacuate from that area.
4. Flammable gases released from batteries during charging, discharging and normal operation shall not exceed 25 percent of their lower flammability limit (LFL).
5. Flammable gases released from batteries during fire, overcharging and other abnormal conditions shall not create an explosion hazard that will injure occupants or emergency responders.

CS513.2.3.3 (IFC 1206.2.3.3) Additional protection measures. Construction, equipment and systems that are required for the stationary storage battery system to comply with the hazardous mitigation analysis, including but not limited to those specifically described in Section CS513.2 (IFC 1206.2), shall be installed, maintained and tested in accordance with nationally recognized standards and specified design parameters.

CS513.2.4 (IFC 1206.2.4) Seismic and structural design. Stationary storage battery systems shall comply with the seismic design requirements in Chapter 16 of the *International Building Code*, and shall not exceed the floor-loading limitation of the building.

CS513.2.5 (IFC 1206.2.5) Vehicle impact protection. Where stationary storage battery systems are subject to impact by a motor vehicle, including fork lifts, vehicle impact protection shall be provided in accordance with Section (IFC 312).

CS513.2.6 (IFC 1206.2.6) Combustible storage. Combustible materials not related to the stationary storage battery system shall not be stored in battery rooms, cabinets or enclosures. Combustible materials in occupied work centers covered by Section CS513.2.8.5 (IFC 1206.2.8.5) shall not be stored less than 3 feet (915 mm) from battery cabinets.

CS513.2.7 (IFC 1206.2.7) Testing, maintenance and repair. Storage batteries and associated equipment and systems shall be tested and maintained in accordance with the manufacturer's instructions. Any storage batteries or system components used to replace existing units shall be compatible with the battery charger, energy management systems, other storage batteries and other safety systems. Introducing other types of storage batteries into the stationary storage battery system or other types of electrolytes into flow battery systems shall be treated as a new installation and require approval by the *fire code official* before the replacements are introduced into service.

CS513.2.8 (IFC 1206.2.8) Location and construction. Rooms and areas containing stationary storage battery systems shall be designed, located and constructed in accordance with Sections CS513.2.8.1 (IFC 1206.2.8.1) through CS513.2.8.7.4 (IFC 1206.2.8.7.4).

CS513.2.8.1 (IFC 1206.2.8.1) Location. Stationary storage battery systems shall not be located in areas where the floor is located more than 75 feet (22 860 mm) above the lowest level of fire department vehicle access, or where the floor level is more than 30 feet (9144 mm) below the finished floor of the lowest level of exit discharge.

Exceptions:

1. Lead acid and nickel cadmium stationary storage battery systems.
2. Installations on noncombustible rooftops of buildings exceeding 75 feet (22 860 mm) in height that do not obstruct fire department rooftop operations, where *approved* by the *fire code official*.

CS513.2.8.2 (IFC 1206.2.8.2) Separation. Rooms containing stationary storage battery systems shall be separated from other areas of the building in accordance with Section 509.1 of the *International Building Code*. Battery systems shall be allowed to be in the same room with the equipment they support.

CS513.2.8.3 (IFC 1206.2.8.3) Stationary battery arrays. Storage batteries, prepackaged stationary storage battery systems and preengineered stationary storage battery systems shall be segregated into stationary battery arrays not exceeding 50 kWh (180 megajoules) each. Each stationary battery array shall be spaced not less than 3 feet (914 mm) from other stationary battery arrays and from walls in the storage room or area. The

TABLE CS513.2 (IFC 1206.2)
BATTERY STORAGE SYSTEM THRESHOLD QUANTITIES.

BATTERY TECHNOLOGY	CAPACITY[a]
Flow batteries[b]	20 kWh
Lead acid, all types	70 kWh
Lithium, all types	20 kWh
Nickel cadmium (Ni-Cd)	70 kWh
Sodium, all types	20 kWh[c]
Other battery technologies	10 kWh

For SI: 1 kilowatt hour = 3.6 megajoules.

a. For batteries rated in amp-hours, kWh shall equal rated voltage times amp-hour rating divided by 1000.

b. Shall include vanadium, zinc-bromine, polysulfide-bromide, and other flowing electrolyte-type technologies.

c. 70 kWh for sodium-ion technologies.

storage arrangements shall comply with (IFC) Chapter 10.

Exceptions:

1. Lead acid and nickel cadmium storage battery arrays.
2. Listed preengineered stationary storage battery systems and prepackaged stationary storage battery systems shall not exceed 250 kWh (900 megajoules) each.
3. The fire code official is authorized to approve listed, preengineered and prepackaged battery arrays with larger capacities or smaller battery array spacing if large-scale fire and fault condition testing conducted or witnessed and reported by an approved testing laboratory is provided showing that a fire involving one array will not propagate to an adjacent array, and be contained within the room for a duration equal to the fire-resistance rating of the room separation specified in Table 509 of the *International Building Code*.

CS513.2.8.4 (IFC 1206.2.8.4) Separate rooms. Where stationary batteries are installed in a separate equipment room that can be accessed only by authorized personnel, they shall be permitted to be installed on an open rack for ease of maintenance.

CS513.2.8.5 (IFC 1206.2.8.5) Occupied work centers. Where stationary storage batteries are located in an occupied work center, they shall be housed in a noncombustible cabinet or other enclosure to prevent access by unauthorized personnel.

CS513.2.8.5.1 (IFC 1206.2.8.5.1) Cabinets. Where stationary batteries are contained in cabinets in occupied work centers, the cabinet enclosures shall be located within 10 feet (3048 mm) of the equipment that they support.

CS513.2.8.6 (IFC 1206.2.8.6) Signage. Approved signs shall be provided on doors or in locations near entrances to stationary storage battery system rooms and shall include the following or equivalent:

1. The room contains energized battery systems.
2. The room contains energized electrical circuits.
3. The additional markings required in Section CS513.2.12 (IFC 1206.2.12) for the types of storage batteries contained within the room.

Exception: Existing stationary storage battery systems shall be permitted to include the signage required at the time it was installed.

CS513.2.8.6.1 (IFC 1206.2.8.6.1) Electrical disconnects. Where the stationary storage battery system disconnecting means is not within sight of the main service disconnecting means, placards or directories shall be installed at the location of the main service disconnecting means indicating the location of stationary storage battery system disconnecting means in accordance with NFPA 70.

CS513.2.8.6.2 (IFC 1206.2.8.6.2) Cabinet signage. Battery storage cabinets provided in occupied work centers in accordance with Section CS513.2.8.5 (IFC 1206.2.8.5) shall have exterior labels that identify the manufacturer and model number of the system and electrical rating (voltage and current) of the contained battery system. There shall be signs within the cabinet that indicate the relevant electrical and chemical hazards, as required by Section CS513.2.12 (IFC 1206.2.12).

CS513.2.8.7 (IFC 1206.2.8.7) Outdoor installations. Stationary storage battery systems located outdoors shall comply with Sections CS513.2.8.7 (IFC 1206.2.8.7) through CS513.2.8.7.4 (IFC 1206.2.8.7.4), in addition to all applicable requirements of Section CS513.2 (IFC 1206.2). Installations in outdoor enclosures or containers that can be occupied for servicing, testing, maintenance and other functions shall be treated as battery storage rooms.

Exception: Stationary battery arrays in noncombustible containers shall not be required to be spaced 3 feet (914 mm) from the container walls.

CS513.2.8.7.1 (IFC 1206.2.8.7.1) Separation. Stationary storage battery systems located outdoors shall be separated by a minimum 5 feet (1524 mm) from the following:

1. Lot lines.
2. Public ways.
3. Buildings.
4. Stored combustible materials.
5. Hazardous materials.
6. High-piled stock.
7. Other exposure hazards.

Exception: The fire code official is authorized to approve smaller separation distances if large-scale fire and fault condition testing conducted or witnessed and reported by an approved testing laboratory is provided showing that a fire involving the system will not adversely impact occupant egress from adjacent buildings, or adversely impact adjacent stored materials or structures.

CS513.2.8.7.2 (IFC 1206.2.8.7.2) Means of egress. Stationary storage battery systems located outdoors shall be separated from any *means of egress* as required by the *fire code official* to ensure safe egress under fire conditions, but not less than 10 feet (3048 mm).

Exception: The *fire code official* is authorized to approve lesser separation distances if large-scale fire and fault condition testing conducted or witnessed and reported by an *approved* testing laboratory is provided showing that a fire involving the system will not adversely impact occupant egress.

CS513.2.8.7.3 (IFC 1206.2.8.7.3) Security of outdoor areas. Outdoor areas in which stationary stor-

age battery systems are located shall be secured against unauthorized entry and safeguarded in an approved manner.

CS513.2.8.7.4 (IFC 1206.2.8.7.4) Walk-in units. Where a stationary storage battery system includes an outer enclosure, the unit shall only be entered for inspection, maintenance and repair of batteries and electronics, and shall not be occupied for other purposes.

CS513.2.9 (IFC 1206.2.9) Maximum allowable quantities. *Fire areas* within buildings containing stationary storage battery systems exceeding the maximum allowable quantities in Table CS513.2.9 (IFC Table 1206.2.9) shall comply with all applicable Group H occupancy requirements in [this code] and the *International Building Code*.

Exception: Where approved by the *fire code official*, areas containing stationary storage batteries that exceed the amounts in Table CS513.2.9 (IFC Table 1206.2.9) shall be treated as incidental use areas and not Group H occupancies based on a hazardous mitigation analysis in accordance with Section CS513.2.3 (IFC 1206.2.3) and large-scale fire and fault condition testing conducted or witnessed and reported by an approved testing laboratory.

CS513.2.9.1 (IFC 1206.2.9.1) Mixed battery systems. Where areas within buildings contain different types of storage battery technologies, the total aggregate quantities of batteries shall be determined based on the sum of percentages of each battery type quantity divided by the maximum allowable quantity of each battery type. If the sum of the percentages exceeds 100 percent, the area shall be treated as a Group H occupancy in accordance with Table CS513.2.9 (IFC Table 1206.2.9).

CS513.2.10 (IFC 1206.2.10) Storage batteries and equipment. The design and installation of storage batteries and related equipment shall comply with Sections CS513.2.10.1 (IFC 1206.2.10.1) through CS513.2.10.8 (IFC 1206.2.10.8).

CS513.2.10.1 (IFC 1206.2.10.1) Listings. Storage batteries and battery storage systems shall comply with the following:

1. Storage batteries shall be listed in accordance with UL 1973.
2. Prepackaged and preengineered stationary storage battery systems shall be listed in accordance with UL 9540.

Exception: Lead-acid batteries are not required to be listed.

CS513.2.10.2 (IFC 1206.2.10.2) Prepackaged and preengineered systems. Prepackaged and preengineered stationary storage battery systems shall be installed in accordance with their listing and the manufacturer's instructions.

CS513.2.10.3 (IFC 1206.2.10.3) Energy management system. An approved energy management system shall be provided for battery technologies other than lead-acid and nickel cadmium for monitoring and balancing cell voltages, currents and temperatures within the manufacturer's specifications. The system shall transmit an alarm signal to an approved location if potentially hazardous temperatures or other conditions such as short circuits, over voltage or under voltage are detected.

CS513.2.10.4 (IFC 1206.2.10.4) Battery chargers. Battery chargers shall be compatible with the battery chemistry and the manufacturer's electrical ratings and charging specifications. Battery chargers shall be listed and labeled in accordance with UL 1564 or provided as part of a listed preengineered or prepackaged stationary storage battery system.

CS513.2.10.5 (IFC 1206.2.10.5) Inverters. Inverters shall be listed and labeled in accordance with UL 1741. Only inverters listed and labeled for utility interactive system use and identified as interactive shall be allowed to operate in parallel with the electric utility power system to supply power to common loads.

CS513.2.10.6 (IFC 1206.2.10.6) Safety caps. Vented batteries shall be provided with flame-arresting safety caps.

CS513.2.10.7 (IFC 1206.2.10.7) Thermal runaway. Where required by Section CS513.6.2.12 (IFC 1206.2.12), storage batteries shall be provided with a

TABLE CS513.2.9 (IFC 1206.2.9)
MAXIMUM ALLOWABLE BATTERY QUANTITIES

BATTERY TECHNOLOGY	MAXIMUM ALLOWABLE QUANTITIES[a]	GROUP H OCCUPANCY
Flow batteries[b]	600 kWh	Group H-2
Lead acid, all types	Unlimited	Not Applicable
Lithium, all types	600 kWh	Group H-2
Nickel cadmium (Ni-Cd)	Unlimited	Not Applicable
Sodium, all types	600 kWh	Group H-2
Other battery technologies	200 kWh	Group H-2[c]

For SI: 1 kilowatt hour = 3.6 megajoules.

a. For batteries rated in amp-hours, Kilowatt-hours (kWh) shall equal rated battery voltage times the amp-hour rating divided by 1,000.

b. Shall include vanadium, zinc-bromine, polysulfide-bromide, and other flowing electrolyte-type technologies.

c. Shall be a Group H-4 occupancy if the fire code official determines that a fire or thermal runaway involving the battery technology does not represent a significant fire hazard.

listed device or other approved method to prevent, detect and control thermal runaway.

CS513.2.10.8 (IFC 1206.2.10.8) Toxic and highly toxic gas. Stationary storage battery systems that have the potential to release toxic and highly toxic gas during charging, discharging and normal use conditions shall comply with (IFC) Chapter 60.

CS513.2.11 (IFC 1206.2.11) Fire-extinguishing and detection systems. Fire-extinguishing and detection systems shall be provided in accordance with Sections CS513.2.11.1 (IFC 1206.2.11.1) through CS513.2.11.5 (IFC 1206.2.11.5).

CS513.2.11.1 (IFC 1206.2.11.1) Fire-extinguishing systems. Rooms containing stationary storage battery systems shall be equipped with an *automatic sprinkler system* installed in accordance with Section (IFC 903.3.1.1). Commodity classifications for specific technologies of storage batteries shall be in accordance with Chapter 5 of NFPA 13. If the storage battery types are not addressed in Chapter 5 of NFPA 13, the *fire code official* is authorized to approve the fire-extinguishing system based on full-scale fire and fault condition testing conducted or witnessed and reported by an *approved* laboratory.

Exception: Spaces or areas containing stationary storage battery systems used exclusively for telecommunications equipment in accordance with Section (IFC 903.2).

CS513.2.11.1.1 (IFC 1206.2.11.1.1) Alternative fire-extinguishing systems. Battery systems that utilize water-reactive materials shall be protected by an approved alternative automatic fire-extinguishing system in accordance with Section (IFC 904). The system shall be listed for protecting the type, arrangement and quantities of storage batteries in the room. The *fire code official* shall be permitted to approve the alternative fire extinguishing system based on full-scale fire and fault condition testing conducted or witnessed and reported by an *approved* laboratory.

CS513.2.11.2 (IFC 1206.2.11.2) Smoke detection system. An *approved automatic smoke detection system* shall be installed in rooms containing *stationary storage battery systems* in accordance with Section CS511.2 (IFC 907.2).

CS513.2.11.3 (IFC 1206.2.11.3) Ventilation. Where required by Section CS513.2.3 (IFC 1206.2.3) or CS513.2.12 (IFC 1206.2.12), ventilation of rooms containing stationary storage battery systems shall be provided in accordance with the *International Mechanical Code* and one of the following:

1. The ventilation system shall be designed to limit the maximum concentration of flammable gas to 25 percent of the lower flammability limit, or for hydrogen, 1.0 percent of the total volume of the room.
2. Continuous ventilation shall be provided at a rate of not less than 1 cubic foot per minute (cfm) per square foot [0.00508 $m^3/(s \cdot m^2)$] of floor area, but not less than 150 cfm (4 m^3/min).

The exhaust system shall be designed to provide air movement across all parts of the floor for gases having a vapor density greater than air and across all parts of the vault ceiling for gases having a vapor density less than air.

CS513.2.11.3.1 (IFC 1206.2.11.3.1) Cabinet ventilation. Where cabinets located in occupied spaces contain storage batteries that are required by Section CS513.2.3 (IFC 1206.2.3) or CS513.2.12 (IFC 1206.2.12) to be provided with ventilation, the cabinet shall be provided with ventilation in accordance with Section CS513.2.11.3 (IFC 1206.2.11.3).

CS513.2.11.3.2 (IFC 1206.2.11.3.2) Supervision. Required mechanical ventilation systems for rooms and cabinets containing storage batteries shall be supervised by an *approved* central station, proprietary or remote station service or shall initiate an audible and visual signal at an *approved* constantly attended on-site location.

CS513.2.11.4 (IFC 1206.2.11.4) Gas detection system. Where required by Section CS513.2.3 (IFC 1206.2.3) or CS513.2.12 (IFC 1206.2.12), rooms containing stationary storage battery systems shall be protected by a gas detection system complying with Section (IFC 916). The gas detection system shall be designed to activate where the level of flammable gas exceeds 25 percent of the lower flammable limit (LFL), or where the level of toxic or highly toxic gas exceeds one-half of the IDLH.

CS513.2.11.4.1 (IFC 1206.2.11.4.1) System activation. Activation of the gas detection system shall result in all the following:

1. Initiation of distinct audible and visible alarms in the battery storage room.
2. Transmission of an alarm to an approved location.
3. De-energizing of the battery charger.
4. Activation of the mechanical ventilation system, where the system is interlocked with the gas detection system.

Exception: Lead-acid and nickel-cadmium stationary storage battery systems shall not be required to comply with Items 1, 2 and 3.

CS513.2.11.5 (IFC 1206.2.11.5) Spill control and neutralization. Where required by Section CS513.2.12 (IFC 1206.2.12), approved methods and materials shall be provided for the control and neutralization of spills of electrolyte or other hazardous materials in areas containing stationary storage batteries as follows:

1. For batteries with free-flowing electrolyte, the method and materials shall be capable of neutralizing a spill of the total capacity from the largest cell or block to a pH between 5.0 and 9.0.
2. For batteries with immobilized electrolyte, the method and material shall be capable of neutral-

izing a spill of 3.0 percent of the capacity of the largest cell or block in the room to a pH between 5.0 and 9.0.

CS513.2.12 (IFC 1206.2.12) Specific battery-type requirements. This section includes requirements applicable to specific types of storage batteries. Stationary storage battery systems with more than one type of storage battery shall comply with requirements applicable to each battery type.

CS513.2.12.1 (IFC 1206.2.12.1) Lead-acid storage batteries. Stationary storage battery systems utilizing lead-acid storage batteries shall comply with the following:

1. Ventilation shall be provided in accordance with Section CS513.2.11.3 (IFC 1206.2.11.3).
2. Spill control and neutralization shall be in accordance with Section CS513.2.11.5 (IFC 1206.2.11.5).
3. Thermal runaway protection shall be provided for valve-regulated lead-acid (VRLA) storage batteries in accordance with Section CS513.2.10.7 (IFC 1206.2.10.7).
4. The signage in Section CS513.2.8.6 (IFC 1206.2.8.6) shall indicate the room contains lead-acid batteries.

CS513.2.12.2 (IFC 1206.2.12.2) Nickel-cadmium (Ni-Cd) storage batteries. *Stationary storage battery systems* utilizing nickel-cadmium (Ni-Cd) storage batteries shall comply with the following:

1. Ventilation shall be provided in accordance with Section CS513.2.11.3 (IFC 1206.2.11.3).
2. Spill control and neutralization shall be in accordance with Section CS513.2.11.5 (IFC 1206.2.11.5).
3. Thermal runaway protection shall be provided for valve-regulated sealed nickel-cadmium storage batteries in accordance with Section CS513.2.10.7 (IFC 1206.2.10.7).
4. The signage in Section CS513.2.8.6 (IFC 1206.2.8.6) shall indicate the room contains nickel-cadmium batteries.

CS513.2.12.3 (IFC 1206.2.12.3) Lithium-ion storage batteries. The signage in Section CS513.2.8.6 (IFC 1206.2.8.6) shall indicate the type of lithium batteries contained in the room.

CS513.2.12.4 (IFC 1206.2.12.4) Sodium-beta storage batteries. *Stationary storage battery systems* utilizing sodium-beta storage batteries shall comply with the following:

1. Ventilation shall be provided in accordance with Section CS513.2.11.3 (IFC 1206.2.11.3).
2. The signage in Section CS513.2.8.6 (IFC 1206.2.8.6) shall indicate the type of sodium batteries in the room and include the instructions, "APPLY NO WATER."

CS513.2.12.5 (IFC 1206.2.12.5) Flow storage batteries. Stationary storage battery systems utilizing flow storage batteries shall comply with the following:

1. Ventilation shall be provided in accordance with Section CS513.2.11.3 (IFC 1206.2.11.3).
2. Spill control and neutralization shall be in accordance with Section CS513.2.11.5 (IFC 1206.2.11.5).
3. The signage required in Section CS513.2.8.6 (IFC 1206.2.8.6) shall indicate the type of flow batteries in the room.

CS513.2.12.6 (IFC 1206.2.12.6) Other battery technologies. *Stationary storage battery systems* utilizing battery technologies other than those described in Sections CS513.2.12.1 (IFC 1206.2.12.1) through CS513.2.12.5 (IFC 1206.2.12.5) shall comply with the following:

1. Gas detection systems complying with Section (IFC 916) shall be provided in accordance with Section CS513.2.11.4 (IFC 1206.2.11.4) where the batteries have the potential to produce toxic or highly toxic gas in the storage room or cabinet in excess of the permissible exposure limits (PEL) during charging, discharging and normal system operation.
2. Mechanical ventilation shall be provided in accordance with Section CS513.2.11.3 (IFC 1206.2.11.3).
3. Spill control and neutralization shall be in accordance with Section CS513.2.11.5 (IFC 1206.2.11.5).
4. In addition to the signage required in Section CS513.2.8.6 (IFC 1206.2.8.6), the marking shall identify the type of batteries present, describe the potential hazards associated with the battery type, and indicate that the room contains energized electrical circuits.

CS513.3 (IFC 1206.3) Capacitor energy storage systems. Capacitor energy storage systems having capacities exceeding 3 kWh (10.8 megajoules) shall comply with Sections CS513.3 (IFC 1206.3) through CS513.3.2.6.1 (IFC 1206.3.2.6.1).

Exception: Capacitors regulated by NFPA 70, Chapter 460, and capacitors included as a component part of other listed electrical equipment are not required to comply with this section.

CS513.3.1 (IFC 1206.3.1) Permits. Permits shall be obtained for the installation of capacitor energy storage systems in accordance with Section (IFC 105.7.3).

CS513.3.2 (IFC 1206.3.2) Location and construction. Rooms and areas containing capacitor energy storage systems shall be designed, located and constructed in accordance with Sections CS513.3.2 (IFC 1206.3.2) through CS513.3.2.5 (IFC 1206.3.2.5).

CS513.3.2.1 (IFC 1206.3.2.1) Location. Capacitor energy storage systems shall not be located in areas

where the floor is located more than 75 feet (22 860 mm) above the lowest level of fire department vehicle access, or where the floor level is more than 30 feet (9144 mm) below the finished floor of the lowest level of exit discharge.

CS513.3.2.2 (IFC 1206.3.2.2) Separation. Rooms containing capacitor energy storage systems shall be separated from the following occupancies by fire barriers or horizontal assemblies, or both, constructed in accordance with the *International Building Code*.

1. Group B, F, M, S and U occupancies by 1-hour fire-resistance-rated construction.
2. Group A, E, I and R occupancies by 2-hour fire-resistance-rated construction.

CS513.3.2.3 (IFC 1206.3.2.3) Capacitor arrays. Capacitor energy storage systems shall be segregated into capacitor arrays not exceeding 50 kWh (180 megajoules) each. Each array shall be spaced not less than 3 feet (914 mm) from other arrays and from walls in the storage room or area. The storage arrangements shall comply with (IFC) Chapter 10.

Exception: Capacitor energy storage systems in noncombustible containers located outdoors shall not be required to be spaced 3 feet (914 mm) from the container walls.

CS513.3.2.4 (IFC 1206.3.2.4) Signage. Approved signs shall be provided on doors or in locations adjacent to the entrances to capacitor energy storage system rooms and shall include the following or equivalent verbiage and information:.

1. "CAPACITOR ENERGY STORAGE ROOM."
2. "THIS ROOM CONTAINS ENERGIZED ELECTRICAL CIRCUITS."
3. An identification of the type of capacitors present and the potential hazards associated with the capacitor type.

CS513.3.2.5 (IFC 1206.3.2.5) Electrical disconnects. Where the capacitor energy storage system disconnecting means is not within sight of the main service disconnecting means, placards or directories shall be installed at the location of the main service disconnecting means identifying the location of the capacitor energy storage system disconnecting means in accordance with NFPA 70.

CS513.3.2.6 (IFC 1206.3.2.6) Outdoor installation. Capacitor energy systems located outdoors shall comply with Sections CS513.3.2.6 (IFC 1206.3.2.6) through CS513.3.2.6.4 (IFC 1206.3.2.6.4) in addition to all applicable requirements of Section CS513.3 (IFC 1206.3). Installations in outdoor enclosures or containers that can be occupied for servicing, testing, maintenance and other functions shall be treated as capacitor storage rooms.

Exception: Capacitor arrays in noncombustible containers shall not be required to be spaced 3 feet (914 mm) from the container walls.

CS513.3.2.6.1 (IFC 1206.3.2.6.1) Separation. Capacitor energy systems located outdoors shall be not less than 5 feet (1524 mm) from the following:

1. Lot lines.
2. Public ways.
3. Buildings.
4. Stored combustible materials.
5. Hazardous materials.
6. High-piled stock.
7. Other exposure hazards.

Exception: The *fire code official* is authorized to approve lesser separation distances if large-scale fire and fault condition testing conducted or witnessed and reported by an approved testing laboratory is provided showing that a fire involving the system will not adversely impact occupant egress from adjacent buildings, or adversely impact adjacent stored materials or structures.

CS513.3.2.6.2 (IFC 1206.3.2.6.2) Means of egress. *Capacitor energy storage systems* located outdoors shall be separated from any means of egress as required by the fire code official to ensure safe egress under fire conditions, but not less than 10 feet (3048 mm).

Exception: The *fire code official* is authorized to approve lesser separation distances if large-scale fire and fault condition testing conducted or witnessed and reported by an approved testing laboratory is provided showing that a fire involving the system will not adversely impact occupant egress.

CS513.3.2.6.3 (IFC 1206.3.2.6.3) Security of outdoor areas. Outdoor areas in which *capacitor energy storage systems* are located shall be secured against unauthorized entry and safeguarded in an approved manner.

CS513.3.2.6.4 (IFC 1206.3.2.6.4) Walk-in units. Where a capacitor energy storage system includes an outer enclosure, the unit shall only be entered for inspection, maintenance and repair of batteries and electronics, and shall not be occupied for other purposes.

CS513.3.3 (IFC 1206.3.3) Maximum allowable quantities. Fire areas within buildings containing *capacitor energy storage systems* that exceed 600 kWh of energy capacity shall comply with all applicable Group H occupancy requirements in [this code] and the *International Building Code*.

CS513.3.4 (IFC 1206.3.4) Capacitors and equipment. The design and installation of *capacitor energy storage systems* and related equipment shall comply with Sections

CS513.3.4.1 (IFC 1206.3.4.1) through CS513.3.4.5 (IFC 1206.3.4.5).

CS513.3.4.1 (IFC 1206.3.4.1) Listing. Capacitors and *capacitor energy storage systems* shall comply with the following:

1. Capacitors shall be listed in accordance with UL 1973.
2. Prepackaged and preengineered stationary capacitor energy storage systems shall be listed in accordance with UL 9540.

CS513.3.4.2 (IFC 1206.3.4.2) Prepackaged and preengineered systems. In addition to other applicable requirements of [this code], prepackaged and preengineered *capacitor energy storage systems* shall be installed in accordance with their listing and the manufacturer's instructions.

CS513.3.4.3 (IFC 1206.3.4.3) Energy management system. An approved energy management system shall be provided for monitoring and balancing capacitor voltages, currents and temperatures within the manufacturer's specifications. The system shall transmit an alarm signal to an approved location if potentially hazardous temperatures or other conditions such as short circuits, over voltage or under voltage are detected.

CS513.3.4.4 (IFC 1206.3.4.4) Capacitor chargers. Capacitor chargers shall be compatible with the capacitor manufacturer's electrical ratings and charging specifications. Capacitor chargers shall be listed and labeled in accordance with UL 1564 or provided as part of a listed preengineered or prepackaged *capacitor energy storage system.*

CS513.3.4.5 (IFC 1206.3.4.5) Toxic and highly toxic gas. *Capacitor energy storage systems* that have the potential to release toxic and highly toxic materials during charging, discharging and normal use conditions shall comply with (IFC) Chapter 60.

CS513.3.5 (IFC 1206.3.5) Fire-extinguishing and detection systems. Fire-extinguishing and smoke detection systems shall be provided in *capacitor energy storage system* rooms in accordance with Sections CS513.3.5.1 (IFC 1206.3.5.1) through CS513.3.5.2 (IFC 1206.3.5.2).

CS513.3.5.1 (IFC 1206.3.5.1) Fire-extinguishing systems. Rooms containing *capacitor energy storage systems* shall be equipped with an *automatic sprinkler system* installed in accordance with Section (IFC 903.3.1.1). Commodity classifications for specific capacitor technologies shall be in accordance with Chapter 5 of NFPA 13. If the capacitor types are not addressed in Chapter 5 of NFPA 13, the *fire code official* is authorized to approve the *automatic sprinkler system* based on full-scale fire and fault condition testing conducted by an *approved* laboratory.

CS513.3.5.1.1 (IFC 1206.3.5.1.1) Alternative fire-extinguishing systems. *Capacitor energy storage systems* that utilize water-reactive materials shall be protected by an approved alternative *automatic fire-extinguishing system* in accordance with Section (IFC 904). The system shall be listed for protecting the type, arrangement and quantities of capacitors in the room. The *fire code official* shall be permitted to approve the system based on full-scale fire and fault condition testing conducted by an *approved* laboratory.

CS513.3.5.2 (IFC 1206.3.5.2) Smoke detection system. An approved *automatic smoke detection system* shall be installed in rooms containing *capacitor energy storage systems* in accordance with Section CS511.2 (IFC 907.2).

CS513.3.5.3 (IFC 1206.3.5.3) Ventilation. Where capacitors release flammable gases during normal operating conditions, ventilation of rooms containing capacitor energy storage systems shall be provided in accordance with the *International Mechanical Code* and one of the following:

1. The ventilation system shall be designed to limit the maximum concentration of flammable gas to 25 percent of the lower flammability limit.
2. Continuous ventilation shall be provided at a rate of not less than 1 cubic foot per minute (cfm) per square foot [0.00508 $m^3/(s \cdot m^2)$] of floor area, but not less than 150 cfm (4 m^3/min).

The exhaust system shall be designed to provide air movement across all parts of the floor for gases having a vapor density greater than air and across all parts of the ceiling for gases having a vapor density less than air.

CS513.3.5.3.1 (IFC 1206.3.5.3.1) Supervision. Required mechanical ventilation systems for rooms containing *capacitor energy storage systems* shall be supervised by an *approved* central station, proprietary or remote station service, or shall initiate an audible and visible signal at an *approved,* constantly attended on-site location.

CS513.3.5.4 (IFC 1206.3.5.4) Spill control and neutralization. Where capacitors contain liquid electrolyte, *approved* methods and materials shall be provided for the control and neutralization of spills of electrolyte or other hazardous materials in areas containing capacitors as follows:

1. For capacitors with free-flowing electrolyte, the method and materials shall be capable of neutralizing a spill of the total capacity from the largest cell or block to a pH between 5.0 and 9.0.
2. For capacitors with immobilized electrolyte, the method and material shall be capable of neutralizing a spill of 3.0 percent of the capacity of the largest cell or block in the room to a pH between 5.0 and 9.0.

CS513.3.6 (IFC 1206.3.6) Testing, maintenance and repair. Capacitors and associated equipment and systems shall be tested and maintained in accordance with the manufacturer's instructions. Any capacitors or system components used to replace existing units shall be compatible with the capacitor charger, energy management systems,

other capacitors, and other safety systems. Introducing different capacitor technologies into the capacitor energy storage system shall be treated as a new installation and require approval by the *fire code official* before the replacements are introduced into service.

SECTION CS514 (IFC 5001) GENERAL

CS514.1 (IFC 5001.1) Scope. Prevention, control and mitigation of dangerous conditions related to storage, dispensing, use and handling of hazardous materials shall be in accordance with [this chapter].

[This chapter] shall apply to all hazardous materials, including those materials regulated elsewhere in [this code], except that where specific requirements are provided in other chapters, those specific requirements shall apply in accordance with the applicable chapter. Where a material has multiple hazards, all hazards shall be addressed.

Exceptions:

7. Stationary storage battery systems regulated by Section CS513.2 (IFC 1206.2).

SECTION CS515 (IFC 5401) CORROSIVE MATERIALS

CS515.1 (IFC 5401.1) Scope. The storage and use of *corrosive* materials shall be in accordance with [this chapter]. *Compressed gases* shall also comply with (IFC) Chapter 53.

Exceptions:

2. Stationary storage battery systems in accordance with Section CS513.2 (IFC 1206.2).

SECTION CS516 (IFC 907) FIRE ALARM AND DETECTION SYSTEMS

CS516.1 (IFC 907.1) General. This section covers the application, installation, performance and maintenance of fire alarm systems and their components in new and existing buildings and structures. The requirements of Section CS516.2 (IFC 907.2) are applicable to new buildings and structures. The requirements of Section (IFC 907.9) are applicable to existing buildings.

CS516.2 (IFC 907.2) Where required—new buildings and structures. An *approved* fire alarm system installed in accordance with the provisions of [this code] and NFPA 72 shall be provided in new buildings and structures in accordance with Sections (IFC 907.2.1) through CS516.2.2 (IFC 907.2.23) and provide occupant notification in accordance with Section (IFC 907.5), unless other requirements are provided by another section of [this code].

Not fewer than one manual fire alarm box shall be provided in an *approved* location to initiate a fire alarm signal for fire alarm systems employing automatic fire detectors or waterflow detection devices. Where other sections of [this code] allow elimination of fire alarm boxes due to sprinklers, a single fire alarm box shall be installed.

Exceptions:

1. The manual fire alarm box is not required for fire alarm systems dedicated to elevator recall control and supervisory service.
2. The manual fire alarm box is not required for Group R-2 occupancies unless required by the *fire code official* to provide a means for fire watch personnel to initiate an alarm during a sprinkler system impairment event. Where provided, the manual fire alarm box shall not be located in an area that is open to the public.

CS516.2.1 (IFC 907.2.22) Battery rooms. An automatic smoke detection system shall be installed in areas containing stationary storage battery systems as required in Section CS513.2 (IFC 1206.2).

CS516.2.2 (IFC 907.2.23) Capacitor energy storage systems. An automatic smoke detection system shall be installed in areas containing capacitor energy storage systems as required by Section CS513.3 (IFC 1206.3).

CHAPTER 6 [CS]

ALTERNATE COMPLIANCE PROVISIONS

User note:

About this chapter: *This chapter contains alternate compliance provisions associated with solar energy systems excerpted directly from the International Energy Conservation Code® and the International Swimming Pool and Spa Code®.*

SECTION CS601 (IECC CHAPTER 2 [CE]) DEFINITIONS

ON-SITE RENEWABLE ENERGY. Energy derived from solar radiation, wind, waves, tides, landfill gas, biomass or the internal heat of the earth. The energy system providing on-site renewable energy shall be located on the project site.

SECTION CS602 (IECC CHAPTER 4 [CE]) COMMERCIAL ENERGY EFFICIENCY

CS602.1 (IECC C402.3) Roof solar reflectance and thermal emittance. Low-sloped roofs directly above cooled conditioned spaces in *Climate Zones* 1, 2 and 3 shall comply with one or more of the options in Table (IECC C402.3).

Exceptions: The following roofs and portions of roofs are exempt from the requirements of Table (IECC C402.3):

1. Portions of the roof that include or are covered by the following:
   1.1. Photovoltaic systems or components.
   1.2. Solar air or water-heating systems or components.

CS602.2 (IECC C403) Building mechanical systems.

CS602.2.1 (IECC C403.3.2) HVAC equipment performance requirements. Equipment shall meet the minimum efficiency requirements of Tables [IECC C403.3.2(1) through C403.3.2(9)] when tested and rated in accordance with the applicable test procedure. Plate-type liquid-to-liquid heat exchangers shall meet the minimum requirements of Table CS602.2.1 [IECC Table C403.3.2(10)]. The efficiency shall be verified through certification under an *approved* certification program or, where a certification program does not exist, the equipment efficiency ratings shall be supported by data furnished by the manufacturer. Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements. Where components, such as indoor or outdoor coils, from different manufacturers are used, calculations and supporting data shall be furnished by the designer that demonstrates that the combined efficiency of the specified components meets the requirements herein.

CS602.2.2 (IECC C403.12.3) Freeze protection system controls. Freeze protection systems, such as heat tracing of outdoor piping and heat exchangers, including self-regulating heat tracing, shall include automatic controls configured to shut off the systems when outdoor air temperatures are above 40°F (4°C) or when the conditions of the protected fluid will prevent freezing.

CS602.2.3 (IECC C403.7.4) Energy recovery ventilation systems. Where the supply airflow rate of a fan system exceeds the values specified in Tables [IECC C403.7.4(1)] and [IECC C403.7.4(2)], the system shall include an energy recovery system. The energy recovery system shall be configured to provide a change in the enthalpy of the outdoor air supply of not less than 50 percent of the difference between the outdoor air and return air enthalpies, at design conditions. Where an air economizer is required, the energy recovery system shall include a bypass or controls which permit operation of the economizer as required by Section (IECC C403.5).

Exception: An energy recovery ventilation system shall not be required in any of the following conditions:

1. Where energy recovery systems are prohibited by the *International Mechanical Code*.
2. Laboratory fume hood systems that include at least one of the following features:
   2.1. Variable-air-volume hood exhaust and room supply systems configured to reduce exhaust and makeup air volume to 50 percent or less of design values.
   2.2. Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated not warmer than 2°F (1.1°C) above room setpoint, cooled to not cooler than

TABLE CS602.2.1 [IECC TABLE C403.3.2(10)]
HEAT TRANSFER EQUIPMENT

EQUIPMENT TYPE	SUBCATEGORY	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Liquid-to-liquid heat exchangers	Plate type	NR	AHRI 400

NR = No Requirement.

a. Chapter 7 [CS] (IECC Chapter 6 [CE]) contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

3°F (1.7°C) below room setpoint, with no humidification added, and no simultaneous heating and cooling used for dehumidification control.

3. Systems serving spaces that are heated to less than 60°F (15.5°C) and are not cooled.
4. Where more than 60 percent of the outdoor heating energy is provided from site-recovered or site solar energy.

CS602.2.4 (IECC C403.4.4) Requirements for complex mechanical systems serving multiple zones. Sections (IECC C403.4.4.1) through (IECC C403.4.6.4) shall apply to complex mechanical systems serving multiple zones. Supply air systems serving multiple zones shall be variable air volume (VAV) systems that, during periods of occupancy, are designed and capable of being controlled to reduce primary air supply to each zone to one of the following before reheating, recooling or mixing takes place:

1. Thirty percent of the maximum supply air to each *zone*.
2. Three hundred cfm (142 L/s) or less where the maximum flow rate is less than 10 percent of the total fan system supply airflow rate.
3. The minimum ventilation requirements of Chapter 4 of the *International Mechanical Code*.
4. Any higher rate that can be demonstrated to reduce overall system annual energy use by offsetting reheat/recool energy losses through a reduction in outdoor air intake for the system, as *approved* by the *code official*.
5. The airflow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates.

Exception: The following individual *zones* or entire air distribution systems are exempted from the requirement for VAV control:

1. *Zones* or supply air systems where not less than 75 percent of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered or site-solar energy source.

CS602.2.5 (IECC C403.4.4.5) Supply-air temperature reset controls. Multiple-*zone* HVAC systems shall include controls that automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperature. The controls shall be capable of resetting the supply air temperature not less than 25 percent of the difference between the design supply-air temperature and the design room air temperature.

Exceptions:

1. Systems that prevent reheating, recooling or mixing of heated and cooled supply air.
2. Seventy-five percent of the energy for reheating is from site-recovered or site-solar energy sources.
3. *Zones* with peak supply air quantities of 300 cfm (142 L/s) or less.

CS602.2.6 (IECC C403.9.5) Heat recovery for service water heating. Condenser heat recovery shall be installed for heating or reheating of service hot water provided that the facility operates 24 hours a day, the total installed heat capacity of water-cooled systems exceeds 6,000,000 Btu/hr (1 758 kW) of heat rejection, and the design service water heating load exceeds 1,000,000 Btu/h (293 kW).

The required heat recovery system shall have the capacity to provide the smaller of the following:

1. Sixty percent of the peak heat rejection load at design conditions.
2. The preheating required to raise the peak service hot water draw to 85°F (29°C).

Exceptions:

1. Facilities that employ condenser heat recovery for space heating or reheat purposes with a heat recovery design exceeding 30 percent of the peak water-cooled condenser load at design conditions.
2. Facilities that provide 60 percent of their service water heating from site solar or site recovered energy or from other sources.

CS602.3 (IECC C404) Service water heating (Mandatory).

CS602.3.1 (IECC C404.2.1) High input-rated service water-heating systems. Gas-fired water-heating equipment installed in new buildings shall be in compliance with this section. Where a singular piece of water-heating equipment serves the entire building and the input rating of the equipment is 1,000,000 Btu/h (293 kW) or greater, such equipment shall have a thermal efficiency, E_t, of not less than 90 percent. Where multiple pieces of water-heating equipment serve the building and the combined input rating of the water-heating equipment is 1,000,000 Btu/h (293 kW) or greater, the combined input-capacity-weighted-average thermal efficiency, E_t, shall be not less than 90 percent.

Exceptions:

1. Where not less than 25 percent of the annual *service water heating* requirement is provided by *on-site renewable energy* or site-recovered energy, the minimum thermal efficiency requirements of this section shall not apply.

CS602.3.2 (IECC C404.3) Heat traps for hot water storage tanks. Storage tank-type water heaters and hot water storage tanks that have vertical water pipes connecting to the inlet and outlet of the tank shall be provided with integral heat traps at those inlets and outlets or shall have pipe-configured heat traps in the piping connected to those inlets and outlets. Tank inlets and outlets associated with solar water heating system circulation loops shall not be required to have heat traps.

CS602.4 (IECC C404.10) Energy consumption of pools and permanent spas (Mandatory).

CS602.4.1 (IECC C404.10.2) Time switches. Time switches or other control methods that can automatically turn off and on heaters and pump motors according to a preset schedule shall be installed for heaters and pump motors. Heaters and pump motors that have built-in time switches shall be in compliance with this section.

Exceptions:

1. Where public health standards require 24-hour pump operation.
2. Pumps that operate solar- and waste-heat-recovery pool heating systems.

CS602.4.2 (IECC C404.9.3) Covers. Outdoor heated pools and outdoor permanent spas shall be provided with a vapor-retardant cover or other approved vapor-retardant means.

Exception: Where more than 70 percent of the energy for heating, computed over an operating season, is from site-recovered energy such as from a heat pump or solar energy source, covers or other vapor-retardant means shall not be required.

CS602.5 (IECC C406) Additional efficiency package options.

CS602.5.1 (IECC C406.5) On-site renewable energy. The total minimum ratings of on-site renewable energy systems shall be one of the following:

1. Not less than 1.71 Btu/h per square foot (5.4 W/m^2) or 0.50 watts per square foot (5.4 W/m^2) of conditioned floor area.
2. Not less than 3 percent of the energy used within the building for building mechanical and service water heating equipment and lighting regulated in (IECC) Chapter 4.

CS602.5.2 (IECC C406.7.1) Load fraction. The building service water-heating system shall have one or more of the following that are sized to provide not less than 60 percent of the building's annual hot water requirements, or sized to provide 100 percent of the building's annual hot water requirements if the building shall otherwise comply with Section CS602.2.6 (IECC C403.9.5):

1. Waste heat recovery from service hot water, heat-recovery chillers, building equipment, or process equipment.
2. *On-site renewable energy* water-heating systems.

SECTION CS603 (ISPSC 303) ENERGY

CS603.1 (ISPSC 303.1.2) Time switches. Time switches or other control methods that can automatically turn off and on heaters and pump motors according to a preset schedule shall be installed for heaters and pump motors. Heaters and pump motors that have built-in time switches shall be in compliance with this section.

Exceptions:

1. Where public health standards require 24-hour pump operation.
2. Pumps that operate solar- or waste-heat recovery pool heating systems.

CS603.2 (ISPSC 303.1.3) Covers. Outdoor heated pools and outdoor permanent spas shall be provided with a vapor-retardant cover or other *approved* vapor-retardant means in accordance with Section (ISPSC 104.11).

Exception: Where more than 70 percent of the energy for heating, computed over an operating season, is from a heat pump or solar energy source, covers or other vapor-retardant means shall not be required.

CHAPTER 7 [CS]
REFERENCED STANDARDS

User note:

About this chapter: This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title, and the section or sections of this document that reference the standard. The application of the referenced standards shall be as specified in Section CS102.8.

AHRI

Air-Conditioning, Heating, and Refrigeration Institute
2111 Wilson Blvd, Suite 500
Arlington, VA 22201

400—2001: Liquid to Liquid Heat Exchangers with Addendum 1 and 2
Table CS602.2.1

1160 (I-P) —09: Performance Rating of Heat Pump Pool Heaters
Table CS505.1

ASCE/SEI

American Society of Civil Engineers
Structural Engineering Institute
1801 Alexander Bell Drive
Reston, VA 20191

7—10: Minimum Design Loads for Buildings and Other Structures with Supplement No. 1
CS509.1, CS509.2

ASHRAE

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

180—2012: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems
CS102.3

ANSI/ASHRAE/ACCA Standard 183—2007 (RA2011): Peak Cooling and Heating Load Calculations in Buildings, Except Low-rise Residential Buildings
CS309.1

ASME

American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990

BPVC—2010/2011 addenda: ASME Boiler and Pressure Vessel Code (2007 Edition)
CS407.1, CS408.1, CS413.2, CS415.1

CSD-1—2011: Controls and Safety Devices for Automatically Fired Boilers
CS408.1

ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2859

D56—05(2010): Test Method for Flash Point by Tag Closed Tester
CS202

D93—12: Test Method for Flash Point of Pensky-Martens Closed Cup Tester
CS202

D226/D226M—09: Specification for Asphalt-saturated Organic Felt Used in Roofing and Waterproofing
CS502.2, CS504.2.3

ASTM—continued

D1970/D1970M—2013: Specification for Self-adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roof Underlayment for Ice Dam Protection
CS504.1.1

D2898—10: Test Methods for Accelerated Weathering of Fire-retardant-treated Wood for Fire Testing
CS502.1

D3161/D3161M—13: Test Method for a Wind Resistance of Asphalt Shingles (Fan Induced Method)
CS504.2.8

D3278—1996 (2011): Test Methods for Flash Point of Liquids by Small Scale Closed-cup Apparatus
CS202

D4869/D4869M—05(2011)e01: Specification for Asphalt-saturated (Organic Felt) Underlayment Used in Steep Slope Roofing
CS504.2.3

D6757—2013: Standard Specification for Underlayment for Use with Steep Slope Roofing
CS504.2.3

E108—2011: Test Methods for Fire Tests of Roof Coverings
CS502.1

F1667—11AE1: Specification for Driven Fasteners: Nails, Spikes and Staples
CS504.2.5

ICC

International Code Council, Inc.
500 New Jersey Avenue, NW
6th Floor
Washington, DC 20001

IBC—15: International Building Code®
CS201.3, CS301.15, CS301.16, CS301.17, CS301.18, CS302.1, CS302.2, CS304.7, CS304.10, CS306.5.1, CS402.8.1.2, CS402.8.1.3, CS408.6, CS502.1, Table CS502.1, CS504.2.8, CS507.1, CS508.1, CS508.1.1.3, CS508.1.1.4, CS508.2

ICC 900/SRCC 300—2015: Solar Thermal System Standard
CS311.4.2, CS401.4, CS402.1, CS402.3.1, CS402.4, CS402.8.1.4, CS402.8.5, CS402.8.5.3, CS403.2, CS405.1, CS406.1, CS511.2.1

ICC 901/SRCC 100—2015: Solar Thermal Collector Standard
CS311.4.2, CS401.4.1, CS402.8.1.1, CS511.2.1

IECC—15: International Energy Conservation Code®
CS301.2, CS309.1, CS602.1, CS602.2.1, CS602.2.3, CS602.2.4, CS602.4.1, CS604.2

IFC—15: International Fire Code®
CS101.1, CS201.3, CS506.1

IFGC—15: International Fuel Gas Code®
CS201.3, CS301.6

IMC—15: International Mechanical Code®
CS102.8, CS307.2, CS402.7.1, CS402.8.2, CS402.8.7, CS405.1, CS408.6, CS602.2.3, CS602.2.4

IPC—15: International Plumbing Code®
CS201.3, CS301.11, CS401.2, CS405.1, CS406.3, CS406.4, CS409.2, CS410.6, CS412.2, CS413.3

IRC—15: International Residential Code®
CS311.3, CS311.4.1, CS513.1, CS513.2.1

IWUIC—15: International Wildland and Urban Interface Code®
Table CS502.1

MSS

Manufacturers Standardization Society of the Valve & Fittings Industry, Inc.
127 Park Street, N.E.
Vienna, VA 22180

SP 58—2009: Pipe Hangers and Supports—Materials Design and Manufacture, Selection, Application and Installation
CS305.4

NFPA

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02169-7471

30A—15: Code for Motor Fuel-dispensing Facilities and Repair Garages
CS304.5

70—17: National Electrical Code
CS301.10, CS306.3.1, CS306.4.1, CS306.5.2

85—15: Boiler and Combustion Systems Hazards Code
CS408.1

NSF

NSF International
789 N. Dixboro
Ann Arbor, MI 48105

14—2011: Plastics Piping System Components and Related Materials
CS301.4

NSF 50—2012: Equipment for Swimming Pools, Spas, Hot Tubs, and other Recreational Water Facilities
Table CS605.1

UL

UL LLC
333 Pfingsten Road
Northbrook, IL 60062

174—04: Household Electric Storage Tank Water Heaters—with revisions through September 2012
CS405.1

726—95: Oil-fired Boiler Assemblies—with revisions through April 2011
CS408.1

732—95: Oil-fired Storage Tank Water Heaters—with revisions through April 2010
CS405.1

790—04: Standard Test Methods for Fire Tests of Roof Coverings—with Revisions through October 2008
CS502.1

834—04: Heating, Water Supply and Power Boilers Electric—with revisions through January 2013
CS408.1

1261—01: Electric Water Heaters for Pools and Tubs—with revisions through July 2012
Table CS605.1

1453—04: Electric Booster and Commercial Storage Tank Water Heaters—with revisions through July 2011
CS405.1

1563—2009: Standard for Electric Hot Tubs, Spas and Associated Equipment—with revisions through July 2012
Table CS605.1

1703—02: Flat-Plate Photovoltaic Modules and Panels—with Revisions through November 2014
CS502.7, CS504.2.6, CS505.2.2

1995—2011: Heating and Cooling Equipment
Table CS605.1

2523—09: Solid Fuel-fired Hydronic Heating Appliances—with revisions through February 2013
CS405.1, CS408.1

2703—2014: Outline of Investigation for Mounting Systems, Mounting Devices, Clamping/Retention Devices and Ground Lugs for Use with Flat-plate Photovoltaic Modules and Panels
CS502.7

9540—2014: Outline of Investigation for Energy Storage Systems and Equipment
CS514.2.10.1, CS514.3.4.1

APPENDIX CA

SOLAR-READY ZONE—COMMERCIAL

Below is Appendix CA of the 2018 International Energy Conservation Code®—Commercial provisions. Appendix chapters of the I-Codes are not mandatory unless specifically referenced in the I-Code adoption ordinance.

User note:

About this appendix: *Appendix CA is intended to encourage the installation of renewable energy systems by preparing buildings for the future installation of solar energy equipment, piping and wiring.*

SECTION CA101
SCOPE

CA101.1 General. These provisions shall be applicable for new construction where solar-ready provisions are required.

SECTION CA102
GENERAL DEFINITION

SOLAR-READY ZONE. A section or sections of the roof or building overhang designated and reserved for the future installation of a solar photovoltaic or solar thermal system.

SECTION CA103
SOLAR-READY ZONE

CA103.1 General. A solar-ready zone shall be located on the roof of buildings that are five stories or less in height above grade plane, and are oriented between 110 degrees and 270 degrees of true north or have low-slope roofs. Solar-ready zones shall comply with Sections CA103.2 through CA103.8.

Exceptions:

1. A building with a permanently installed, on-site renewable energy system.
2. A building with a solar-ready zone that is shaded for more than 70 percent of daylight hours annually.
3. A building where the licensed design professional certifies that the incident solar radiation available to the building is not suitable for a solar-ready zone.
4. A building where the licensed design professional certifies that the solar zone area required by Section CA103.3 cannot be met because of extensive roof-top equipment, skylights, vegetative roof areas or other obstructions.

CA103.2 Construction document requirements for a solar-ready zone. Construction documents shall indicate the solar-ready zone.

CA103.3 Solar-ready zone area. The total solar-ready zone area shall be not less than 40 percent of the roof area calculated as the horizontally projected gross roof area less the area covered by skylights, occupied roof decks, vegetative roof areas and mandatory *access* or set back areas as required by the *International Fire Code*. The solar-ready zone shall be a single area or smaller, separated sub-zone areas. Each sub-zone shall be not less than 5 feet (1524 mm) in width in the narrowest dimension.

CA103.4 Obstructions. Solar ready zones shall be free from obstructions, including pipes, vents, ducts, HVAC equipment, skylights and roof-mounted equipment.

CA103.5 Roof loads and documentation. A collateral dead load of not less than 5 pounds per square foot (5 psf) (24.41 kg/m^2) shall be included in the gravity and lateral design calculations for the solar-ready zone. The structural design loads for roof dead load and roof live load shall be indicated on the construction documents.

CA103.6 Interconnection pathway. Construction documents shall indicate pathways for routing of conduit or piping from the solar-ready zone to the electrical service panel or service hot water system.

CA103.7 Electrical service reserved space. The main electrical service panel shall have a reserved space to allow installation of a dual-pole circuit breaker for future solar electric installation and shall be labeled “For Future Solar Electric.” The reserved space shall be positioned at the end of the panel that is opposite from the panel supply conductor connection.

CA103.8 Construction documentation certificate. A permanent certificate, indicating the solar-ready zone and other requirements of this section, shall be posted near the electrical distribution panel, water heater or other conspicuous location by the builder or registered design professional.

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ISEP—RESIDENTIAL PROVISIONS

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CHAPTER 1 [RS]
SCOPE AND ADMINISTRATION

User notes:

About this chapter: *Chapter 1 establishes the limits of applicability of this code and describes how the code is to be applied and enforced. Chapter 1 is in two parts: Part 1—Scope and Application (Sections R101–R102) and Part 2—Administration and Enforcement (Sections R103–R114). Section R101 identifies which buildings and structures come under its purview and references other I-Codes as applicable. Standards and codes are scoped to the extent referenced (see Section R102.4).*

The source code for section numbers in parenthesis is the 2015 International Residential Code®, except where the International Fire Code® has been denoted.

PART 1—SCOPE AND APPLICATION

SECTION RS101 (R101) GENERAL

RS101.1 (R101.2) Scope. The provisions of [this code] shall apply to the construction, *alteration*, movement, enlargement, replacement, repair, *equipment*, use and occupancy, location, removal and demolition of detached one- and two-family dwellings and *townhouses* not more than three stories above *grade plane* in height with a separate means of egress and their *accessory structures* not more than three stories above *grade plane* in height.

Exception: The following shall be permitted to be constructed in accordance with [this code] where provided with a residential fire sprinkler system complying with Section (P2904):

1. Live/work units located in *townhouses* and complying with the requirements of Section 419 of the *International Building Code*.
2. Owner-occupied lodging houses with five or fewer guestrooms.
3. A care facility with five or fewer persons receiving custodial care within a dwelling unit.
4. A care facility with five or fewer persons receiving medical care within a dwelling unit.
5. A care facility for five or fewer persons receiving care that are within a single-family dwelling.

This collection of provisions imports code sections which address both Solar Thermal and Photovoltaic Solar Systems, and the structural, mechanical, plumbing, fire safety and energy conservation measures for each. Some are specific to Solar Systems, and others to their auxiliary, or backup systems. The installation of Photovoltaic Solar Systems is also addressed in NFPA 70.

RS101.2 (R101.3) Intent. The purpose of [this code] is to establish minimum requirements to safeguard the public safety, health and general welfare through affordability, structural strength, means of egress facilities, stability, sanitation, light and ventilation, energy conservation and safety to life and property from fire and other hazards attributed to the built environment, and to provide safety to fire fighters and emergency responders during emergency operations.

SECTION RS102 (R102) APPLICABILITY

RS102.1 (R102.1) General. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable. Where, in any specific case, different sections of [this code] specify different materials, methods of construction or other requirements, the most restrictive shall govern.

RS102.2 (R102.2) Other laws. The provisions of [this code] shall not be deemed to nullify any provisions of local, state or federal law.

RS102.3 (R102.3) Application of references. References to chapter or section numbers, or to provisions not specifically identified by number, shall be construed to refer to such chapter, section or provision of [this code].

RS102.4 (R102.4) Referenced codes and standards. The codes and standards referenced in [this code] shall be considered part of the requirements of [this code] to the prescribed extent of each such reference and as further regulated in Sections RS102.4.1 (R102.4.1) and RS102.4.2 (R102.4.2).

Exception: Where enforcement of a code provision would violate the conditions of the *listing* of the *equipment* or *appliance*, the conditions of the *listing* and manufacturer's instructions shall apply.

RS102.4.1 (R102.4.1) Conflicts. Where conflicts occur between provisions of [this code] and referenced codes and standards, the provisions of [this code] shall apply.

RS102.4.2 (R102.4.2) Provisions in referenced codes and standards. Where the extent of the reference to a referenced code or standard includes subject matter that is within the scope of [this code], the provisions of [this code], as applicable, shall take precedence over the provisions in the referenced code or standard.

RS102.5 (R102.5) Appendices. Provisions in the appendices shall not apply unless specifically referenced in the adopting ordinance.

RS102.6 (R102.6) Partial invalidity. In the event any part or provision of [this code] is held to be illegal or void, this shall not have the effect of making void or illegal any of the other parts or provisions.

RS102.7 (R102.7) Existing structures. The legal occupancy of any structure existing on the date of adoption of [this code] shall be permitted to continue without change, except as is specifically covered in [this code], the *International Property Maintenance Code* or the *International Fire Code*, or as is deemed necessary by the *building official* for the general safety and welfare of the occupants and the public.

RS102.7.1 (R102.7.1) Additions, alterations or repairs. *Additions*, *alterations* or repairs to any structure shall conform to the requirements for a new structure without requiring the existing structure to comply with the requirements of [this code], unless otherwise stated. *Additions*, *alterations*, repairs and relocations shall not cause an existing structure to become unsafe or adversely affect the performance of the building.

PART 2—ADMINISTRATION AND ENFORCEMENT

SECTION RS103 (R104)
DUTIES AND POWERS OF THE BUILDING OFFICIAL

RS103.1 (R104.9) Approved materials and equipment. Materials, *equipment* and devices *approved* by the *building official* shall be constructed and installed in accordance with such approval.

RS103.1.1 (R104.9.1) Used materials and equipment. Used materials, *equipment* and devices shall not be reused unless *approved* by the *building official*.

RS103.2 (R104.10) Modifications. Where there are practical difficulties involved in carrying out the provisions of [this code], the *building official* shall have the authority to grant modifications for individual cases, provided the *building official* shall first find that special individual reason makes the strict letter of [this code] impractical and the modification is in compliance with the intent and purpose of [this code] and that such modification does not lessen health, life and fire safety or structural requirements. The details of action granting modifications shall be recorded and entered in the files of the department of building safety.

RS103.2.1 (R104.10.1) Flood hazard areas. The *building official* shall not grant modifications to any provisions required in flood hazard areas as established by Table (IRC R301.2(1)) unless a determination has been made that:

1. There is good and sufficient cause showing that the unique characteristics of the size, configuration or topography of the site render the elevation standards of Section (R322) inappropriate.
2. Failure to grant the modification would result in exceptional hardship by rendering the lot undevelopable.
3. The granting of modification will not result in increased flood heights, additional threats to public safety, extraordinary public expense, cause fraud on or victimization of the public, or conflict with existing laws or ordinances.
4. The modification is the minimum necessary to afford relief, considering the flood hazard.
5. Written notice specifying the difference between the design flood elevation and the elevation to which the building is to be built, stating that the cost of flood insurance will be commensurate with the increased risk resulting from the reduced floor elevation and stating that construction below the design flood elevation increases risks to life and property, has been submitted to the applicant.

RS103.3 (R104.11) Alternative materials, design and methods of construction and equipment. The provisions of [this code] are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by [this code]. The *building official* shall have the authority to approve an alternative material, design or method of construction upon application of the owner or the owner's authorized agent. The *building official* shall first find that the proposed design is satisfactory and complies with the intent of the provisions of [this code], and that the material, method or work offered is, for the purpose intended, not less than the equivalent of that prescribed in [this code] in quality, strength, effectiveness, fire resistance, durability and safety. Compliance with the specific performance-based provisions of the International Codes shall be an alternative to the specific requirements of [this code]. Where the alternative material, design or method of construction is not *approved*, the *building official* shall respond in writing, stating the reasons why the alternative was not *approved*.

RS103.3.1 (R104.11.1) Tests. Where there is insufficient evidence of compliance with the provisions of [this code], or evidence that a material or method does not conform to the requirements of [this code], or in order to substantiate claims for alternative materials or methods, the *building official* shall have the authority to require tests as evidence of compliance to be made at no expense to the *jurisdiction*. Test methods shall be as specified in [this code] or by other recognized test standards. In the absence of recognized and accepted test methods, the *building official* shall approve the testing procedures. Tests shall be performed by an *approved* agency. Reports of such tests shall be retained by the *building official* for the period required for retention of public records.

SECTION RS104 (R105)
PERMITS

RS104.1 (R105.1) Required. Any owner or owner's authorized agent who intends to construct, enlarge, alter, repair,

move, demolish or change the occupancy of a building or structure, or to erect, install, enlarge, alter, repair, remove, convert or replace any electrical, gas, mechanical or plumbing system, the installation of which is regulated by [this code], or to cause any such work to be performed, shall first make application to the *building official* and obtain the required *permit*.

RS104.2 (R105.2) Work exempt from permit. Exemption from *permit* requirements of [this code] shall not be deemed to grant authorization for any work to be done in any manner in violation of the provisions of [this code] or any other laws or ordinances of this *jurisdiction*.

RS104.2.1 (R105.2.1) Emergency repairs. Where *equipment* replacements and repairs must be performed in an emergency situation, the *permit* application shall be submitted within the next working business day to the *building official*.

RS104.2.2 (R105.2.2) Repairs. Application or notice to the *building official* is not required for ordinary repairs to structures, replacement of lamps or the connection of *approved* portable electrical *equipment* to *approved* permanently installed receptacles. Such repairs shall not include the cutting away of any wall, partition or portion thereof, the removal or cutting of any structural beam or load-bearing support, or the removal or change of any required means of egress, or rearrangement of parts of a structure affecting the egress requirements; nor shall ordinary repairs include *addition* to, *alteration* of, replacement or relocation of any water supply, sewer, drainage, drain leader, gas, soil, waste, vent or similar piping, electric wiring or mechanical or other work affecting public health or general safety.

RS104.2.3 (R105.2.3) Public service agencies. A *permit* shall not be required for the installation, *alteration* or repair of generation, transmission, distribution, metering or other related *equipment* that is under the ownership and control of public service agencies by established right.

SECTION RS105 (R106) CONSTRUCTION DOCUMENTS

RS105.1 (R106.1) Submittal documents. Submittal documents consisting of *construction documents*, and other data shall be submitted in two or more sets with each application for a *permit*. The *construction documents* shall be prepared by a registered *design professional* where required by the statutes of the *jurisdiction* in which the project is to be constructed. Where special conditions exist, the *building official* is authorized to require additional *construction documents* to be prepared by a registered *design professional*.

Exception: The *building official* is authorized to waive the submission of *construction documents* and other data not required to be prepared by a registered *design professional* if it is found that the nature of the work applied for is such that reviewing of *construction documents* is not necessary to obtain compliance with [this code].

SECTION RS106 (R109) INSPECTIONS

RS106.1 (R109.1) Types of inspections. For on-site construction, from time to time the *building official*, upon notification from the *permit* holder or his agent, shall make or cause to be made any necessary inspections and shall either approve that portion of the construction as completed or shall notify the *permit* holder or his or her agent wherein the same fails to comply with [this code].

RS106.1.1 (R109.1.1) Foundation inspection. Inspection of the foundation shall be made after poles or piers are set or trenches or *basement* areas are excavated and any required forms erected and any required reinforcing steel is in place and supported prior to the placing of concrete. The foundation inspection shall include excavations for thickened slabs intended for the support of bearing walls, partitions, structural supports, or *equipment* and special requirements for wood foundations.

RS106.1.2 (R109.1.2) Plumbing, mechanical, gas and electrical systems inspection. Rough inspection of plumbing, mechanical, gas and electrical systems shall be made prior to covering or concealment, before fixtures or *appliances* are set or installed, and prior to framing inspection.

RS106.1.3 (R109.1.3) Floodplain inspections. For construction in flood hazard areas as established by Table (IRC R301.2(1)), upon placement of the lowest floor, including *basement*, and prior to further vertical construction, the *building official* shall require submission of documentation, prepared and sealed by a registered *design professional*, of the elevation of the lowest floor, including *basement*, required in Section (R322).

RS106.1.4 (R109.1.4) Frame and masonry inspection. Inspection of framing and masonry construction shall be made after the roof, masonry, framing, firestopping, draftstopping and bracing are in place and after the plumbing, mechanical and electrical rough inspections are *approved*.

RS106.1.5 (R109.1.5) Other inspections. In addition to inspections in Sections RS106.1.1 (R109.1.1) through RS106.1.4 (R109.1.4), the *building official* shall have the authority to make or require any other inspections to ascertain compliance with [this code] and other laws enforced by the *building official*.

RS106.1.5.1 (R109.1.5.1) Fire-resistance-rated construction inspection. Where fire-resistance-rated construction is required between *dwelling units* or due to location on property, the *building official* shall require an inspection of such construction after lathing or gypsum board or gypsum panel products are in place, but before any plaster is applied, or before board or panel joints and fasteners are taped and finished.

RS106.1.6 (R109.1.6) Final inspection. Final inspection shall be made after the permitted work is complete and prior to occupancy.

RS106.1.6.1 (R109.1.6.1) Elevation documentation. If located in a flood hazard area, the documentation of elevations required in Section (IRC R322.1.10) shall be

submitted to the *building official* prior to the final inspection.

RS106.2 (R109.2) Inspection agencies. The *building official* is authorized to accept reports of approved agencies, provided such agencies satisfy the requirements as to qualifications and reliability.

RS106.3 (R109.3) Inspection requests. It shall be the duty of the *permit* holder or their agent to notify the *building official* that such work is ready for inspection. It shall be the duty of the person requesting any inspections required by [this code] to provide access to and means for inspection of such work.

RS106.4 (R109.4) Approval required. Work shall not be done beyond the point indicated in each successive inspection without first obtaining the approval of the *building official*. The *building official* upon notification, shall make the requested inspections and shall either indicate the portion of the construction that is satisfactory as completed, or shall notify the *permit* holder or an agent of the *permit* holder wherein the same fails to comply with [this code]. Any portions that do not comply shall be corrected and such portion shall not be covered or concealed until authorized by the *building official.*

SECTION RS107 (R111) SERVICE UTILITIES

RS107.1 (R111.1) Connection of service utilities. A person shall not make connections from a utility, source of energy, fuel or power to any building or system that is regulated by [this code] for which a *permit* is required, until *approved* by the *building official*.

RS107.2 (R111.2) Temporary connection. The *building official* shall have the authority to authorize the temporary connection of the building or system to the utility, source of energy, fuel or power.

RS107.3 (R111.3) Authority to disconnect service utilities. The *building official* shall have the authority to authorize disconnection of utility service to the building, structure or system regulated by [this code] and the referenced codes and standards set forth in Section RS102.4 (R102.4) in case of emergency where necessary to eliminate an immediate hazard to life or property or where such utility connection has been made without the approval required by Section RS107.1 (R111.1) or RS107.2 (R111.2). The *building official* shall notify the serving utility and where possible the owner or the owner's authorized agent and occupant of the building, structure or service system of the decision to disconnect prior to taking such action. If not notified prior to disconnection, the owner, the owner's authorized agent or occupant of the building, structure or service system shall be notified in writing as soon as practical thereafter.

CHAPTER 2 [RS]

DEFINITIONS

User notes:

About this chapter: *Codes, by their very nature, are technical documents. Every word, term and punctuation mark can add to or change the meaning of a technical requirement. It is necessary to maintain a consensus on the specific meaning of each term contained in the code. Chapter 2 performs this function by stating clearly what specific terms mean for the purpose of the code.*

The source code for section numbers in parenthesis is the 2015 International Residential Code®, except where the International Fire Code® has been denoted.

SECTION RS201 (R201) GENERAL

RS201.1 (R201.1) Scope. Unless otherwise expressly stated, the following words and terms shall, for the purposes of [this code], have the meanings indicated in [this chapter].

Not all italicized terms in these provisions are defined in Chapter 2 [RS] of this document. Where terms are italicized and not defined herein, the definitions can be found in the code document that is the source of the section.

RS201.2 (R201.2) Interchangeability. Words used in the present tense include the future; words in the masculine gender include the feminine and neuter; the singular number includes the plural and the plural, the singular.

RS201.3 (R201.3) Terms defined in other codes. Where terms are not defined in [this code] such terms shall have the meanings ascribed in other code publications of the International Code Council.

RS201.4 (R201.4) Terms not defined. Where terms are not defined through the methods authorized by this section, such terms shall have ordinarily accepted meanings such as the context implies.

SECTION RS202 (R202) DEFINITIONS

Definitions in this section are from the International Residential Code.

ACCESSIBLE. For the definition applicable in (IRC) Chapter 11, see Section (N1101.6).

ACCESSIBLE, READILY. Signifies access without the necessity for removing a panel or similar obstruction.

ALTERATION. Any construction, retrofit or renovation to an existing structure other than repair or addition that requires a permit. Also, a change in a building, electrical, gas, mechanical or plumbing system that involves an extension, addition or change to the arrangement, type or purpose of the original installation that requires a permit.

APPLIANCE. A device or apparatus that is manufactured and designed to utilize energy and for which [this code] provides specific requirements.

APPROVED. Acceptable to the *building official*.

BATTERY SYSTEM, STATIONARY STORAGE. A rechargeable energy storage system consisting of electrochemical storage batteries, battery chargers, controls and associated electrical *equipment* designed to provide electrical power to a building. The system is typically used to provide standby or emergency power, an uninterruptable power supply, load shedding, load sharing or similar capabilities.

BUILDING-INTEGRATED PHOTOVOLTAIC PRODUCT. A building product that incorporates photovoltaic modules and functions as a component of the building envelope.

BUILDING-INTEGRATED PHOTOVOLTAIC ROOF PANEL (BIPV Roof Panel). A *photovoltaic panel* that functions as a component of the building envelope.

DIRECT SYSTEM. A solar thermal system in which the gas or liquid in the solar collector loop is not separated from the load.

DRAIN-BACK SYSTEM. A solar thermal system in which the fluid in the solar collector loop is drained from the collector into a holding tank under prescribed circumstances.

DWELLING. Any building that contains one or two *dwelling units* used, intended, or designed to be built, used, rented, leased, let or hired out to be occupied, or that are occupied for living purposes.

EQUIPMENT. Piping, ducts, vents, control devices and other components of systems other than appliances that are permanently installed and integrated to provide control of environmental conditions for buildings. This definition shall also include other systems specifically regulated in [this code].

ESSENTIALLY NONTOXIC TRANSFER FLUIDS. Fluids having a Gosselin rating of 1, including propylene glycol; mineral oil; polydimethy oil oxane; hydrochlorofluorocarbon, chlorofluorocarbon and hydrofluorocarbon refrigerants; and FDA-approved boiler water additives for steam boilers.

ESSENTIALLY TOXIC TRANSFER FLUIDS. Soil, water or gray water and fluids having a Gosselin rating of 2 or more including ethylene glycol, hydrocarbon oils, ammonia refrigerants and hydrazine.

HOT WATER. Water at a temperature greater than or equal to 110°F (43°C).

INDIRECT SYSTEM. A solar thermal system in which the gas or liquid in the solar collector loop circulates between the solar collector and a heat exchanger and such gas or liquid is not drained from the system or supplied to the load during normal operation.

LABEL. An identification applied on a product by the manufacturer that contains the name of the manufacturer, the function and performance characteristics of the product or material, and the name and identification of an *approved agency* and that indicates that the representative sample of the product or material has been tested and evaluated by an *approved agency*. (See also "Manufacturer's designation" and "Mark.")

LABELED. *Equipment*, materials or products to which have been affixed a *label*, seal, symbol or other identifying *mark* of a nationally recognized testing laboratory, approved agency or other organization concerned with product evaluation that maintains periodic inspection of the production of such *labeled* items and whose labeling indicates either that the *equipment*, material or product meets identified standards or has been tested and found suitable for a specified purpose. For the definition applicable in (IRC) Chapter 11, see Section (N1101.6).

LISTED. *Equipment*, materials, products or services included in a list published by an organization acceptable to the code official and concerned with evaluation of products or services that maintains periodic inspection of production of *listed equipment* or materials or periodic evaluation of services and whose listing states either that the *equipment*, material, product or service meets identified standards or has been tested and found suitable for a specified purpose. For the definition applicable in (IRC) Chapter 11, see Section (N1101.6).

PERMIT. An official document or certificate issued by the *building official* that authorizes performance of a specified activity.

PHOTOVOLTAIC MODULE. A complete, environmentally protected unit consisting of solar cells, optics and other components, exclusive of a tracker, designed to generate DC power where exposed to sunlight.

PHOTOVOLTAIC PANEL. A collection of photovoltaic modules mechanically fastened together, wired, and designed to provide a field-installable unit.

PHOTOVOLTAIC PANEL SYSTEM. A system that incorporates discrete photovoltaic panels that convert solar radiation into electricity, including rack support systems.

PHOTOVOLTAIC SHINGLES. A *roof covering* that resembles shingles and that incorporates photovoltaic modules.

PRESSURE-RELIEF VALVE. A pressure-actuated valve held closed by a spring or other means and designed to automatically relieve pressure at the pressure at which it is set.

RELIEF VALVE, VACUUM. A device to prevent excessive buildup of vacuum in a pressure vessel.

SOLAR ENERGY SYSTEM. A system that converts solar radiation to usable energy, including *photovoltaic panel systems* and *solar thermal systems*.

SOLAR THERMAL COLLECTOR. Components in a *solar thermal system* that collect and convert solar radiation to thermal energy.

SOLAR THERMAL SYSTEM. A system that converts solar radiation to thermal energy for use in heating or cooling.

TEMPERATURE- AND PRESSURE-RELIEF (T AND P) VALVE. A combination relief valve designed to function as both a temperature-relief and pressure-relief valve.

THIRD-PARTY CERTIFICATION AGENCY. An approved agency operating a product or material certification system that incorporates initial product testing, assessment and surveillance of a manufacturer's quality control system.

THIRD-PARTY CERTIFIED. Certification obtained by the manufacturer indicating that the function and performance characteristics of a product or material have been determined by testing and ongoing surveillance by an approved third-party certification agency. Assertion of certification is in the form of identification in accordance with the requirements of the third-party certification agency.

CHAPTER 3 [RS]

SOLAR THERMAL AND AUXILIARY SYSTEMS

User notes:

About this chapter: *Chapter 3 is specific to thermal solar systems and equipment. Solar photovoltaic systems are not addressed in this chapter. This chapter covers solar collectors, system design, safety devices, relief valves, freeze protection, expansion tanks, signage, labeling, heat transfer fluids, protection of potable water and potable water heating.*

The source code for section numbers in parenthesis is the 2015 International Residential Code®, except where the International Fire Code® has been denoted.

PART 1—SOLAR THERMAL SYSTEMS

SECTION RS301 (M2301) THERMAL SOLAR ENERGY SYSTEMS

RS301.1 (M2301.1) General. This section provides for the design, construction, installation, *alteration* and repair of *equipment* and systems using thermal solar energy to provide space heating or cooling, hot water heating and swimming pool heating.

RS301.2 (M2301.2) Design and installation. The design and installation of thermal solar energy systems shall comply with Sections RS301.2.1 (M2301.2.1) through RS301.2.13 (M2301.2.13).

RS301.2.1 (M2301.2.1) Access. Access shall be provided to solar energy *equipment* for maintenance. Solar systems and appurtenances shall not obstruct or interfere with the operation of any doors, windows or other building components requiring operation or access. Roof-mounted solar thermal equipment shall not obstruct or interfere with the operation of roof-mounted equipment, appliances, chimneys, plumbing vents, roof hatches, smoke vents, skylights and other roof penetrations and openings.

RS301.2.2 (M2301.2.2) Collectors and panels. Solar collectors and panels shall comply with Sections RS301.2.2.1 (M2301.2.2.1) and RS301.2.2.2 (M2301.2.2.2).

RS301.2.2.1 (IFC 317.3) Rooftop structure and equipment clearance. For all vegetated roofing systems abutting combustible vertical surfaces, a Class A-rated roof system complying with ASTM E108 or UL 790 shall be achieved for a minimum 6-foot-wide (1829 mm) continuous border placed around rooftop structures and all rooftop equipment including, but not limited to, mechanical and machine rooms, penthouses, skylights, roof vents, solar panels, antenna supports and building service equipment.

RS301.2.2.2 (M2301.2.2.1) Roof-mounted collectors. The roof shall be constructed to support the loads imposed by roof-mounted solar collectors. Roof-mounted solar collectors that serve as a roof covering shall conform to the requirements for roof coverings in (IRC) Chapter 9 of [this code]. Where mounted on or above the roof coverings, the collectors and supporting structure shall be constructed of noncombustible materials or fire-retardant-treated wood equivalent to that required for the roof construction.

RS301.2.2.3 (M2301.2.2.2) Collector sensors. Collector sensor installation, sensor location and the protection of exposed sensor wires from degradation shall be in accordance with ICC 900/SRCC 300.

RS301.2.3 (M2301.2.3) Pressure and temperature relief valves and system components. System components containing fluids shall be protected with temperature and pressure relief valves or pressure relief valves. Relief devices shall be installed in sections of the system so that a section cannot be valved off or isolated from a relief device. Direct systems and the potable water portion of indirect systems shall be equipped with a relief valve in accordance with Section (P2804). For indirect systems, pressure relief valves in solar loops shall comply with ICC 900/SRCC 300. System components shall have a working pressure rating of not less than the setting of the pressure relief device.

RS301.2.4 (M2301.2.4) Vacuum relief. System components that might be subjected to a vacuum during operation or shutdown shall be designed to withstand such a vacuum or shall be protected with vacuum relief valves.

RS301.2.5 (M2301.2.5) Piping insulation. Piping shall be insulated in accordance with the requirements of (IRC) Chapter 11. Exterior insulation shall be protected from ultraviolet degradation. The entire solar loop shall be insulated. Where split-style insulation is used, the seam shall be sealed. Fittings shall be fully insulated.

Exceptions:

1. Those portions of the piping that are used to help prevent the system from overheating shall not be required to be insulated.
2. Those portions of piping that are exposed to solar radiation, made of the same material as the solar collector absorber plate and are covered in the same manner as the solar collector absorber, or that are used to collect additional solar energy, shall not be required to be insulated.
3. Piping in thermal solar systems using unglazed solar collectors to heat a swimming pool shall not be required to be insulated.

RS301.2.6 (M2301.2.6) Protection from freezing. System components shall be protected from damage resulting from freezing of heat-transfer liquids at the winter design temperature provided in Table (IRC R301.2(1)). Freeze protection shall be provided in accordance with ICC 900/SRCC 300. Drain-back systems shall be installed in compliance with Section (M2301.2.6.1). Systems utilizing freeze-protection valves shall comply with Section (M2301.2.6.2).

Exception: Where the 97.5-percent winter design temperature is greater than or equal to 48°F (9°C).

RS301.2.7 (M2301.2.7) Storage tank sensors. Storage tank sensors shall comply with ICC 900/SRCC 300.

RS301.2.8 (M2301.2.8) Expansion tanks. Expansion tanks in solar energy systems shall be installed in accordance with Section (M2003) in solar collector loops that contain pressurized heat transfer fluid. Where expansion tanks are used, the system shall be designed in accordance with ICC 900/SRCC 300 to provide an expansion tank that is sized to withstand the maximum operating pressure of the system.

Exception: Expansion tanks shall not be required in the collector loop of *drain-back systems*.

RS301.2.9 (M2301.2.9) Roof and wall penetrations. Roof and wall penetrations shall be flashed and sealed in accordance with (IRC) Chapter 9 to prevent entry of water, rodents and insects.

RS301.2.10 (M2301.2.10) Description and warning labels. Solar thermal systems shall comply with description label and warning label requirements of Section RS301.2.11.2 (M2301.2.11.2) and ICC 900/SRCC 300.

RS301.2.11 (M2301.2.11) Solar loop. Solar loops shall be in accordance with Sections RS301.2.11.1 (M2301.2.11.1) and RS301.2.11.2 (M2301.2.11.2).

RS301.2.11.1 (M2301.2.11.1) Solar loop isolation. Valves shall be installed to allow the solar collectors to be isolated from the remainder of the system.

RS301.2.11.2 (M2301.2.11.2) Drain and fill valve labels and caps. Drain and fill valves shall be labeled with a description and warning that identifies the fluid in the solar loop and a warning that the fluid might be discharged at high temperature and pressure. Drain caps shall be installed at drain and fill valves.

RS301.2.12 (M2301.2.12) Maximum temperature limitation. Systems shall be equipped with means to limit the maximum water temperature of the system fluid entering or exchanging heat with any pressurized vessel inside the *dwelling* to 180°F (82°C). This protection is in addition to the required temperature- and pressure-relief valves required by Section RS301.2.3 (M2301.2.3).

RS301.2.13 (M2301.2.13) Thermal storage unit seismic bracing. In Seismic Design Categories D_0, D_1 and D_2 and in townhouses in Seismic Design Category C, thermal storage units shall be anchored in accordance with Section (M1307.2).

RS301.3 (M2301.3) Labeling. *Labeling* shall comply with Sections RS301.3.1 (M2301.3.1) and RS301.3.2 (M2301.3.2).

RS301.3.1 (M2301.3.1) Collectors and panels. Solar thermal collectors and panels shall be listed and labeled in accordance with ICC 901/SRCC 100. Factory-built collectors shall bear a label indicating the manufacturer's name, model number and serial number.

RS301.3.2 (M2301.3.2) Thermal storage units. Pressurized water storage tanks shall bear a label indicating the manufacturer's name and address, model number, serial number, storage unit maximum and minimum allowable operating temperatures and storage unit maximum and minimum allowable operating pressures. The *label* shall clarify that these specifications apply only to the water storage tanks.

RS301.4 (M2301.4) Heat transfer gasses or liquids and heat exchangers. *Essentially toxic transfer fluids*, ethylene glycol, flammable gases and flammable liquids shall not be used as heat transfer fluids. Heat transfer gasses and liquids shall be rated to withstand the system's maximum design temperature under operating conditions without degradation. Heat exchangers used in solar thermal systems shall comply with Section RS303.1.2 (P2902.5.2) and ICC 900/SRCC 300.

Heat transfer fluids shall be in accordance with ICC 900/SRCC 300. The flash point of the heat transfer fluids utilized in solar thermal systems shall be not less than 50°F (28°C) above the design maximum nonoperating or no-flow temperature attained by the fluid in the collector.

RS301.5 (M2301.5) Backflow protection. Connections from the potable water supply to solar systems shall comply with Section RS303.1.3 (P2902.5.5).

RS301.6 (M2301.6) Filtering. Air provided to occupied spaces that passes through thermal mass storage systems by mechanical means shall be filtered for particulates at the outlet of the thermal mass storage system.

RS301.7 (M2301.7) Solar thermal systems for heating potable water. Where a solar thermal system heats potable water to supply a potable hot water distribution system, the solar thermal system shall be in accordance with Sections RS301.7.1 (M2301.7.1), RS301.7.2 (M2301.7.2) and RS303.1.3 (P2902.5.5).

RS301.7.1 (M2301.7.1) Indirect systems. Heat exchangers that are components of indirect solar thermal heating systems shall comply with Section RS303.1.2 (P2902.5.2).

RS301.7.2 (M2301.7.2) Direct systems. Where potable water is directly heated by a solar thermal system, the pipe, fittings, valves and other components that are in contact with the potable water in the solar heating system shall comply with the requirements of (IRC) Chapter 29.

The requirements for Chapter 29 of the International Residential Code can be found in Section RS303 of the International Solar Energy Provisions.

SECTION RS302 (P2802)
SOLAR WATER HEATING SYSTEMS

RS302.1 (P2802.1) Water temperature control. Where heated water is discharged from a solar thermal system to a *hot water* distribution system, a thermostatic mixing valve complying with ASSE 1017 shall be installed to temper the water to a temperature of not greater than 140°F (60°C). Solar thermal systems supplying *hot water* for both space heating and domestic uses shall comply with Section RS302.3 (P2803.2). A temperature-indicating device shall be installed to indicate the temperature of the water discharged from the outlet of the mixing valve. The thermostatic mixing valve required by this section shall not be a substitute for water temperature limiting devices required by (IRC) Chapter 27 for specific fixtures.

RS302.2 (P2802.2) Isolation valves. Isolation valves in accordance with RS303.2 (P2903.9.2) shall be provided on the cold water feed to the water heater. Isolation valves and associated piping shall be provided to bypass solar storage tanks where the system contains multiple storage tanks.

RS302.3 (P2803.2) Temperature control. Where a combination water heater-space heating system requires water for space heating at temperatures exceeding 140°F (60°C), a master thermostatic mixing valve complying with ASSE 1017 shall be installed to temper the water to a temperature of not greater than 140°F (60°C) for domestic uses.

SECTION RS303 (P2902)
PROTECTION OF POTABLE WATER SUPPLY

RS303.1 (P2902.5) Protection of potable water connections. Connections to the potable water shall conform to Sections RS303.1.1 (P2902.5.1) through RS303.1.3 (P2902.5.5).

RS303.1.1 (P2902.5.1) Connections to boilers. Where chemicals will not be introduced into a boiler, the potable water supply to the boiler shall be protected from the boiler by a backflow preventer with an intermediate atmospheric vent complying with ASSE 1012 or CSA B64.3. Where chemicals will be introduced into a boiler, the potable water supply to the boiler shall be protected from the boiler by an *air gap* or a reduced pressure principle backflow prevention assembly complying with ASSE 1013, CSA B64.4 or AWWA C511.

RS303.1.2 (P2902.5.2) Heat exchangers. Heat exchangers using an essentially toxic transfer fluid shall be separated from the potable water by double-wall construction. An *air gap* open to the atmosphere shall be provided between the two walls. Single-wall construction heat exchangers shall be used only where an *essentially nontoxic transfer fluid* is utilized.

RS303.1.3 (P2902.5.5) Solar thermal systems. Where a solar thermal system heats potable water to supply a potable *hot water* distribution or any other type of heating system, the solar thermal system shall be in accordance with Section RS303.1.3.1 (P2902.5.5.1), RS303.1.3.2 (P2902.5.5.2) or RS303.1.3.3 (P2902.5.5.3) as applicable.

RS303.1.3.1 (P2902.5.5.1) Indirect systems. Water supplies of any type shall not be connected to the solar heating loop of an indirect solar thermal *hot water* heating system. This requirement shall not prohibit the presence of inlets or outlets on the solar heating loop for the purposes of servicing the fluid in the solar heating loop.

RS303.1.3.2 (P2902.5.5.2) Direct systems for potable water distribution systems. Where a solar thermal system directly heats potable water for a potable water distribution system, the pipe, fittings, valves and other components that are in contact with the potable water in the system shall comply with the requirements of (IRC) Chapter 29.

RS303.1.3.3 (P2902.5.5.3) Direct systems for other than potable water distribution systems. Where a solar thermal system directly heats water for a system other than a potable water distribution system, a potable water supply connected to such system shall be protected by a backflow preventer with an intermediate atmospheric vent complying with ASSE 1012. Where a solar thermal system directly heats chemically treated water for a system other than a potable water distribution system, a potable water supply connected to such system shall be protected by a reduced pressure principle backflow prevention assembly complying with ASSE 1013.

RS303.2 (P2903.9.2) Water heater valve. A *readily accessible* full-open valve shall be installed in the cold-water supply pipe to each water heater at or near the water heater.

RS303.3 (P2912.2) Collection surface. Rainwater shall be collected only from above-ground impervious roofing surfaces constructed from *approved* materials. Collection of water from vehicular parking or pedestrian walkway surfaces shall be prohibited except where the water is used exclusively for landscape irrigation. Overflow and bleed-off pipes from roof-mounted *appliances* including, but not limited to, evaporative coolers, water heaters and solar water heaters shall not discharge onto rainwater collection surfaces.

This section refers to nonpotable rainwater collection and distribution systems.

PART 2—AUXILIARY AND BACKUP THERMAL SYSTEMS

SECTION RS304 (M2001)
BOILERS

RS304.1 (M2001.1) Installation. In addition to the requirements of [this code], the installation of boilers shall conform to the manufacturer's instructions. The manufacturer's rating data, the nameplate and operating instructions of a permanent type shall be attached to the boiler. Boilers shall have their controls set, adjusted and tested by the installer. A complete control diagram together with complete boiler operating instructions shall be furnished by the installer. Solid and liquid fuel-burning boilers shall be provided with *combustion air* as required by (IRC) Chapter 17.

RS304.1.1 (M2001.1.1) Standards. Packaged oil-fired boilers shall be *listed* and *labeled* in accordance with UL 726. Packaged electric boilers shall be *listed* and *labeled* in accordance with UL 834. Solid fuel-fired boilers shall be *listed* and *labeled* in accordance with UL 2523. Boilers shall be designed, constructed and certified in accordance with the ASME *Boiler and Pressure Vessel Code*, Section I or IV. Controls and safety devices for boilers with fuel input ratings of 12,500,000 Btu/hr (3663 kW) or less shall meet the requirements of ASME CSD-1. Gas-fired boilers shall conform to the requirements listed in (IRC) Chapter 24.

RS304.2 (M2001.2) Clearance. Boilers shall be installed in accordance with their *listing* and *label*.

RS304.3 (M2001.3) Valves. Every boiler or modular boiler shall have a shutoff valve in the supply and return piping. For multiple boiler or multiple modular boiler installations, each boiler or modular boiler shall have individual shutoff valves in the supply and return piping.

Exception: Shutoff valves are not required in a system having a single low-pressure steam boiler.

RS304.4 (M2001.4) Flood-resistant installation. In flood hazard areas established in Table (IRC R301.2(1)), boilers, water heaters and their control systems shall be located or installed in accordance with Section (R322.1.6).

SECTION RS305 (M2002)
OPERATING AND SAFETY CONTROLS

RS305.1 (M2002.1) Safety controls. Electrical and mechanical operating and safety controls for boilers shall be *listed* and *labeled*.

RS305.2 (M2002.2) Hot water boiler gauges. Every hot water boiler shall have a pressure gauge and a temperature gauge, or combination pressure and temperature gauge. The gauges shall indicate the temperature and pressure within the normal range of the system's operation.

RS305.3 (M2002.3) Steam boiler gauges. Every steam boiler shall have a water-gauge glass and a pressure gauge. The pressure gauge shall indicate the pressure within the normal range of the system's operation. The gauge glass shall be installed so that the midpoint is at the normal water level.

RS305.4 (M2002.4) Pressure relief valve. Boilers shall be equipped with pressure relief valves with minimum rated capacities for the *equipment* served. Pressure-relief valves shall be set at the maximum rating of the boiler. Discharge shall be piped to drains by gravity to within 18 inches (457 mm) of the floor or to an open receptor.

RS305.5 (M2002.5) Boiler low-water cutoff. Steam and hot water boilers shall be protected with a low-water cutoff control.

Exception: A low-water cutoff is not required for coil-type and water-tube type boilers that require forced circulation of water through the boiler and that are protected with a flow sensing control.

RS305.6 (M2002.6) Operation. Low-water cutoff controls and flow sensing controls required by Section RS305.5 (M2002.5) shall automatically stop the combustion operation of the appliance when the water level drops below the lowest safe water level as established by the manufacturer or when the water circulation flow is less than that required for safe operation of the appliance, respectively.

SECTION RS306 (M2003)
EXPANSION TANKS

RS306.1 (M2003.1) General. Hot water boilers shall be provided with expansion tanks. Nonpressurized expansion tanks shall be securely fastened to the structure or boiler and supported to carry twice the weight of the tank filled with water. Provisions shall be made for draining nonpressurized tanks without emptying the system.

RS306.1.1 (M2003.1.1) Pressurized expansion tanks. Pressurized expansion tanks shall be consistent with the volume and capacity of the system. Tanks shall be capable of withstanding a hydrostatic test pressure of two and one-half times the allowable working pressure of the system.

RS306.2 (M2003.2) Minimum capacity. The minimum capacity of expansion tanks shall be determined from Table RS306.2 (Table M2003.2).

TABLE RS306.2 (TABLE M2003.2)
EXPANSION TANK MINIMUM CAPACITY[a]
FOR FORCED HOT-WATER SYSTEMS

SYSTEM VOLUME[b] (gallons)	PRESSURIZED DIAPHRAGM TYPE	NONPRESSURIZED TYPE
10	1.0	1.5
20	1.5	3.0
30	2.5	4.5
40	3.0	6.0
50	4.0	7.5
60	5.0	9.0
70	6.0	10.5
80	6.5	12.0
90	7.5	13.5
100	8.0	15.0

For SI: 1 gallon = 3.785 L, 1 pound per square inch gauge = 6.895 kPa, °C = [(°F)-32]/1.8.

a. Based on average water temperature of 195°F, fill pressure of 12 psig and an operating pressure of not greater than 30 psig.

b. System volume includes volume of water in boiler, convectors and piping, not including the expansion tank.

SECTION RS307 (M2004)
WATER HEATERS USED FOR SPACE HEATING

RS307.1 (M2004.1) General. Water heaters used to supply both potable hot water and hot water for space heating shall be installed in accordance with [this chapter], (IRC) Chapter 24, (IRC) Chapter 28 and the manufacturer's instructions.

SECTION RS308 (M2005)
WATER HEATERS

RS308.1 (M2005.1) General. Water heaters shall be installed in accordance with (IRC) Chapter 28, the manufacturer's instructions and the requirements of [this code]. Water heaters installed in an attic shall comply with the requirements of Section (M1305.1.2). Gas-fired water heaters shall comply with the requirements in (IRC) Chapter 24. Domestic electric water heaters shall comply with UL 174. Oiled-fired water heaters shall comply with UL 732. Solar thermal water heating systems shall comply with (IRC) Chapter 23 and ICC 900/SRCC 300. Solid fuel-fired water heaters shall comply with UL 2523.

RS308.2 (M2005.2) Prohibited locations. Fuel-fired water heaters shall not be installed in a room used as a storage closet. Water heaters located in a bedroom or bathroom shall be installed in a sealed enclosure so that *combustion air* will not be taken from the living space. Installation of direct-vent water heaters within an enclosure is not required.

RS308.2.1 (M2005.2.1) Water heater access. Access to water heaters that are located in an *attic* or underfloor crawl space is permitted to be through a closet located in a sleeping room or bathroom where *ventilation* of those spaces is in accordance with [this code].

RS308.3 (M2005.3) Electric water heaters. Electric water heaters shall also be installed in accordance with the applicable provisions of (IRC) Chapters 34 through 43.

RS308.4 (M2005.4) Supplemental water-heating devices. Potable water heating devices that use refrigerant-to-water heat exchangers shall be *approved* and installed in accordance with the manufacturer's instructions.

SECTION RS309 (ISPSC 316)
SWIMMING POOL AND SPA HEATERS

RS309.1 (ISPSC 316.1) General. The provisions of this section apply to heaters for pools and spas.

Exception: Portable *residential* spas and portable *residential* exercise spas.

RS309.2 (ISPSC 316.2) Listed and labeled. Heaters and hot water storage tanks shall be listed and labeled in accordance with the applicable standard listed in Table RS309.2 (ISPSC Table 316.2).

RS309.3 (M2006.1) General. Pool and spa heaters shall be installed in accordance with the manufacturer's installation instructions. Oil-fired pool heaters shall comply with UL 726. Electric pool and spa heaters shall comply with UL 1261. Pool and spa heat pump water heaters shall comply with UL 1995 or CSA C22.2 No. 236.

Exception: Portable residential spas and portable residential exercise spas shall comply with UL 1563 or CSA C22.2 No. 218.1.

RS309.4 (M2006.2) Clearances. The clearances shall not interfere with *combustion air*, draft hood or flue terminal relief, or accessibility for servicing.

RS309.5 (M2006.3) Bypass valves. Where an integral bypass system is not provided as a part of the pool heater, a bypass line and valve shall be installed between the inlet and outlet piping for use in adjusting the flow of water through the heater.

RS309.6 (ISPSC 316.6) Solar thermal water heaters. Solar thermal heaters utilized for pools and spas shall comply with Sections RS309.6.1 (ISPSC 316.6.1) through RS309.6.2 (ISPSC 316.6.2).

RS309.6.1 (ISPSC 316.6.1) Installation. Solar thermal water heaters shall be installed in accordance with the *International Mechanical Code* or *International Residential Code*, as applicable in accordance with Section (ISPSC 102.7.1).

RS309.6.2 (ISPSC 316.6.2) Collectors and panels. Solar thermal collectors and panels shall be *listed* and *labeled* in accordance with ICC 901/SRCC 100 or ICC 900/SRCC 300. Collectors and panels shall be permanently marked with the manufacturer's name, model number, and serial number. Such markings shall be located on each collector in a position that is readily viewable after installation of the collector or panel.

SECTION RS310 (N1103)
SYSTEMS

(Energy Efficiency)

RS310.1 (N1103.4) Mechanical system piping insulation (Mandatory). Mechanical system piping capable of carrying fluids greater than 105°F (41°C) or less than 55°F (13°C) shall be insulated to an *R*-value of not less than R-3.

RS310.1.1 (N1103.4.1) Protection of piping insulation. Piping insulation exposed to weather shall be protected from damage, including that caused by sunlight, moisture, equipment maintenance and wind. The protection shall provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall be prohibited.

TABLE RS309.2 (ISPSC TABLE 316.2)
WATER HEATERS

DEVICE	STANDARD
Electric water heater	UL 1261, UL 1563 or CSA C22.2 No. 218.1
Gas-fired water heater	ANSI Z21.56/CSA 4.7a
Heat exchanger	AHRI 400
Heat pump water heater	UL 1995, AHRI 1160, CSA C22.2 No. 236

RS310.2 (N1103.10) Pools and permanent spa energy consumption (Mandatory). The energy consumption of pools and permanent spas shall be in accordance with Sections (N1103.10.1) through (N1103.10.3).

RS310.3 (N1103.10.2) Time switches. Time switches or other control methods that can automatically turn off and on according to a preset schedule shall be installed for heaters and pump motors. Heaters and pump motors that have built-in time switches shall be in compliance with this section.

Exceptions:

1. Where public health standards require 24-hour pump operation.
2. Pumps that operate solar- and waste-heat-recovery pool heating systems.

RS310.4 (N1103.10.3) Covers. Outdoor heated pools and outdoor permanent spas shall be provided with a vapor retardant cover or other *approved* vapor-retardant means.

Exception: Where more than 75 percent of the energy for heating, computed over an operation season of not less than 3 calendar months, is from a heat pump or an on-site renewable energy system, covers or other vapor-retardant means shall not be required.

CHAPTER 4 [RS]
PHOTOVOLTAIC SYSTEMS

User notes:

About this chapter: *Chapter 4 is specific to photovoltaic solar systems and equipment. Solar thermal systems are not addressed in this chapter. This chapter covers solar modules and shingles, system design, and roof access and pathways.*

The source code for section numbers in parenthesis is the 2015 International Residential Code®, except where the International Fire Code® has been denoted.

SECTION RS401 (R301)
DESIGN CRITERIA

RS401.1 (R301.1) Application. Buildings and structures, and parts thereof, shall be constructed to safely support all loads, including dead loads, live loads, roof loads, flood loads, snow loads, wind loads and seismic loads as prescribed by [this code]. The construction of buildings and structures in accordance with the provisions of [this code] shall result in a system that provides a complete load path that meets the requirements for the transfer of loads from their point of origin through the load-resisting elements to the foundation. Buildings and structures constructed as prescribed by [this code] are deemed to comply with the requirements of this section.

SECTION RS402 (R324)
SOLAR ENERGY SYSTEMS

RS402.1 (R324.3) Photovoltaic systems. Photovoltaic systems shall be designed and installed in accordance with Sections RS402.1.1 (R324.3.1) through RS402.5.1 (R324.7.1), NFPA 70 and the manufacturer's installation instructions.

RS402.1.1 (R324.3.1) Equipment listings. Photovoltaic panels and modules shall be listed and labeled in accordance with UL 1703. Inverters shall be *listed* and *labeled* in accordance with UL 1741. Systems connected to the utility grid shall use inverters *listed* for utility interaction.

RS402.2 (R324.4) Rooftop-mounted photovoltaic systems. Rooftop-mounted *photovoltaic panel systems* installed on or above the roof covering shall be designed and installed in accordance this section.

RS402.2.1 (R324.4.1) Structural requirements. Rooftop-mounted *photovoltaic panel systems* shall be designed to structurally support the system and withstand applicable gravity loads in accordance with Chapter 3. The roof on which these systems are installed shall be designed and constructed to support the loads imposed by such systems in accordance with Chapter 8.

RS402.2.1.1 (R324.4.1.1) Roof load. Portions of roof structures not covered with *photovoltaic panel systems* shall be designed for dead loads and roof loads in accordance with Sections (R301.4) and (R301.6). Portions of roof structures covered with *photovoltaic panel systems* shall be designed for the following load cases:

1. Dead load (including *photovoltaic panel* weight) plus snow load in accordance with Table (IRC R301.2(1)).
2. Dead load (excluding *photovoltaic panel* weight) plus roof live load or snow load, whichever is greater, in accordance with Section (R301.6).

RS402.2.1.2 (R324.4.1.2) Wind load. Rooftop-mounted *photovoltaic panel* or *module* systems and their supports shall be designed and installed to resist the component and cladding loads specified in Table (R301.2(2)), adjusted for height and exposure in accordance with Table (R301.2(3)).

RS402.3 (R324.5) Building-integrated photovoltaic systems. Building-integrated photovoltaic systems that serve as roof coverings shall be designed and installed in accordance with Section RS404 (R905).

RS402.3.1 (R324.5.1) Photovoltaic shingles. Photovoltaic shingles shall comply with Section RS404.2 (R905.16).

RS402.3.2 (R324.5.2) Fire classification. *Building-integrated photovoltaic systems* shall have a fire classification in accordance with Section R902.3.

RS402.4 (R324.6) Roof access and pathways. Roof access, pathways and setback requirements shall be provided in accordance with Sections RS402.4.1 (R324.6.1) through RS402.4.2 (R324.6.2). Access and minimum spacing shall be required to provide emergency access to the roof, to provide pathways to specific areas of the roof, provide for smoke ventilation opportunity areas, and to provide emergency egress from the roof.

Exceptions:

1. Detached, nonhabitable structures, including but not limited to detached garages, parking shade structures, carports, solar trellises and similar structures, shall not be required to provide roof access.

2. Roof access, pathways and setbacks need not be provided where the code official has determined that rooftop operations will not be employed.
3. These requirements shall not apply to roofs with slopes of two units vertical in 12 units horizontal (17-percent slope) or less.

RS402.4.1 (R324.6.1) Pathways. Not fewer than two pathways, on separate roof planes from lowest roof edge to ridge and not less than 36 inches (914 mm) wide, shall be provided on all buildings. Not fewer than one pathway shall be provided on the street or driveway side of the roof. For each roof plane with a photovoltaic array, a pathway not less than 36 inches wide (914 mm) shall be provided from the lowest roof edge to ridge on the same roof plane as the photovoltaic array, on an adjacent roof plane, or straddling the same and adjacent roof planes. Pathways shall be over areas capable of supporting fire fighters accessing the roof. Pathways shall be located in areas with minimal obstructions such as vent pipes, conduit, or mechanical equipment.

RS402.4.2 (R324.6.2) Setback at ridge. For photovoltaic arrays occupying not more than 33 percent of the plan view total roof area, not less than an 18-inch (457 mm) clear setback is required on both sides of a horizontal ridge. For photovoltaic arrays occupying more than 33 percent of the plan view total roof area, not less than a 36-inch (914 mm) clear setback is required on both sides of a horizontal ridge.

RS402.4.2.1 (R324.6.2.1) Alternative setback at ridge. Where an automatic sprinkler system is installed within the dwelling in accordance with NFPA 13D or Section (P2904), setbacks at ridges shall comply with one of the following:

1. For photovoltaic arrays occupying not more than 66 percent of the plan view total roof area, not less than an 18-inch (457 mm) clear setback is required on both sides of a horizontal ridge.
2. For photovoltaic arrays occupying more than 66 percent of the plan view total roof area, not less than a 36-inch (914 mm) clear setback is required on both sides of a horizontal ridge.

RS402.4.2.2 (R324.6.2.2) Emergency escape and rescue opening. Panels and modules installed on dwellings shall not be placed on the portion of a roof that is below an emergency escape and rescue opening. A pathway not less than 36 inches (914 mm) wide shall be provided to the emergency escape and rescue opening.

RS402.5 (R324.7) Ground-mounted photovoltaic systems. Ground- mounted photovoltaic systems shall be designed and in-stalled in accordance with Section RS401 (R301).

RS402.5.1 (R324.7.1) Fire separation distances. Ground-mounted photovoltaic systems shall be subject to the *fire separation distance* requirements determined by the local *jurisdiction*.

SECTION RS403 (R902)
FIRE CLASSIFICATION

RS403.1 (R902.1) Roofing covering materials. Roofs shall be covered with materials as set forth in Sections (R904) and RS404 (R905). Class A, B or C roofing shall be installed in jurisdictions designated by law as requiring their use or where the edge of the roof is less than 3 feet (914 mm) from a lot line. Class A, B and C roofing required by this section to be listed shall be tested in accordance with UL 790 or ASTM E108.

Exceptions:

1. Class A roof assemblies include those with coverings of brick, masonry and exposed concrete roof deck.
2. Class A roof assemblies include ferrous or copper shingles or sheets, metal sheets and shingles, clay or concrete roof tile, or slate installed on noncombustible decks.
3. Class A roof assemblies include minimum 16 ounces per square foot copper sheets installed over combustible decks.
4. Class A roof assemblies include slate installed over underlayment over combustible decks.

RS403.2 (R902.2) Fire-retardant-treated shingles and shakes. Fire-retardant-treated wood shakes and shingles shall be treated by impregnation with chemicals by the full-cell vacuum-pressure process, in accordance with AWPA C1. Each bundle shall be marked to identify the manufactured unit and the manufacturer, and shall be *labeled* to identify the classification of the material in accordance with the testing required in Section RS403.1 (R902.1), the treating company and the quality control agency.

RS403.3 (R902.3) Building-integrated photovoltaic product. Building-integrated photovoltaic products installed as the roof covering shall be tested, listed and labeled for fire classification in accordance with Section RS403.1 (R902.1).

RS403.4 (R902.4) Rooftop-mounted photovoltaic panel systems. Rooftop-mounted *photovoltaic panel systems* installed on or above the roof covering shall be tested, listed and identified with a fire classification in accordance with UL 1703 and UL 2703. Class A, B or C *photovoltaic panel systems* shall be installed in jurisdictions designated by law as requiring their use or where the edge of the roof is less than 3 feet (914 mm) from a lot line.

SECTION RS404 (R905)
REQUIREMENTS FOR ROOF COVERINGS

RS404.1 (R905.1) Roof covering application. Roof coverings shall be applied in accordance with the applicable provisions of this section and the manufacturer's installation instructions. Unless otherwise specified in this section, roof coverings shall be installed to resist the component and cladding loads specified in Table (IRC R301.2(2)), adjusted for height and exposure in accordance with Table (IRC R301.2(3)).

RS404.1.1 (R905.1.1) Underlayment. *Underlayment* for asphalt shingles, clay and concrete tile, metal roof shingles, mineral-surfaced roll roofing, slate and slate-type shingles, wood shingles, wood shakes, metal roof panels and *photovoltaic shingles* shall conform to the applicable standards listed in [this chapter]. *Underlayment* materials required to comply with ASTM D226, D1970, D4869 and D6757 shall bear a label indicating compliance to the standard designation and, if applicable, type classification indicated in Table (IRC R905.1.1(1)). *Underlayment* shall be applied in accordance with Table (IRC R905.1.1(2)). *Underlayment* shall be attached in accordance with Table (IRC R905.1.1(3)).

Exceptions:

1. As an alternative, self-adhering polymer-modified bitumen *underlayment* complying with ASTM D1970 installed in accordance with both the *underlayment* manufacturer's and roof covering manufacturer's instructions for the deck material, roof ventilation configuration and climate exposure for the roof covering to be installed, shall be permitted.
2. As an alternative, a minimum 4-inch-wide (102 mm) strip of self-adhering polymer-modified bitumen membrane complying with ASTM D1970, installed in accordance with the *manufacturer's installation instructions* for the deck material, shall be applied over all joints in the roof decking. An *approved underlayment* for the applicable roof covering for maximum ultimate design wind speeds, V_{ult}, less than 140 miles per hour shall be applied over the entire roof over the 4-inch-wide (102 mm) membrane strips.
3. As an alternative, two layers of *underlayment* complying with ASTM D226 Type II or ASTM D4869 Type III or Type IV shall be permitted to be installed as follows in 3.1–3.4:
    3.1. Apply a 19-inch-wide (483 mm) strip of *underlayment* parallel with the eave. Starting at the eave, apply 36-inch-wide (914 mm) strips of *underlayment* felt, overlapping successive sheets 19 inches (483 mm). End laps shall be 4 inches (102 mm) and shall be offset by 6 feet (1829 mm).
    3.2. The *underlayment* shall be attached with corrosion-resistant fasteners in a grid pattern of 12 inches (305 mm) between side laps with a 6-inch (152 mm) spacing at side and end laps.
    3.3. *Underlayment* shall be attached using metal or plastic cap nails with a nominal cap diameter of not less than 1 inch (25 mm). Metal caps shall have a thickness of not less than 32-gage sheet metal. Power-driven metal caps shall have a thickness of not less than 0.010 inch (0.25 mm). Minimum thickness of the outside edge of plastic caps shall be 0.035 inch (0.89 mm).
    3.4. The cap nail shank shall be not less than 0.083 inch (2.11 mm) for ring shank cap nails and 0.091 inch (2.31 mm) for smooth shank cap nails. Cap nail shank shall have a length sufficient to penetrate through the roof sheathing or not less than $^3/_4$ inch (19 mm) into the roof sheathing.

RS404.2 (R905.16) Photovoltaic shingles. The installation of *photovoltaic shingles* shall comply with the provisions of this section, Section RS402 (R324) and NFPA 70.

RS404.2.1 (R905.16.1) Deck requirements. *Photovoltaic shingles* shall be applied to a solid or closely-fitted deck, except where the roof covering is specifically designed to be applied over spaced sheathing.

RS404.2.2 (R905.16.2) Deck slope. *Photovoltaic shingles* shall be used only on roof slopes of two units vertical in 12 units horizontal (2:12) or greater.

RS404.2.3 (R905.16.3) Underlayment. *Underlayment* shall comply with Section RS404.1.1 (R905.1.1).

RS404.2.4 (R905.16.4) Material standards. *Photovoltaic shingles* shall be listed and labeled in accordance with UL 1703.

RS404.2.5 (R905.16.5) Attachment. *Photovoltaic shingles* shall be attached in accordance with the manufacturer's installation instructions.

RS404.2.6 (R905.16.6) Wind resistance. *Photovoltaic shingles* shall be tested in accordance with procedures and acceptance criteria in ASTM D3161. *Photovoltaic shingles* shall comply with the classification requirements of Table (IRC R905.2.4.1) for the appropriate maximum basic wind speed. *Photovoltaic shingle* packaging shall bear a label to indicate compliance with the procedures in ASTM D3161 and the required classification from Table (IRC R905.2.4.1).

RS404.3 (R905.17) Building-integrated Photovoltaic (BIPV) roof panels applied directly to the roof deck. The installation of *BIPV roof panels* shall comply with the provisions of this section, Section RS402 (R324) and NFPA 70.

RS404.3.1 (R905.17.1) Deck requirements. *BIPV roof panels* shall be applied to a solid or closely-fitted deck, except where the roof covering is specifically designed to be applied over spaced sheathing.

RS404.3.2 (R905.17.2) Deck slope. *BIPV roof panels* shall be used only on roof slopes of two units vertical in 12 units horizontal (17-percent slope) or greater.

RS404.3.3 (R905.17.3) Underlayment. *Underlayment* shall comply with Section RS404.1.1 (R905.1.1).

RS404.3.3.1 (R905.17.3.1) Ice barrier. Where required, an ice barrier shall comply with Section (R905.1.2).

RS404.3.4 (R905.17.4) Ice barrier. In areas where there has been a history of ice forming along the eaves causing a

backup of water, as designated in Table (IRC 301.2(1)), an ice barrier that consists of not less than two layers of *underlayment* cemented together or of a self-adhering polymer-modified bitumen sheet shall be used in lieu of normal *underlayment* and extend from the lowest edges of all roof surfaces to a point not less than 24 inches (610 mm) inside the exterior wall line of the building.

Exception: Detached accessory structures that do not contain conditioned floor area.

RS404.3.5 (R905.17.5) Material standards. *BIPV roof panels* shall be *listed* and *labeled* in accordance with UL 1703.

RS404.3.6 (R905.17.6) Attachment. *BIPV roof panels* shall be attached in accordance with the manufacturer's installation instructions.

RS404.3.7 (R905.17.7) Wind resistance. *BIPV roof panels* shall be tested in accordance with UL 1897. *BIPV roof panel* packaging shall bear a *label* to indicate compliance with UL 1897.

SECTION RS405 (P3103) VENT TERMINALS

RS405.1 (P3103.1) Vent pipes terminating outdoors. Vent pipes terminating outdoors shall be extended to the outdoors through the roof or a sidewall of the building in accordance with one of the methods identified in Sections (IRC P3103.1.1 through IRC P3103.1.4).

RS405.1.1 (P3103.1.3) Roof extension covered. Where an open vent pipe terminates above a sloped roof and is covered by either a roof-mounted panel (such as a solar collector or photovoltaic panel mounted over the vent opening) or a roof element (such as an architectural feature or a decorative shroud), the vent pipe shall terminate not less than 2 inches (51 mm) above the roof surface. Such roof elements shall be designed to prevent the adverse effects of snow accumulation and wind on the function of the vent. The placement of a panel over a vent pipe and the design of a roof element covering the vent pipe shall provide for an open area for the vent pipe to the outdoors that is not less than the area of the pipe, as calculated from the inside diameter of the pipe. Such vent terminals shall be protected by a method that prevents birds and rodents from entering or blocking the vent pipe opening.

SECTION RS406 (R327) STATIONARY STORAGE BATTERY SYSTEMS

RS406.1 (R327.1) General. *Stationary storage battery system* shall comply with the provisions of this section.

RS406.2 (R327.2) Equipment listings. *Stationary storage battery systems* shall be *listed* and *labeled* for residential use in accordance with UL 9540.

Exceptions:

1. Where *approved*, repurposed unlisted battery systems from electric vehicles are allowed to be installed outdoors or in detached sheds located not less than 5 feet (1524 mm) from exterior walls, property lines and public ways.
2. *Battery systems* that are an integral part of an electric vehicle are allowed provided that the installation complies with Section 625.48 of NFPA 70.
3. Battery systems less than 1 kWh (3.6 megajoules).

RS406.3 (R327.3) Installation. *Stationary storage battery systems* shall be installed in accordance with the manufacturer's instructions and their *listing*, if applicable, and shall not be installed within the habitable space of a dwelling unit.

RS406.4 (R327.4) Electrical installation. *Stationary storage battery systems* shall be installed in accordance with NFPA 70. Inverters shall be *listed* and *labeled* in accordance with UL 1741 or provided as part of the UL 9540 listing. Systems connected to the utility grid shall use inverters listed for utility interaction.

RS406.5 (R327.5) Ventilation. Indoor installations of *stationary storage battery systems* that include batteries that produce hydrogen or other flammable gases during charging shall be provided with ventilation in accordance with Section (IRC M1307.4).

RS406.6 (R327.6) Protection from impact. *Stationary storage battery systems* installed in a location subject to vehicle damage shall be protected by approved barriers.

CHAPTER 5 [RS]

ALTERNATE COMPLIANCE PROVISIONS

User notes:

About this chapter: *Chapter 5 includes provisions for installing products or systems as an alternative to prescriptive code requirements.*

This chapter contains alternate compliance provisions associated with solar energy systems excerpted directly from the International Energy Conservation Code® and the International Swimming Pool and Spa Code®.

SECTION RS501 (IECC CHAPTER 4 [RE]) RESIDENTIAL ENERGY EFFICIENCY—GENERAL

RS501.1 (IECC R401.1) Scope. [This chapter] applies to *residential buildings*.

RS501.2 (IECC R401.2) Compliance. Projects shall comply with one of the following:

1. Sections RS501.1 (IECC R401.1) through RS502.1.2 (IECC R403.10.4).
2. Section (IECC R405) and the provisions of Sections RS501.1 (IECC R401.1) through RS502.3 (IECC R403.10.4) indicated as "Mandatory."
3. The energy rating index (ERI) approach in Section (IECC R406).

RS501.2.1 (IECC R401.2.1) Tropical zone. *Residential buildings* in the tropical zone at elevations less than 2,400 feet (731.5 m) above sea level shall be deemed to be in compliance with [this chapter] provided that the following conditions are met:

1. Not more than one-half of the *occupied* space is air conditioned.
2. The *occupied* space is not heated.
3. Solar, wind or other renewable energy source supplies not less than 80 percent of the energy for service water heating.

SECTION RS502 (IECC R403) SYSTEMS

RS502.1 (IECC R403.10) Pools and permanent spa energy consumption (Mandatory).

RS502.1.1 (IECC R403.10.2) Time switches. Time switches or other control methods that can automatically turn off and on according to a preset schedule shall be installed for heaters and pump motors. Heaters and pump motors that have built-in time switches shall be in compliance with this section.

Exceptions:

1. Where public health standards require 24-hour pump operation.
2. Pumps that operate solar- and waste-heat-recovery pool heating systems.

RS502.1.2 (IECC R403.10.3) Covers. Outdoor heated pools and outdoor permanent spas shall be provided with a vapor-retardant cover or other *approved* vapor-retardant means.

Exception: Where more than 75 percent of the energy for heating, computed over an operation season of not less than three calendar months, is from a heat pump or an on-site renewable energy system, covers or other vapor-retardant means shall not be required.

SECTION RS503 (ISPSC 303) ENERGY

RS503.1 (ISPSC 303.1.2) Time switches. Time switches or other control methods that can automatically turn off and on heaters and pump motors according to a preset schedule shall be installed for heaters and pump motors. Heaters and pump motors that have built-in time switches shall be in compliance with this section.

Exceptions:

1. Where public health standards require 24-hour pump operation.
2. Pumps that operate solar- or waste-heat recovery pool heating systems.

RS503.2 (ISPSC 303.1.3) Covers. Outdoor heated pools and outdoor permanent spas shall be provided with a vapor-retardant cover or other *approved* vapor-retardant means in accordance with Section (ISPSC 104.11).

Exception: Where more than 70 percent of the energy for heating, computed over an operating season, is from site-recovered energy such as from a heat pump or solar energy source, covers or other vapor-retardant means shall not be required.

SECTION 504 (ISPSC 316) HEATERS

RS504.1 (ISPSC 316.2) Listed and labeled. Heaters and hot water storage tanks shall be *listed* and *labeled* in accordance with the applicable standard listed in Table RS309.2 (ISPSC Table 316.2).

CHAPTER 6 [RS]
REFERENCED STANDARDS

User note:

About this chapter: *This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title, and the section or sections of this document that reference the standard. The application of the referenced standards shall be as specified in Section RS102.4.*

AHRI

Air-Conditioning, Heating, and Refrigeration Institute
2111 Wilson Blvd, Suite 500
Arlington, VA 22201

1160 (I-P) —09: Performance Rating of Heat Pump Pool Heaters
Table RS309.2

ASME

American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

BPVC—2010/2011 addenda: ASME Boiler and Pressure Vessel Code (2007 Edition)
RS304.1.1

CSD-1—2011: Controls and Safety Devices for Automatically Fired Boilers
RS304.1.1

ASSE

American Society of Sanitary Engineering
901 Canterbury, Suite A
Westlake, OH 44145

1012—2009: Performance Requirements for Backflow Preventers with Intermediate Atmospheric Vent
RS303.1.1, RS303.1.3.3

1013—2009: Performance Requirements for Reduced Pressure Principle Backflow Preventers and Reduced Pressure Principle Fire Protection Backflow Preventers
RS303.1.1, RS303.1.3.3

1017—2010: Performance Requirements for Temperature-actuated Mixing Valves for Hot Water Distribution Systems
RS302.1, RS302.3

ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428

D1970/D1970M—2013: Specification for Self-adhering Polymer Modified Bitumen Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection
RS404.1.1

D3161/D3161M—2013: Test Method for Wind Resistance of Asphalt Shingles (Fan Induced Method)
RS404.2.6

D4869/D4869M—05 (2011)e01: Specification for Asphalt-saturated (Organic Felt) Underlayment Used in Steep Slope Roofing
RS404.2.3

D6757—2013: Standard Specification for Inorganic Underlayment for Use with Steep Slope Roofing Products
RS404.2.3

E108—2011: Test Methods for Fire Tests of Roof Coverings
RS301.2.2.1, RS403.1

AWPA

American Wood Protection Association
P.O. Box 361784
Birmingham, AL 35236-1784

C1—03: All Timber Products—Preservative Treatment by Pressure Processes
RS403.2

AWWA

American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235

C511—07: Reduced-pressure Principle Backflow Prevention Assembly
RS303.1.1

CSA

CSA Group
8501 East Pleasant Valley Road
Cleveland, OH 44131-5516

B64.3—11: Dual Check Backflow Preventers with Atmospheric Port (DCAP)
RS303.1.1

B64.4—11: Backflow Preventers, Reduced Pressure Principle Type (RP)
RS303.1.1

C22.2 No. 218.1—M89 (R2011): Spas, Hot Tubs and Associated Equipment
Table RS309.2

C22.2 No. 236—11: Cooling Equipment
Table RS309.2

Z21.56a/CSA 4.7—2013: Gas Fired Pool Heaters
Table RS309.2

ICC

International Code Council, Inc.
500 New Jersey Avenue, NW; 6th Floor
Washington, DC 20001

IBC—15: International Building Code®
RS101.1

ICC 900/SRCC 300—2015: Solar Thermal System Standard
RS301.2.2.2, RS301.2.2.3, RS301.2.7, RS301.2.8, RS301.2.10, RS301.4

ICC 901/SRCC 100—2015: Solar Thermal Collector Standard
RS301.3.1

IFC—15: International Fire Code®
RS102.7

IPMC—15: International Property Maintenance Code®
RS102.7

IRC—15: International Residential Code®
RS101.1, RS103.2.1, RS106.1.3, RS106.1.6.1, RS301.2.3, RS301.2.6, RS301.2.8, RS301.2.13, RS304.4, RS308.1, RS310.2, RS402.5, RS403.1, RS404.1, RS404.2.6, RS501.2, RS503.2, RS504.1

NFPA

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269

70—17: National Electrical Code
RS101.1, RS402.1, RS404.2, RS405.1

NSF

NSF International
789 N. Dixboro
Ann Arbor, MI 48105

NSF 50—2012: Equipment for Swimming Pools, Spas, Hot Tubs, and other Recreational Water Facilities
Table RS309.2

UL

UL LLC
333 Pfingsten Road
Northbrook, IL 60062

174—04: Household Electric Storage Tank Water Heaters—with revisions through September 2012
RS308.1

726—95: Oil-fired Boiler Assemblies—with revisions through April 2011
RS304.1.1, RS309.3

732—95: Oil-fired Storage Tank Water Heaters—with revisions through April 2010
RS308.1

790—04: Standard Test Methods for Fire Tests of Roof Coverings—with revisions through October 2008
RS301.2.2.1, RS403.1

834—04: Heating, Water Supply and Power Boilers—Electric—with revisions through January 2013
RS304.1.1

1261—01: Electric Water Heaters for Pools and Tubs—with revisions through July 2012
RS309.3, Table RS309.2

1703—02: Flat-plate Photovoltaic Modules and Panels—with revisions through November 2014
RS402.1.1, RS403.4, RS404.2.4

1741—2010: Inverters, Converters, Controllers and Interconnection System Equipment for use with Distributed Energy Resources
RS402.1

1995—2011: Heating and Cooling Equipment
Table RS309.2

2523—09: Standard for Solid Fuel-fired Hydronic Heating Appliances, Water Heaters and Boilers—with revisions through February 2013
RS304.1.1, RS308.1

2703—2014: Outline of Investigation for Mounting Systems, Mounting Devices, Clamping/Retention Devices and Ground Lugs for Use with Flat-plate Photovoltaic Modules and Panels
RS403.4

9540—2014: Outline of Investigation for Energy Storage Systems and Equipment
RS406

APPENDIX T

SOLAR-READY PROVISIONS—DETACHED ONE- AND TWO-FAMILY DWELLINGS AND TOWNHOUSES

This appendix is informative and is not part of the code.

Below is Appendix T of the 2018 International Residential Code® which is also reproduced in the 2018 International Energy Conservation Code® as Appendix RA. Appendix chapters of the I-Codes are not mandatory unless specifically referenced in the I-Code adoption ordinance.

User notes:

About this chapter: *Harnessing the heat or radiation from the sun's rays is a method to reduce the energy consumption of a building. Although Appendix T does not require solar systems to be installed for a building, it does require the space(s) for installing such systems, providing pathways for connections and requiring adequate structural capacity of roof systems to support solar systems.*

Section numbers in parenthesis are those in Appendix A of the residential provisions of the International Energy Conservation Code®.

SECTION T101 (RA101) SCOPE

T101.1 (RA101.1) General. These provisions shall be applicable for new construction where solar-ready provisions are required.

SECTION T102 (RA102) GENERAL DEFINITIONS

T102.1 General. The following term shall, for the purpose of this appendix, have the meaning shown herein.

SOLAR-READY ZONE. A section or sections of the roof or building overhang designated and reserved for the future installation of a solar photovoltaic or solar thermal system.

SECTION T103 (RA103) SOLAR-READY ZONE

T103.1 General. New detached one- and two-family dwellings, and townhouses with not less than 600 square feet (55.74 m^2) of roof area oriented between 90 degrees and 270 degrees of true north shall comply with Sections T103.2 through T103.10.

Exceptions:

1. New residential buildings with a permanently installed on-site renewable energy system.
2. A building where all areas of the roof that would otherwise meet the requirements of Section T103 are in full or partial shade for more than 70 percent of daylight hours annually

T103.2 (RA103.2) Construction document requirements for solar ready zone. Construction documents shall indicate the solar- ready zone.

T103.3 (RA103.3) Solar-ready zone area. The total solar-ready zone area shall be not less than 300 square feet (27.87 m^2) exclusive of mandatory access or set back areas as required by the *International Fire Code*. New townhouses three stories or less in height above grade plane and with a total floor area less than or equal to 2,000 square feet (185.8 m^2) per dwelling shall have a solar-ready zone area of not less than 150 square feet (13.94 m^2). The solar-ready zone shall be composed of areas not less than 5 feet (1524 mm) in width and not less than 80 square feet (7.44 m^2) exclusive of access or set back areas as required by the *International Fire Code*.

T103.4 (RA103.4) Obstructions. Solar-ready zones shall be free from obstructions, including but not limited to vents, chimneys, and roof-mounted equipment.

T103.5 Shading. The solar-ready zone shall be set back from any existing or new, permanently affixed object on the building or site that is located south, east or west of the solar zone a distance not less than two times the object's height above the nearest point on the roof surface. Such objects include, but are not limited to, taller portions of the building itself, parapets, chimneys, antennas, signage, rooftop equipment, trees and roof plantings.

T103.6 Capped roof penetration sleeve. A capped roof penetration sleeve shall be provided adjacent to a solar-ready zone located on a roof slope of not greater than 1 unit vertical in 12 units horizontal (8-percent slope). The capped roof penetration sleeve shall be sized to accommodate the future photovoltaic system conduit, but shall have an inside diameter of not less than $1^1/_4$ inches (32 mm).

T103.7 (RA103.5) Roof load documentation. The structural design loads for roof dead load and roof live load shall be clearly indicated on the construction documents.

T103.8 (RA103.6) Interconnection pathway. Construction documents shall indicate pathways for routing of conduit or plumbing from the solar-ready zone to the electrical service panel or service hot water system.

T103.9 (RA103.7) Electrical service reserved space. The main electrical service panel shall have a reserved space to

allow installation of a dual pole circuit breaker for future solar electric installation and shall be labeled "For Future Solar Electric." The reserved space shall be positioned at the opposite (load) end from the input feeder location or main circuit location.

T103.10 (RA103.8) Construction documentation certificate. A permanent certificate, indicating the solar-ready zone and other requirements of this section, shall be posted near the electrical distribution panel, water heater or other conspicuous location by the builder or registered design professional.

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NATIONAL ELECTRICAL CODE® (NEC®) SOLAR PROVISIONS

As electrical related components and systems are a critical part of any solar energy system, those provisions of the *National Electrical Code* (NFPA 70) that are most directly related to solar energy systems have been extracted and reprinted in this *International Solar Energy Provisions* (ISEP). These electrical provisions have been organized in the same format as the ISEP chapters in specifically coordinated sections such as definitions (SE200), general (SE300), solar water heating (SE400), and photovoltaic (SE500) so the user can easily and conveniently locate and apply them. The NEC provisions are copyrighted by and have been included by permission of and cooperation of the National Fire Protection Association.

The NEC Provisions in the *International Solar Energy Provisions* (ISEP) apply to both commercial and residential systems and are a part of the ISEP Commercial and ISEP Residential provisions. Readers should refer to NFPA's 2017 *National Electrical Code Handbook* for the reasoning behind the NFPA 70, including NEC concepts, real-world examples and the background behind code revisions.

ARTICLE 90
Introduction

90.3 Code Arrangement. This *Code* is divided into the introduction and nine chapters, as shown in Figure 90.3. Chapters 1, 2, 3, and 4 apply generally. Chapters 5, 6, and 7 apply to special occupancies, special equipment, or other special conditions and may supplement or modify the requirements in Chapters 1 through 7.

Chapter 8 covers communications systems and is not subject to the requirements of Chapters 1 through 7 except where the requirements are specifically referenced in Chapter 8.

Chapter 9 consists of tables that are applicable as referenced.

Informative annexes are not part of the requirements of this *Code* but are included for informational purposes only.

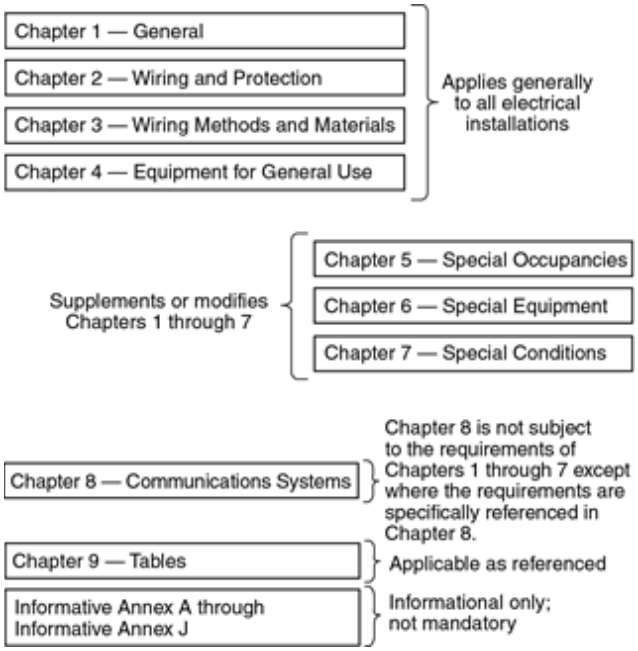


Figure 90.3
Code Arrangement

SE 200
DEFINITIONS

SE202 General definitions.

ARTICLE 100
Definitions

Accessible (as applied to equipment). Admitting close approach; not guarded by locked doors, elevation, or other effective means. (CMP-1)

Accessible (as applied to wiring methods). Capable of being removed or exposed without damaging the building structure or finish or not permanently closed in by the structure or finish of the building. (CMP-1)

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 alterna-

tive to the ready access requirements under such supervised conditions as provided elsewhere in the NEC.

Ampacity. The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. (CMP-6)

Appliance. Utilization equipment, generally other than industrial, that is normally built in standardized sizes or types and is installed or connected as a unit to perform one or more functions such as clothes washing, air-conditioning, food mixing, deep frying, and so forth. (CMP-17)

Approved. Acceptable to the authority having jurisdiction. (CMP-1)

Arc-Fault Circuit Interrupter (AFCI). A device intended to provide protection from the effects of arc faults by recognizing characteristics unique to arcing and by functioning to de-energize the circuit when an arc fault is detected. (CMP-2)

Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure. (CMP-1)

Informational Note: The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Automatic. Performing a function without the necessity of human intervention. (CMP-1)

Battery System. Interconnected battery subsystems consisting of one or more storage batteries and battery chargers, and can include inverters, converters, and associated electrical equipment. (CMP-13)

Bonded (Bonding). Connected to establish electrical continuity and conductivity. (CMP-5)

Bonding Conductor or Jumper. A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected. (CMP-5)

Bonding Jumper, Equipment. The connection between two or more portions of the equipment grounding conductor. (CMP-5)

Bonding Jumper, Main. The connection between the grounded circuit conductor and the equipment grounding conductor at the service. (CMP-5)

Bonding Jumper, System. The connection between the grounded circuit conductor and the supply-side bonding jumper, or the equipment grounding conductor, or both, at a separately derived system. (CMP-5)

Branch Circuit. The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s). (CMP-2)

Building. A structure that stands alone or that is separated from adjoining structures by fire walls. (CMP-1)

Cabinet. An enclosure that is designed for either surface mounting or flush mounting and is provided with a frame, mat, or trim in which a swinging door or doors are or can be hung. (CMP-9)

Charge Controller. Equipment that controls dc voltage or dc current, or both, and that is used to charge a battery or other energy storage device. (CMP-13)

Circuit Breaker. A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating. (CMP-10)

Informational Note: The automatic opening means can be integral, direct acting with the circuit breaker, or remote from the circuit breaker.

Adjustable (as applied to circuit breakers). A qualifying term indicating that the circuit breaker can be set to trip at various values of current, time, or both, within a predetermined range.

Instantaneous Trip (as applied to circuit breakers). A qualifying term indicating that no delay is purposely introduced in the tripping action of the circuit breaker.

Inverse Time (as applied to circuit breakers). A qualifying term indicating that there is purposely introduced a delay in the tripping action of the circuit breaker, which delay decreases as the magnitude of the current increases.

Nonadjustable (as applied to circuit breakers). A qualifying term indicating that the circuit breaker does not have any adjustment to alter the value of the current at which it will trip or the time required for its operation.

Setting (of circuit breakers). The value of current, time, or both, at which an adjustable circuit breaker is set to trip.

Concealed. Rendered inaccessible by the structure or finish of the building. (CMP-1)

Informational Note: Wires in concealed raceways are considered concealed, even though they may become accessible by withdrawing them.

Conductor, Bare. A conductor having no covering or electrical insulation whatsoever. (CMP-6)

Conductor, Covered. A conductor encased within material of composition or thickness that is not recognized by this *Code* as electrical insulation. (CMP-6)

Conductor, Insulated. A conductor encased within material of composition and thickness that is recognized by this *Code* as electrical insulation. (CMP-6)

Conduit Body. A separate portion of a conduit or tubing system that provides access through a removable cover(s) to the

interior of the system at a junction of two or more sections of the system or at a terminal point of the system.

Boxes such as FS and FD or larger cast or sheet metal boxes are not classified as conduit bodies. (CMP-9)

Continuous Load. A load where the maximum current is expected to continue for 3 hours or more. (CMP-2)

Control Circuit. The circuit of a control apparatus or system that carries the electric signals directing the performance of the controller but does not carry the main power current. (CMP-11)

Copper-Clad Aluminum Conductors. Conductors drawn from a copper-clad aluminum rod, with the copper metallurgically bonded to an aluminum core, where the copper forms a minimum of 10 percent of the cross-sectional area of a solid conductor or each strand of a stranded conductor. (CMP-6)

Device. A unit of an electrical system, other than a conductor, that carries or controls electric energy as its principal function. (CMP-1)

Disconnecting Means. A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply. (CMP-1)

Dusttight. Enclosures constructed so that dust will not enter under specified test conditions. (CMP-14)

> Informational Note No. 1: Enclosure Types 3, 3S, 3SX, 4, 4X, 5, 6, 6P, 12, 12K, and 13, per ANSI/NEMA 250-2014, *Enclosures for Electrical Equipment*, are considered dusttight and suitable for use in unclassified locations and in Class II, Division 2; Class III; and Zone 22 hazardous (classified) locations.
>
> Informational Note No. 2: For further information, see ANSI/ISA-12.12.01-2013, Nonincendive Electrical Equipment for Use in Class I and II, Division 2, and Class III, Divisions 1 and 2 Hazardous (Classified) Locations.

Duty, Continuous. Operation at a substantially constant load for an indefinitely long time. (CMP-1)

Duty, Intermittent. Operation for alternate intervals of (1) load and no load; or (2) load and rest; or (3) load, no load, and rest. (CMP-1)

Duty, Periodic. Intermittent operation in which the load conditions are regularly recurrent. (CMP-1)

Duty, Short-Time. Operation at a substantially constant load for a short and definite, specified time. (CMP-1)

Duty, Varying. Operation at loads, and for intervals of time, both of which may be subject to wide variation. (CMP-1)

Dwelling, One-Family. A building that consists solely of one dwelling unit. (CMP-1)

Dwelling, Two-Family. A building that consists solely of two dwelling units. (CMP-1)

Dwelling, Multifamily. A building that contains three or more dwelling units. (CMP-1)

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)

Effective Ground-Fault Current Path. An intentionally constructed, low-impedance electrically conductive path designed and intended to carry current under ground-fault conditions from the point of a ground fault on a wiring system to the electrical supply source and that facilitates the operation of the overcurrent protective device or ground-fault detectors. (CMP-5)

Enclosed. Surrounded by a case, housing, fence, or wall(s) that prevents persons from accidentally contacting energized parts. (CMP-1)

Enclosure. The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts or to protect the equipment from physical damage. (CMP-1)

> Informational Note: See Table 110.28 for examples of enclosure types.

Energized. Electrically connected to, or is, a source of voltage. (CMP-1)

Equipment. A general term, including fittings, devices, appliances, luminaires, apparatus, machinery, and the like used as a part of, or in connection with, an electrical installation. (CMP-1)

Exposed (as applied to live parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. (CMP-1)

> Informational Note: This term applies to parts that are not suitably guarded, isolated, or insulated.

Exposed (as applied to wiring methods). On or attached to the surface or behind panels designed to allow access. (CMP-1)

Externally Operable. Capable of being operated without exposing the operator to contact with live parts. (CMP-1)

Feeder. All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device. (CMP-2)

Fitting. An accessory such as a locknut, bushing, or other part of a wiring system that is intended primarily to perform a mechanical rather than an electrical function. (CMP-1)

Ground. The earth. (CMP-5)

Ground Fault. An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non–current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth. (CMP-5)

Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection. (CMP-5)

Grounded, Solidly. Connected to ground without inserting any resistor or impedance device. (CMP-5)

Grounded Conductor. A system or circuit conductor that is intentionally grounded. (CMP-5)

Ground-Fault Circuit Interrupter (GFCI). A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established for a Class A device. (CMP-2)

Informational Note: Class A ground-fault circuit interrupters trip when the current to ground is 6 mA or higher and do not trip when the current to ground is less than 4 mA. For further information, see UL 943, *Standard for Ground-Fault Circuit Interrupters*.

Ground-Fault Current Path. An electrically conductive path from the point of a ground fault on a wiring system through normally non–current-carrying conductors, equipment, or the earth to the electrical supply source. (CMP-5)

Informational Note: Examples of ground-fault current paths are any combination of equipment grounding conductors, metallic raceways, metallic cable sheaths, electrical equipment, and any other electrically conductive material such as metal, water, and gas piping; steel framing members; stucco mesh; metal ducting; reinforcing steel; shields of communications cables; and the earth itself.

Ground-Fault Protection of Equipment. A system intended to provide protection of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device. (CMP-5)

Grounding Conductor, Equipment (EGC). The conductive path(s) that provides a ground-fault current path and connects normally non–current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both. (CMP-5)

Informational Note No. 1: It is recognized that the equipment grounding conductor also performs bonding.

Informational Note No. 2: See 250.118 for a list of acceptable equipment grounding conductors.

Grounding Electrode. A conducting object through which a direct connection to earth is established. (CMP-5)

Grounding Electrode Conductor. A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system. (CMP-5)

Guarded. Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger. (CMP-1)

Hybrid System. A system comprised of multiple power sources. These power sources could include photovoltaic, wind, micro-hydro generators, engine-driven generators, and others, but do not include electric power production and distribution network systems. Energy storage systems such as batteries, flywheels, or superconducting magnetic storage equipment do not constitute a power source for the purpose of this definition. The energy regenerated by an overhauling (descending) elevator does not constitute a power source for the purpose of this definition. (CMP-4)

Identified (as applied to equipment). Recognizable as suitable for the specific purpose, function, use, environment, application, and so forth, where described in a particular *Code* requirement. (CMP-1)

Informational Note: Some examples of ways to determine suitability of equipment for a specific purpose, environment, or application include investigations by a qualified testing laboratory (listing and labeling), an inspection agency, or other organizations concerned with product evaluation.

In Sight From (Within Sight From, Within Sight). Where this *Code* specifies that one equipment shall be "in sight from," "within sight from," or "within sight of," and so forth, another equipment, the specified equipment is to be visible and not more than 15 m (50 ft) distant from the other. (CMP-1)

Interactive Inverter. An inverter intended for use in parallel with an electric utility to supply common loads that may deliver power to the utility. (CMP-13)

Interactive System. An electric power production system that is operating in parallel with and capable of delivering energy to an electric primary source supply system. (CMP-4)

Interrupting Rating. The highest current at rated voltage that a device is identified to interrupt under standard test conditions. (CMP-10)

Informational Note: Equipment intended to interrupt current at other than fault levels may have its interrupting rating implied in other ratings, such as horsepower or locked rotor current.

Isolated (as applied to location). Not readily accessible to persons unless special means for access are used. (CMP-1)

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner. (CMP-1)

Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose. (CMP-1)

Informational Note: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. Use of the system employed by the listing organization allows the authority having jurisdiction to identify a listed product.

Live Parts. Energized conductive components. (CMP-1)

Location, Damp. Locations protected from weather and not subject to saturation with water or other liquids but subject to moderate degrees of moisture. (CMP-1)

> Informational Note: Examples of such locations include partially protected locations under canopies, marquees, roofed open porches, and like locations, and interior locations subject to moderate degrees of moisture, such as some basements, some barns, and some cold-storage warehouses.

Location, Dry. A location not normally subject to dampness or wetness. A location classified as dry may be temporarily subject to dampness or wetness, as in the case of a building under construction. (CMP-1)

Location, Wet. Installations underground or in concrete slabs or masonry in direct contact with the earth; in locations subject to saturation with water or other liquids, such as vehicle washing areas; and in unprotected locations exposed to weather. (CMP-1)

Neutral Conductor. The conductor connected to the neutral point of a system that is intended to carry current under normal conditions. (CMP-5)

Overcurrent. Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault. (CMP-10)

> Informational Note: A current in excess of rating may be accommodated by certain equipment and conductors for a given set of conditions. Therefore, the rules for overcurrent protection are specific for particular situations.

Overcurrent Protective Device, Branch-Circuit. A device capable of providing protection for service, feeder, and branch circuits and equipment over the full range of overcurrents between its rated current and its interrupting rating. Such devices are provided with interrupting ratings appropriate for the intended use but no less than 5000 amperes. (CMP-10)

Overcurrent Protective Device, Supplementary. A device intended to provide limited overcurrent protection for specific applications and utilization equipment such as luminaires and appliances. This limited protection is in addition to the protection provided in the required branch circuit by the branch-circuit overcurrent protective device. (CMP-10)

Panelboard. A single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall, partition, or other support; and accessible only from the front. (CMP-9)

Photovoltaic (PV) System. The total components and subsystem that, in combination, convert solar energy into electric energy for connection to a utilization load. (CMP-4)

Plenum. A compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system. (CMP-3)

Power Outlet. An enclosed assembly that may include receptacles, circuit breakers, fuseholders, fused switches, buses, and watt-hour meter mounting means; intended to supply and control power to mobile homes, recreational vehicles, park trailers, or boats or to serve as a means for distributing power required to operate mobile or temporarily installed equipment.(CMP-19)

Premises Wiring (System). Interior and exterior wiring, including power, lighting, control, and signal circuit wiring together with all their associated hardware, fittings, and wiring devices, both permanently and temporarily installed. This includes (a) wiring from the service point or power source to the outlets or (b) wiring from and including the power source to the outlets where there is no service point.

Such wiring does not include wiring internal to appliances, luminaires, motors, controllers, motor control centers, and similar equipment. (CMP-1)

> Informational Note: Power sources include, but are not limited to, interconnected or stand-alone batteries, solar photovoltaic systems, other distributed generation systems, or generators.

Qualified Person. One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved. (CMP-1)

> Informational Note: Refer to NFPA 70E-2012, *Standard for Electrical Safety in the Workplace*, for electrical safety training requirements.

Raceway. An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in this *Code*. (CMP-8)

> Informational Note: A raceway is identified within specific article definitions.

Rainproof. Constructed, protected, or treated so as to prevent rain from interfering with the successful operation of the apparatus under specified test conditions. (CMP-1)

Raintight. Constructed or protected so that exposure to a beating rain will not result in the entrance of water under specified test conditions. (CMP-1)

Separately Derived System. An electrical source, other than a service, having no direct connection(s) to circuit conductors of any other electrical source other than those established by grounding and bonding connections. (CMP-5)

Service. The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served. (CMP-4)

Service Cable. Service conductors made up in the form of a cable. (CMP-4)

Service Conductors. The conductors from the service point to the service disconnecting means. (CMP-4)

Service Conductors, Overhead. The overhead conductors between the service point and the first point of connection to the service-entrance conductors at the building or other structure. (CMP-4)

Service Conductors, Underground. The underground conductors between the service point and the first point of connection to the service-entrance conductors in a terminal box,

meter, or other enclosure, inside or outside the building wall. (CMP-4)

> Informational Note: Where there is no terminal box, meter, or other enclosure, the point of connection is considered to be the point of entrance of the service conductors into the building.

Service Drop. The overhead conductors between the utility electric supply system and the service point. (CMP-4)

Service-Entrance Conductors, Overhead System. The service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop or overhead service conductors. (CMP-4)

Service-Entrance Conductors, Underground System. The service conductors between the terminals of the service equipment and the point of connection to the service lateral or underground service conductors. (CMP-4)

> Informational Note: Where service equipment is located outside the building walls, there may be no service-entrance conductors or they may be entirely outside the building.

Service Equipment. The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load end of service conductors to a building or other structure, or an otherwise designated area, and intended to constitute the main control and cutoff of the supply. (CMP-4)

Service Point. The point of connection between the utility facilities of the serving utility and the premises wiring. (CMP-4)

> Informational Note: The service point can be described as the point of demarcation between where the serving utility ends and the premises wiring begins. The serving utility generally specifies the location of the service point based on conditions of service.

Short-Circuit Current Rating. The prospective symmetrical fault current at a nominal voltage to which an apparatus or system is able to be connected without sustaining damage exceeding defined acceptance criteria. (CMP-10)

Stand-Alone System. A system that supplies power independently of an electrical production and distribution network. (CMP-4)

Structure. That which is built or constructed, other than equipment. (CMP-1)

Switch, General-Use. A switch intended for use in general distribution and branch circuits. It is rated in amperes, and it is capable of interrupting its rated current at its rated voltage. (CMP-9)

Switch, General-Use Snap. A form of general-use switch constructed so that it can be installed in device boxes or on box covers, or otherwise used in conjunction with wiring systems recognized by this *Code*. (CMP-9)

Switch, Isolating. A switch intended for isolating an electrical circuit from the source of power. It has no interrupting rating, and it is intended to be operated only after the circuit has been opened by some other means. (CMP-9)

Switch, Transfer. An automatic or nonautomatic device for transferring one or more load conductor connections from one power source to another. (CMP-13)

Switchboard. A large single panel, frame, or assembly of panels on which are mounted on the face, back, or both, switches, overcurrent and other protective devices, buses, and usually instruments. These assemblies are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets. (CMP-9)

Switchgear. An assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings and inspection windows) and containing primary power circuit switching, interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors, removable covers, or both. (CMP-9)

> Informational Note: All switchgear subject to NEC requirements is metal enclosed. Switchgear rated below 1000 V or less may be identified as "low-voltage power circuit breaker switchgear." Switchgear rated over 1000 V may be identified as "metal-enclosed switchgear" or "metal-clad switchgear." Switchgear is available in non–arc-resistant or arc-resistant constructions.

Ungrounded. Not connected to ground or to a conductive body that extends the ground connection. (CMP-5)

Interactive Inverter. An inverter intended for use in parallel with an electric utility to supply common loads that may deliver power to the utility.

Ventilated. Provided with a means to permit circulation of air sufficient to remove an excess of heat, fumes, or vapors.(CMP-14)

Voltage (of a circuit). The greatest root-mean-square (rms) (effective) difference of potential between any two conductors of the circuit concerned. (CMP-1)

> Informational Note: Some systems, such as 3-phase 4-wire, single-phase 3-wire, and 3-wire direct current, may have various circuits of various voltages.

Voltage, Nominal. A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (e.g., 120/240 volts, 480Y/277 volts, 600 volts). (CMP-1)

> Informational Note No. 1: The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment.
>
> Informational Note No. 2: See ANSI C84.1-2011, *Voltage Ratings for Electric Power Systems and Equipment* (60 Hz).
>
> Informational Note No. 3: Certain battery units may be considered to be rated at nominal 48 volts dc, but may have a charging float voltage up to 58 volts. In dc applications, 60 volts is used to cover the entire range of float voltages.

Voltage to Ground. For grounded circuits, the voltage between the given conductor and that point or conductor of the circuit that is grounded; for ungrounded circuits, the greatest voltage between the given conductor and any other conductor of the circuit. (CMP-1)

Watertight. Constructed so that moisture will not enter the enclosure under specified test conditions. (CMP-1)

Weatherproof. Constructed or protected so that exposure to the weather will not interfere with successful operation. (CMP-1)

Informational Note: Rainproof, raintight, or watertight equipment can fulfill the requirements for weatherproof where varying weather conditions other than wetness, such as snow, ice, dust, or temperature extremes, are not a factor.

SE 300
General

ARTICLE 110
Requirements for Electrical Installations

110.14 Electrical Connections. Because of different characteristics of dissimilar metals, devices such as pressure terminal or pressure splicing connectors and soldering lugs shall be identified for the material of the conductor and shall be properly installed and used. Conductors of dissimilar metals shall not be intermixed in a terminal or splicing connector where physical contact occurs between dissimilar conductors (such as copper and aluminum, copper and copper-clad aluminum, or aluminum and copper-clad aluminum), unless the device is identified for the purpose and conditions of use. Materials such as solder, fluxes, inhibitors, and compounds, where employed, shall be suitable for the use and shall be of a type that will not adversely affect the conductors, installation, or equipment.

Connectors and terminals for conductors more finely stranded than Class B and Class C stranding as shown in Chapter 9, Table 10, shall be identified for the specific conductor class or classes.

(A) Terminals. Connection of conductors to terminal parts shall ensure a thoroughly good connection without damaging the conductors and shall be made by means of pressure connectors (including set-screw type), solder lugs, or splices to flexible leads. Connection by means of wire-binding screws or studs and nuts that have upturned lugs or the equivalent shall be permitted for 10 AWG or smaller conductors.

Terminals for more than one conductor and terminals used to connect aluminum shall be so identified.

(B) Splices. Conductors shall be spliced or joined with splicing devices identified for the use or by brazing, welding, or soldering with a fusible metal or alloy. Soldered splices shall first be spliced or joined so as to be mechanically and electrically secure without solder and then be soldered. All splices and joints and the free ends of conductors shall be covered with an insulation equivalent to that of the conductors or with an identified insulating device.

Wire connectors or splicing means installed on conductors for direct burial shall be listed for such use.

(C) Temperature Limitations. The temperature rating associated with the ampacity of a conductor shall be selected and coordinated so as not to exceed the lowest temperature rating of any connected termination, conductor, or device. Conductors with temperature ratings higher than specified for terminations shall be permitted to be used for ampacity adjustment, correction, or both.

(1) Equipment Provisions. The determination of termination provisions of equipment shall be based on 110.14(C)(1)(a) or (C)(1)(b). Unless the equipment is listed and marked otherwise, conductor ampacities used in determining equipment termination provisions shall be based on Table 310.15(B)(16) as appropriately modified by 310.15(B)(7).

(a) Termination provisions of equipment for circuits rated 100 amperes or less, or marked for 14 AWG through 1 AWG conductors, shall be used only for one of the following:

(1) Conductors rated 60°C (140°F).

(2) Conductors with higher temperature ratings, provided the ampacity of such conductors is determined based on the 60°C (140°F) ampacity of the conductor size used.

(3) Conductors with higher temperature ratings if the equipment is listed and identified for use with such conductors.

(4) For motors marked with design letters B, C, or D, conductors having an insulation rating of 75°C (167°F) or higher shall be permitted to be used, provided the ampacity of such conductors does not exceed the 75°C (167°F) ampacity.

(b) Termination provisions of equipment for circuits rated over 100 amperes, or marked for conductors larger than 1 AWG, shall be used only for one of the following:

(1) Conductors rated 75°C (167°F).

(2) Conductors with higher temperature ratings, provided the ampacity of such conductors does not exceed the 75°C (167°F) ampacity of the conductor size used, or up to their ampacity if the equipment is listed and identified for use with such conductors.

(2) Separate Connector Provisions. Separately installed pressure connectors shall be used with conductors at the ampacities not exceeding the ampacity at the listed and identified temperature rating of the connector.

Informational Note: With respect to 110.14(C)(1) and (C)(2), equipment markings or listing information may additionally restrict the sizing and temperature ratings of connected conductors.

(D) Installation. Where a tightening torque is indicated as a numeric value on equipment or in installation instructions provided by the manufacturer, a calibrated torque tool shall be used to achieve the indicated torque value, unless the equipment manufacturer has provided installation instructions for an alternative method of achieving the required torque.

110.21 Marking.

(A) Equipment Markings.

(1) General. The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product can be identified shall be placed on all electrical equipment. Other markings that indicate voltage, current, wattage, or other ratings shall be provided as specified else-

where in this *Code*. The marking or label shall be of sufficient durability to withstand the environment involved.

(2) Reconditioned Equipment. Reconditioned equipment shall be marked with the name, trademark, or other descriptive marking by which the organization responsible for reconditioning the electrical equipment can be identified, along with the date of the reconditioning.

Reconditioned equipment shall be identified as "reconditioned" and approval of the reconditioned equipment shall not be based solely on the equipment's original listing.

Exception: In industrial occupancies, where conditions of maintenance and supervision ensure that only qualified persons service the equipment, the markings indicated in 110.21(A)(2) shall not be required.

Informational Note: Industry standards are available for application of reconditioned and refurbished equipment. Normal servicing of equipment that remains within a facility should not be considered reconditioning or refurbishing.

(B) Field-Applied Hazard Markings. Where caution, warning, or danger signs or labels are required by this *Code*, the labels shall meet the following requirements:

(1) The marking shall warn of the hazards using effective words, colors, symbols, or any combination thereof.

Informational Note: ANSI Z535.4-2011, *Product Safety Signs and Labels*, provides guidelines for suitable font sizes, words, colors, symbols, and location requirements for labels.

(2) The label shall be permanently affixed to the equipment or wiring method and shall not be handwritten.

Exception to (2): Portions of labels or markings that are variable, or that could be subject to changes, shall be permitted to be handwritten and shall be legible.

(3) The label shall be of sufficient durability to withstand the environment involved.

Informational Note: ANSI Z535.4-2011, *Product Safety Signs and Labels*, provides guidelines for the design and durability of safety signs and labels for application to electrical equipment.

110.25 Lockable Disconnecting Means. If a disconnecting means is required to be lockable open elsewhere in this *Code*, it shall be capable of being locked in the open position. The provisions for locking shall remain in place with or without the lock installed.

Exception: Locking provisions for a cord-and-plug connection shall not be required to remain in place without the lock installed.

Part II. 1000 Volts, Nominal, or Less

110.26 Spaces About Electrical Equipment. Access and working space shall be provided and maintained about all electrical equipment to permit ready and safe operation and maintenance of such equipment.

(A) Working Space. Working space for equipment operating at 1000 volts, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized shall comply with the dimensions of 110.26(A)(1), (A)(2), (A)(3), and (A)(4) or as required or permitted elsewhere in this *Code*.

Informational Note: NFPA 70E-2015, *Standard for Electrical Safety in the Workplace*, provides guidance, such as determining severity of potential exposure, planning safe work practices, arc flash labeling, and selecting personal protective equipment.

(1) Depth of Working Space. The depth of the working space in the direction of live parts shall not be less than that specified in Table 110.26(A)(1) unless the requirements of 110.26(A)(1)(a), (A)(1)(b), or (A)(1)(c) are met. Distances shall be measured from the exposed live parts or from the enclosure or opening if the live parts are enclosed.

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.

(a) *Dead-Front Assemblies.* Working space shall not be required in the back or sides of assemblies, such as dead-front switchboards, switchgear, or motor control centers, where all connections and all renewable or adjustable parts, such as fuses or switches, are accessible from locations other than the back or sides. Where rear access is required to work on nonelectrical parts on the back of enclosed equipment, a minimum horizontal working space of 762 mm (30 in.) shall be provided.

(b) *Low Voltage.* By special permission, smaller working spaces shall be permitted where all exposed live parts operate at not greater than 30 volts rms, 42 volts peak, or 60 volts dc.

(c) *Existing Buildings.* In existing buildings where electrical equipment is being replaced, Condition 2 working clearance shall be permitted between dead-front switchboards, switchgear, 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 qualified persons who are authorized will service the installation.

(2) Width of Working Space. The width of the working space in front of the electrical equipment shall be the width of the equipment or 762 mm (30 in.), whichever is greater. In all cases, the work space shall permit at least a 90 degree opening of equipment doors or hinged panels.

(3) Height of Working Space. The work space shall be clear and extend from the grade, floor, or platform to a height of 2.0 m ($6^1/_2$ ft) or the height of the equipment, whichever is

greater. Within the height requirements of this section, other equipment that is associated with the electrical installation and is located above or below the electrical equipment shall be permitted to extend not more than 150 mm (6 in.) beyond the front of the electrical equipment.

Exception No. 1: In existing dwelling units, service equipment or panelboards that do not exceed 200 amperes shall be permitted in spaces where the height of the working space is less than 2.0 m (6$^1/_2$ ft).

Exception No. 2: Meters that are installed in meter sockets shall be permitted to extend beyond the other equipment. The meter socket shall be required to follow the rules of this section.

Exception No. 3: On battery systems mounted on open racks, the top clearance shall comply with 480.10(D).

(4) Limited Access. Where equipment operating at 1000 volts, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized is required by installation instructions or function to be located in a space with limited access, all of the following shall apply:

(a) Where equipment is installed above a lay-in ceiling, there shall be an opening not smaller than 559 mm × 559 mm (22 in. × 22 in.), or in a crawl space, there shall be an accessible opening not smaller than 559 mm × 762 mm (22 in. × 30 in.).

(b) The width of the working space shall be the width of the equipment enclosure or a minimum of 762 mm (30 in.), whichever is greater.

(c) All enclosure doors or hinged panels shall be capable of opening a minimum of 90 degrees.

(d) The space in front of the enclosure shall comply with the depth requirements of Table 110.26(A)(1). The maximum height of the working space shall be the height necessary to install the equipment in the limited space. A horizontal ceiling structural member or access panel shall be permitted in this space.

(5) Separation from High-Voltage Equipment. Where switches, cutouts, or other equipment operating at 1000 volts, nominal, or less are installed in a vault, room, or enclosure where there are exposed live parts or exposed wiring operating over 1000 volts, nominal, the high-voltage equipment shall be effectively separated from the space occupied by the low-voltage equipment by a suitable partition, fence, or screen.

(B) Clear Spaces. Working space required by this section shall not be used for storage. When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, shall be suitably guarded.

(C) Entrance to and Egress from Working Space.

(1) Minimum Required. At least one entrance of sufficient area shall be provided to give access to and egress from working space about electrical equipment.

(2) Large Equipment. For equipment rated 1200 amperes or more and over 1.8 m (6 ft) wide that contains overcurrent devices, switching devices, or control devices, there shall be one entrance to and egress from the required working space not less than 610 mm (24 in.) wide and 2.0 m (6$^1/_2$ ft) high at each end of the working space.

A single entrance to and egress from the required working space shall be permitted where either of the conditions in 110.26(C)(2)(a) or (C)(2)(b) is met.

(a) *Unobstructed Egress.* Where the location permits a continuous and unobstructed way of egress travel, a single entrance to the working space shall be permitted.

(b) *Extra Working Space.* Where the depth of the working space is twice that required by 110.26(A)(1), a single entrance shall be permitted. It shall be located such that the distance from the equipment to the nearest edge of the entrance is not less than the minimum clear distance specified in Table 110.26(A)(1) for equipment operating at that voltage and in that condition.

(3) Personnel Doors. Where equipment rated 800 A or more that contains overcurrent devices, switching devices, or control devices is installed and there is a personnel door(s) intended for entrance to and egress from the working space less than 7.6 m (25 ft) from the nearest edge of the working space, the door(s) shall open in the direction of egress and be equipped with listed panic hardware.

(D) Illumination. Illumination shall be provided for all working spaces about service equipment, switchboards, switchgear, panelboards, or motor control centers installed indoors. Control by automatic means only shall not be permitted. Additional lighting outlets shall not be required where the work space is illuminated by an adjacent light source or as permitted by 210.70(A)(1), Exception No. 1, for switched receptacles.

(E) Dedicated Equipment Space. All switchboards, switchgear, panelboards, and motor control centers shall be located in dedicated spaces and protected from damage.

Exception: Control equipment that by its very nature or because of other rules of the Code must be adjacent to or within sight of its operating machinery shall be permitted in those locations.

(1) Indoor. Indoor installations shall comply with 110.26(E)(1)(a) through (E)(1)(d).

(a) *Dedicated Electrical Space.* The space equal to the width and depth of the equipment and extending from the floor to a height of 1.8 m (6 ft) above the equipment or to the structural ceiling, whichever is lower, shall be dedicated to the electrical installation. No piping, ducts, leak protection apparatus, or other equipment foreign to the electrical installation shall be located in this zone.

Exception: Suspended ceilings with removable panels shall be permitted within the 1.8-m (6-ft) zone.

(b) *Foreign Systems.* The area above the dedicated space required by 110.26(E)(1)(a) shall be permitted to contain foreign systems, provided protection is installed to avoid damage to the electrical equipment from condensation, leaks, or breaks in such foreign systems.

(c) *Sprinkler Protection.* Sprinkler protection shall be permitted for the dedicated space where the piping complies with this section.

(d) *Suspended Ceilings.* A dropped, suspended, or similar ceiling that does not add strength to the building structure shall not be considered a structural ceiling.

(2) Outdoor. Outdoor installations shall comply with 110.26(E)(2)(a) through (c).

(a) *Installation Requirements.* Outdoor electrical equipment shall be the following:

(1) Installed in identified enclosures

(2) Protected from accidental contact by unauthorized personnel or by vehicular traffic

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

(b) *Work Space.* The working clearance space shall include the zone described in 110.26(A). No architectural appurtenance or other equipment shall be located in this zone.

Exception: Structural overhangs or roof extensions shall be permitted in this zone.

(c) *Dedicated Equipment Space.* The space equal to the width and depth of the equipment, and extending from grade to a height of 1.8 m (6 ft) above the equipment, shall be dedicated to the electrical installation. No piping or other equipment foreign to the electrical installation shall be located in this zone.

(F) Locked Electrical Equipment Rooms or Enclosures. Electrical equipment rooms or enclosures housing electrical apparatus that are controlled by a lock(s) shall be considered accessible to qualified persons.

110.27 Guarding of Live Parts.

(A) Live Parts Guarded Against Accidental Contact. Except as elsewhere required or permitted by this *Code*, live parts of electrical equipment operating at 50 to 1000 volts, nominal shall be guarded against accidental contact by approved enclosures or by any of the following means:

(1) By location in a room, vault, or similar enclosure that is accessible only to qualified persons.

(2) By permanent, substantial partitions or screens arranged so that only qualified persons have access to the space within reach of the live parts. Any openings in such partitions or screens shall be sized and located so that persons are not likely to come into accidental contact with the live parts or to bring conducting objects into contact with them.

(3) By location on a balcony, gallery, or platform elevated and arranged so as to exclude unqualified persons.

(4) By elevation above the floor or other working surface as follows:

a. A minimum of 2.5 m (8 ft) for 50 volts to 300 volts between ungrounded conductors

b. A minimum of 2.6 m (8 ft 6 in.) for 301 volts to 600 volts between ungrounded conductors

c. A minimum of 2.62 m (8 ft 7 in.) for 601 volts to 1000 volts between ungrounded conductors

(B) Prevent Physical Damage. In locations where electrical equipment is likely to be exposed to physical damage, enclosures or guards shall be so arranged and of such strength as to prevent such damage.

(C) Warning Signs. Entrances to rooms and other guarded locations that contain exposed live parts shall be marked with conspicuous warning signs forbidding unqualified persons to enter. The marking shall meet the requirements in 110.21(B).

Informational Note: For motors, see 430.232 and 430.233. For over 1000 volts, see 110.34.

110.28 Enclosure Types. Enclosures (other than surrounding fences or walls covered in 110.31) of switchboards, switchgear, panelboards, industrial control panels, motor control centers, meter sockets, enclosed switches, transfer switches, power outlets, circuit breakers, adjustable-speed drive systems, pullout switches, portable power distribution equipment, termination boxes, general-purpose transformers, fire pump controllers, fire pump motors, and motor controllers, rated not over 1000 volts nominal and intended for such locations, shall be marked with an enclosure-type number as shown in Table 110.28.

Table 110.28 shall be used for selecting these enclosures for use in specific locations other than hazardous (classified) locations. The enclosures are not intended to protect against conditions such as condensation, icing, corrosion, or contamination that may occur within the enclosure or enter via the conduit or unsealed openings.

ARTICLE 200
Use and Identification of Grounded Conductors

200.3 Connection to Grounded System. Premises wiring shall not be electrically connected to a supply system unless the latter contains, for any grounded conductor of the interior system, a corresponding conductor that is grounded. For the purpose of this section, *electrically connected* shall mean connected so as to be capable of carrying current, as distinguished from connection through electromagnetic induction.

Exception: Listed utility-interactive inverters identified for use in distributed resource generation systems such as photovoltaic and fuel cell power systems shall be permitted to be connected to premises wiring without a grounded conductor where the connected premises wiring or utility system includes a grounded conductor.

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.

Table 110.28 Enclosure Selection

Provides a Degree of Protection Against the Following Environmental Conditions	For Outdoor Use									
	Enclosure Type Number									
	3	3R	3S	3X	3RX	3SX	4	4X	6	6P
Incidental contact with the enclosed equipment	X	X	X	X	X	X	X	X	X	X
Rain, snow, and sleet	X	X	X	X	X	X	X	X	X	X
Sleet*	—	—	X	—	—	X	—	—	—	—
Windblown dust	X	—	X	X	—	X	X	X	X	X
Hosedown	—	—	—	—	—	—	X	X	X	X
Corrosive agents	—	—	—	X	X	X	—	X	—	X
Temporary submersion	—	—	—	—	—	—	—	—	X	X
Prolonged submersion	—	—	—	—	—	—	—	—	—	X

Provides a Degree of Protection Against the Following Environmental Conditions	For Indoor Use									
	Enclosure Type Number									
	1	2	4	4X	5	6	6P	12	12K	13
Incidental contact with the enclosed equipment	X	X	X	X	X	X	X	X	X	X
Falling dirt	X	X	X	X	X	X	X	X	X	X
Falling liquids and light splashing	—	X	X	X	X	X	X	X	X	X
Circulating dust, lint, fibers, and flyings	—	—	X	X	—	X	X	X	X	X
Settling airborne dust, lint, fibers, and flyings	—	—	X	X	X	X	X	X	X	X
Hosedown and splashing water	—	—	X	X	—	X	X	—	—	—
Oil and coolant seepage	—	—	—	—	—	—	—	X	X	X
Oil or coolant spraying and splashing	—	—	—	—	—	—	—	—	—	X
Corrosive agents	—	—	—	X	—	—	X	—	—	—
Temporary submersion	—	—	—	—	—	X	X	—	—	—
Prolonged submersion	—	—	—	—	—	—	X	—	—	—

*Mechanism shall be operable when ice covered.

Informational Note No. 1: The term *raintight* is typically used in conjunction with Enclosure Types 3, 3S, 3SX, 3X, 4, 4X, 6, and 6P. The term *rainproof* is typically used in conjunction with Enclosure Types 3R and 3RX. The term *watertight* is typically used in conjunction with Enclosure Types 4, 4X, 6, and 6P. The term *driptight* is typically used in conjunction with Enclosure Types 2, 5, 12, 12K, and 13. The term *dusttight* is typically used in conjunction with Enclosure Types 3, 3S, 3SX, 3X, 5, 12, 12K, and 13.

Informational Note No. 2: Ingress protection (IP) ratings may be found in ANSI/IEC 60529, *Degrees of Protection Provided by Enclosures*. IP ratings are not a substitute for Enclosure Type ratings.

(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.

(C) Flexible Cords. An insulated conductor that is intended for use as a grounded conductor, where contained within a flexible cord, shall be identified by a white or gray outer finish or by methods permitted by 400.22.

(D) Grounded Conductors of Different Systems. Where grounded conductors of different systems are installed in the same raceway, cable, box, auxiliary gutter, or other type of enclosure, each grounded conductor shall be identified by system. Identification that distinguishes each system grounded conductor shall be permitted by one of the following means:

(1) One system grounded conductor shall have an outer covering conforming to 200.6(A) or (B).

(2) The grounded conductor(s) of other systems shall have a different outer covering conforming to 200.6(A) or 200.6(B) or by an outer covering of white or gray with a readily distinguishable colored stripe other than green running along the insulation.

(3) Other and different means of identification allowed by 200.6(A) or (B) shall distinguish each system grounded conductor.

The means of identification shall be documented in a manner that is readily available or shall be permanently posted where the conductors of different systems originate.

(E) Grounded Conductors of Multiconductor Cables. The insulated grounded conductors in a multiconductor cable shall be identified by a continuous white or gray outer finish or by three continuous white or gray stripes on other than green insulation along its entire length. Multiconductor flat cable 4 AWG or larger shall be permitted to employ an external ridge on the grounded conductor.

Exception No. 1: Where the conditions of maintenance and supervision ensure that only qualified persons service the installation, grounded conductors in multiconductor cables shall be permitted to be permanently identified at their terminations at the time of installation by a distinctive white marking or other equally effective means.

Exception No. 2: The grounded conductor of a multiconductor varnished-cloth-insulated cable shall be permitted to be identified at its terminations at the time of installation by a distinctive white marking or other equally effective means.

Informational Note: The color gray may have been used in the past as an ungrounded conductor. Care should be taken when working on existing systems.

210.5 Identification for Branch Circuits.

(A) Grounded Conductor. The grounded conductor of a branch circuit shall be identified in accordance with 200.6.

(B) Equipment Grounding Conductor. The equipment grounding conductor shall be identified in accordance with 250.119.

(C) Identification of Ungrounded Conductors. Ungrounded conductors shall be identified in accordance with 210.5(C)(1) or (2), as applicable.

(1) Branch Circuits Supplied from More Than One Nominal Voltage System. Where the premises wiring system has branch circuits supplied from more than one nominal voltage system, each ungrounded conductor of a branch circuit shall be identified by phase or line and system at all termination, connection, and splice points in compliance with 210.5(C)(1)(a) and (b).

(a) *Means of Identification.* The means of identification shall be permitted to be by separate color coding, marking tape, tagging, or other approved means.

(b) *Posting of Identification Means.* The method utilized for conductors originating within each branch-circuit panelboard or similar branch-circuit distribution equipment shall be documented in a manner that is readily available or shall be permanently posted at each branch-circuit panelboard or similar branch-circuit distribution equipment. The label shall be of sufficient durability to withstand the environment involved and shall not be handwritten.

Exception: In existing installations where a voltage system(s) already exists and a different voltage system is being added, it shall be permissible to mark only the new system voltage. Existing unidentified systems shall not be required to be identified at each termination, connection, and splice point in compliance with 210.5(C)(1)(a) and (b). Labeling shall be required at each voltage system distribution equipment to identify that only one voltage system has been marked for a new system(s). The new system label(s) shall include the words "other unidentified systems exist on the premises."

(2) Branch Circuits Supplied From Direct-Current Systems. Where a branch circuit is supplied from a dc system operating at more than 60 volts, each ungrounded conductor of 4 AWG or larger shall be identified by polarity at all termination, connection, and splice points by marking tape, tagging, or other approved means; each ungrounded conductor of 6 AWG or smaller shall be identified by polarity at all termination, connection, and splice points in compliance with 210.5(C)(2)(a) and (b). The identification methods utilized for conductors originating within each branch-circuit panelboard or similar branch-circuit distribution equipment shall be documented in a manner that is readily available or shall be permanently posted at each branch-circuit panelboard or similar branch-circuit distribution equipment.

(a) *Positive Polarity, Sizes 6 AWG or Smaller.* Where the positive polarity of a dc system does not serve as the connection point for the grounded conductor, each positive ungrounded conductor shall be identified by one of the following means:

(1) A continuous red outer finish

(2) A continuous red stripe durably marked along the conductor's entire length on insulation of a color other than green, white, gray, or black

(3) Imprinted plus signs (+) or the word POSITIVE or POS durably marked on insulation of a color other than green, white, gray, or black and repeated at intervals not exceeding 610 mm (24 in.) in accordance with 310.120(B)

(4) An approved permanent marking means such as sleeving or shrink-tubing that is suitable for the conductor size, at all termination, connection, and splice points, with imprinted plus signs (+) or the word POSITIVE or POS durably marked on insulation of a color other than green, white, gray, or black

(b) *Negative Polarity, Sizes 6 AWG or Smaller.* Where the negative polarity of a dc system does not serve as the connection point for the grounded conductor, each negative ungrounded conductor shall be identified by one of the following means:

(1) A continuous black outer finish

(2) A continuous black stripe durably marked along the conductor's entire length on insulation of a color other than green, white, gray, or red

(3) Imprinted minus signs (–) or the word NEGATIVE or NEG durably marked on insulation of a color other than green, white, gray, or red and repeated at intervals not exceeding 610 mm (24 in.) in accordance with 310.120(B)

(4) An approved permanent marking means such as sleeving or shrink-tubing that is suitable for the conductor size, at all termination, connection, and splice points, with imprinted minus signs (–) or the word NEGATIVE or NEG durably marked on insulation of a color other than green, white, gray, or red

ARTICLE 230
Services

Part I. General

230.2 Number of Services. A building or other structure served shall be supplied by only one service unless permitted in 230.2(A) through (D). For the purpose of 230.40, Exception No. 2 only, underground sets of conductors, 1/0 AWG and larger, running to the same location and connected together at their supply end but not connected together at their load end shall be considered to be supplying one service.

(A) Special Conditions. Additional services shall be permitted to supply the following:

(1) Fire pumps

(2) Emergency systems

(3) Legally required standby systems

(4) Optional standby systems

(5) Parallel power production systems

(6) Systems designed for connection to multiple sources of supply for the purpose of enhanced reliability

(B) Special Occupancies. By special permission, additional services shall be permitted for either of the following:

(1) Multiple-occupancy buildings where there is no available space for service equipment accessible to all occupants

(2) A single building or other structure sufficiently large to make two or more services necessary

(C) Capacity Requirements. Additional services shall be permitted under any of the following:

(1) Where the capacity requirements are in excess of 2000 amperes at a supply voltage of 1000 volts or less

(2) Where the load requirements of a single-phase installation are greater than the serving agency normally supplies through one service

(3) By special permission

(D) Different Characteristics. Additional services shall be permitted for different voltages, frequencies, or phases, or for different uses, such as for different rate schedules.

(E) Identification. Where a building or structure is supplied by more than one service, or any combination of branch circuits, feeders, and services, a permanent plaque or directory shall be installed at each service disconnect location denoting all other services, feeders, and branch circuits supplying that building or structure and the area served by each. See 225.37.

Part IV. Service-Entrance Conductors

230.40 Number of Service-Entrance Conductor Sets. Each service drop, set of overhead service conductors, set of underground service conductors, or service lateral shall supply only one set of service-entrance conductors.

Exception No. 1: A building with more than one occupancy shall be permitted to have one set of service-entrance conductors for each service, as defined in 230.2, run to each occupancy or group of occupancies. If the number of service disconnect locations for any given classification of service does not exceed six, the requirements of 230.2(E) shall apply at each location. If the number of service disconnect locations exceeds six for any given supply classification, all service disconnect locations for all supply characteristics, together with any branch circuit or feeder supply sources, if applicable, shall be clearly described using suitable graphics or text, or both, on one or more plaques located in an approved, readily accessible location(s) on the building or structure served and as near as practicable to the point(s) of attachment or entry(ies) for each service drop or service lateral, and for each set of overhead or underground service conductors.

Exception No. 2: Where two to six service disconnecting means in separate enclosures are grouped at one location and supply separate loads from one service drop, set of overhead service conductors, set of underground service conductors, or service lateral, one set of service-entrance conductors shall be permitted to supply each or several such service equipment enclosures.

Exception No. 3: A one-family dwelling unit and its accessory structures shall be permitted to have one set of service-entrance conductors run to each from a single service drop, set of overhead service conductors, set of underground service conductors, or service lateral.

Exception No. 4: Two-family dwellings, multifamily dwellings, and multiple occupancy buildings shall be permitted to have one set of service-entrance conductors installed to supply the circuits covered in 210.25.

Exception No. 5: One set of service-entrance conductors connected to the supply side of the normal service disconnecting means shall be permitted to supply each or several systems covered by 230.82(5) or 230.82(6).

230.66 Marking. Service equipment rated at 1000 volts or less shall be marked to identify it as being suitable for use as service equipment. All service equipment shall be listed or field labeled. Individual meter socket enclosures shall not be considered service equipment but shall be listed and rated for the voltage and ampacity of the service.

Exception: Meter sockets supplied by and under the exclusive control of an electric utility shall not be required to be listed.

230.71 Maximum Number of Disconnects.

(A) General. The service disconnecting means for each service permitted by 230.2, or for each set of service-entrance conductors permitted by 230.40, Exception No. 1, 3, 4, or 5, shall consist of not more than six switches or sets of circuit breakers, or a combination of not more than six switches and

sets of circuit breakers, mounted in a single enclosure, in a group of separate enclosures, or in or on a switchboard or in switchgear. There shall be not more than six sets of disconnects per service grouped in any one location.

For the purpose of this section, disconnecting means installed as part of listed equipment and used solely for the following shall not be considered a service disconnecting means:

(1) Power monitoring equipment

(2) Surge-protective device(s)

(3) Control circuit of the ground-fault protection system

(4) Power-operable service disconnecting means

(B) Single-Pole Units. Two or three single-pole switches or breakers, capable of individual operation, shall be permitted on multiwire circuits, one pole for each ungrounded conductor, as one multipole disconnect, provided they are equipped with identified handle ties or a master handle to disconnect all conductors of the service with no more than six operations of the hand.

Informational Note: See 408.36, Exception No. 1 and Exception No. 3, for service equipment in certain panelboards, and see 430.95 for service equipment in motor control centers.

230.82 Equipment Connected to the Supply Side of Service Disconnect. Only the following equipment shall be permitted to be connected to the supply side of the service disconnecting means:

(1) Cable limiters or other current-limiting devices.

(2) Meters and meter sockets nominally rated not in excess of 1000 volts, if all metal housings and service enclosures are grounded in accordance with Part VII and bonded in accordance with Part V of Article 250.

(3) Meter disconnect switches nominally rated not in excess of 1000 V that have a short-circuit current rating equal to or greater than the available short-circuit current, if all metal housings and service enclosures are grounded in accordance with Part VII and bonded in accordance with Part V of Article 250. A meter disconnect switch shall be capable of interrupting the load served. A meter disconnect shall be legibly field marked on its exterior in a manner suitable for the environment as follows:

METER DISCONNECT
NOT SERVICE EQUIPMENT

(4) Instrument transformers (current and voltage), impedance shunts, load management devices, surge arresters, and Type 1 surge-protective devices.

(5) Taps used only to supply load management devices, circuits for standby power systems, fire pump equipment, and fire and sprinkler alarms, if provided with service equipment and installed in accordance with requirements for service-entrance conductors.

(6) Solar photovoltaic systems, fuel cell systems, wind electric systems, energy storage systems, or interconnected electric power production sources.

(7) Control circuits for power-operable service disconnecting means, if suitable overcurrent protection and disconnecting means are provided.

(8) Ground-fault protection systems or Type 2 surge-protective devices, where installed as part of listed equipment, if suitable overcurrent protection and disconnecting means are provided.

(9) Connections used only to supply listed communications equipment under the exclusive control of the serving electric utility, if suitable overcurrent protection and disconnecting means are provided. For installations of equipment by the serving electric utility, a disconnecting means is not required if the supply is installed as part of a meter socket, such that access can only be gained with the meter removed.

ARTICLE 240
Overcurrent Protection

240.4 Protection of Conductors. Conductors, other than flexible cords, flexible cables, and fixture wires, shall be protected against overcurrent in accordance with their ampacities specified in 310.15, unless otherwise permitted or required in 240.4(A) through (G).

Informational Note: See ICEA P-32-382-2007 for information on allowable short-circuit currents for insulated copper and aluminum conductors.

(A) Power Loss Hazard. Conductor overload protection shall not be required where the interruption of the circuit would create a hazard, such as in a material-handling magnet circuit or fire pump circuit. Short-circuit protection shall be provided.

Informational Note: See NFPA 20-2013, *Standard for the Installation of Stationary Pumps for Fire Protection*.

(B) Overcurrent Devices Rated 800 Amperes or Less. The next higher standard overcurrent device rating (above the ampacity of the conductors being protected) shall be permitted to be used, provided all of the following conditions are met:

(1) The conductors being protected are not part of a branch circuit supplying more than one receptacle for cord-and-plug-connected portable loads.

(2) The ampacity of the conductors does not correspond with the standard ampere rating of a fuse or a circuit breaker without overload trip adjustments above its rating (but that shall be permitted to have other trip or rating adjustments).

(3) The next higher standard rating selected does not exceed 800 amperes.

(C) Overcurrent Devices Rated over 800 Amperes. Where the overcurrent device is rated over 800 amperes, the ampacity of the conductors it protects shall be equal to or greater than the rating of the overcurrent device defined in 240.6.

(D) Small Conductors. Unless specifically permitted in 240.4(E) or (G), the overcurrent protection shall not exceed that required by (D)(1) through (D)(7) after any correction

factors for ambient temperature and number of conductors have been applied.

(1) 18 AWG Copper. 7 amperes, provided all the following conditions are met:

(1) Continuous loads do not exceed 5.6 amperes.

(2) Overcurrent protection is provided by one of the following:

a. Branch-circuit-rated circuit breakers listed and marked for use with 18 AWG copper wire

b. Branch-circuit-rated fuses listed and marked for use with 18 AWG copper wire

c. Class CC, Class J, or Class T fuses

(2) 16 AWG Copper. 10 amperes, provided all the following conditions are met:

(1) Continuous loads do not exceed 8 amperes.

(2) Overcurrent protection is provided by one of the following:

a. Branch-circuit-rated circuit breakers listed and marked for use with 16 AWG copper wire

b. Branch-circuit-rated fuses listed and marked for use with 16 AWG copper wire

c. Class CC, Class J, or Class T fuses

(3) 14 AWG Copper. 15 amperes

(4) 12 AWG Aluminum and Copper-Clad Aluminum. 15 amperes

(5) 12 AWG Copper. 20 amperes

(6) 10 AWG Aluminum and Copper-Clad Aluminum. 25 amperes

(7) 10 AWG Copper. 30 amperes

(E) Tap Conductors. Tap conductors shall be permitted to be protected against overcurrent in accordance with the following:

(1) 210.19(A)(3) and (A)(4), Household Ranges and Cooking Appliances and Other Loads

(2) 240.5(B)(2), Fixture Wire

(3) 240.21, Location in Circuit

(4) 368.17(B), Reduction in Ampacity Size of Busway

(5) 368.17(C), Feeder or Branch Circuits (busway taps)

(6) 430.53(D), Single Motor Taps

(F) Transformer Secondary Conductors. Single-phase (other than 2-wire) and multiphase (other than delta-delta, 3-wire) transformer secondary conductors shall not be considered to be protected by the primary overcurrent protective device. Conductors supplied by the secondary side of a single-phase transformer having a 2-wire (single-voltage) secondary, or a three-phase, delta-delta connected transformer having a 3-wire (single-voltage) secondary, shall be permitted to be protected by overcurrent protection provided on the primary (supply) side of the transformer, provided this protection is in accordance with 450.3 and does not exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio.

(G) Overcurrent Protection for Specific Conductor Applications. Overcurrent protection for the specific conductors shall be permitted to be provided as referenced in Table 240.4(G).

Table 240.4(G) Specific Conductor Applications

Conductor	Article	Section
Air-conditioning and refrigeration equipment circuit conductors	440, Parts III, VI	
Capacitor circuit conductors	460	460.8(B) and 460.25(A)–(D)
Control and instrumentation circuit conductors (Type ITC)	727	727.9
Electric welder circuit conductors	630	630.12 and 630.32
Fire alarm system circuit conductors	760	760.43, 760.45, 760.121, and Chapter 9, Tables 12(A) and 12(B)
Motor-operated appliance circuit conductors	422, Part II	
Motor and motor-control circuit conductors	430, Parts II, III, IV, V, VI, VII	
Phase converter supply conductors	455	455.7
Remote-control, signaling, and power-limited circuit conductors	725	725.43, 725.45, 725.121, and Chapter 9, Tables 11(A) and 11(B)
Secondary tie conductors	450	450.6

240.6 Standard Ampere Ratings.

(A) Fuses and Fixed-Trip Circuit Breakers. The standard ampere ratings for fuses and inverse time circuit breakers shall be considered as shown in Table 240.6(A). Additional standard ampere ratings for fuses shall be 1, 3, 6, 10, and 601. The use of fuses and inverse time circuit breakers with nonstandard ampere ratings shall be permitted.

Table 240.6(A) Standard Ampere Ratings for Fuses and Inverse Time Circuit Breakers

Standard Ampere Ratings				
15	20	25	30	35
40	45	50	60	70
80	90	100	110	125
150	175	200	225	250
300	350	400	450	500
600	700	800	1000	1200
1600	2000	2500	3000	4000
5000	6000	—	—	—

(B) Adjustable-Trip Circuit Breakers. The rating of adjustable-trip circuit breakers having external means for adjusting the current setting (long-time pickup setting), not meeting the requirements of 240.6(C), shall be the maximum setting possible.

(C) Restricted Access Adjustable-Trip Circuit Breakers. A circuit breaker(s) that has restricted access to the adjusting means shall be permitted to have an ampere rating(s) that is equal to the adjusted current setting (long-time pickup setting). Restricted access shall be defined as located behind one of the following:

(1) Removable and sealable covers over the adjusting means

(2) Bolted equipment enclosure doors

(3) Locked doors accessible only to qualified personnel

240.21 Location in Circuit. Overcurrent protection shall be provided in each ungrounded circuit conductor and shall be located at the point where the conductors receive their supply except as specified in 240.21(A) through (H). Conductors supplied under the provisions of 240.21(A) through (H) shall not supply another conductor except through an overcurrent protective device meeting the requirements of 240.4.

(A) Branch-Circuit Conductors. Branch-circuit tap conductors meeting the requirements specified in 210.19 shall be permitted to have overcurrent protection as specified in 210.20.

(B) Feeder Taps. Conductors shall be permitted to be tapped, without overcurrent protection at the tap, to a feeder as specified in 240.21(B)(1) through (B)(5). The provisions of 240.4(B) shall not be permitted for tap conductors.

(1) Taps Not over 3 m (10 ft) Long. If the length of the tap conductors does not exceed 3 m (10 ft) and the tap conductors comply with all of the following:

(1) The ampacity of the tap conductors is

   a. Not less than the combined calculated loads on the circuits supplied by the tap conductors, and

   b. Not less than the rating of the equipment containing an overcurrent device(s) supplied by the tap conductors or not less than the rating of the overcurrent protective device at the termination of the tap conductors.

Exception to b: Where listed equipment, such as a surge protective device(s) [SPD(s)], is provided with specific instructions on minimum conductor sizing, the ampacity of the tap conductors supplying that equipment shall be permitted to be determined based on the manufacturer's instructions.

(2) The tap conductors do not extend beyond the switchboard, switchgear, panelboard, disconnecting means, or control devices they supply.

(3) Except at the point of connection to the feeder, the tap conductors are enclosed in a raceway, which extends from the tap to the enclosure of an enclosed switchboard, switchgear, a panelboard, or control devices, or to the back of an open switchboard.

(4) For field installations, if the tap conductors leave the enclosure or vault in which the tap is made, the ampacity of the tap conductors is not less than one-tenth of the rating of the overcurrent device protecting the feeder conductors.

Informational Note: For overcurrent protection requirements for panelboards, see 408.36.

(2) Taps Not over 7.5 m (25 ft) Long. Where the length of the tap conductors does not exceed 7.5 m (25 ft) and the tap conductors comply with all the following:

(1) The ampacity of the tap conductors is not less than one-third of the rating of the overcurrent device protecting the feeder conductors.

(2) The tap conductors terminate in a single circuit breaker or a single set of fuses that limit the load to the ampacity of the tap conductors. This device shall be permitted to supply any number of additional overcurrent devices on its load side.

(3) The tap conductors are protected from physical damage by being enclosed in an approved raceway or by other approved means.

(3) Taps Supplying a Transformer [Primary Plus Secondary Not over 7.5 m (25 ft) Long]. Where the tap conductors supply a transformer and comply with all the following conditions:

(1) The conductors supplying the primary of a transformer have an ampacity at least one-third the rating of the overcurrent device protecting the feeder conductors.

(2) The conductors supplied by the secondary of the transformer shall have an ampacity that is not less than the value of the primary-to-secondary voltage ratio multiplied by one-third of the rating of the overcurrent device protecting the feeder conductors.

(3) The total length of one primary plus one secondary conductor, excluding any portion of the primary conductor that is protected at its ampacity, is not over 7.5 m (25 ft).

(4) The primary and secondary conductors are protected from physical damage by being enclosed in an approved raceway or by other approved means.

(5) The secondary conductors terminate in a single circuit breaker or set of fuses that limit the load current to not more than the conductor ampacity that is permitted by 310.15.

(4) Taps over 7.5 m (25 ft) Long. Where the feeder is in a high bay manufacturing building over 11 m (35 ft) high at walls and the installation complies with all the following conditions:

(1) Conditions of maintenance and supervision ensure that only qualified persons service the systems.

(2) The tap conductors are not over 7.5 m (25 ft) long horizontally and not over 30 m (100 ft) total length.

(3) The ampacity of the tap conductors is not less than one-third the rating of the overcurrent device protecting the feeder conductors.

(4) The tap conductors terminate at a single circuit breaker or a single set of fuses that limit the load to the ampacity of the tap conductors. This single overcurrent device shall be permitted to supply any number of additional overcurrent devices on its load side.

(5) The tap conductors are protected from physical damage by being enclosed in an approved raceway or by other approved means.

(6) The tap conductors are continuous from end-to-end and contain no splices.

(7) The tap conductors are sized 6 AWG copper or 4 AWG aluminum or larger.

(8) The tap conductors do not penetrate walls, floors, or ceilings.

(9) The tap is made no less than 9 m (30 ft) from the floor.

(5) Outside Taps of Unlimited Length. Where the conductors are located outside of a building or structure, except at the point of load termination, and comply with all of the following conditions:

(1) The tap conductors are protected from physical damage in an approved manner.

(2) The tap conductors terminate at a single circuit breaker or a single set of fuses that limits the load to the ampacity of the tap conductors. This single overcurrent device shall be permitted to supply any number of additional overcurrent devices on its load side.

(3) The overcurrent device for the tap conductors is an integral part of a disconnecting means or shall be located immediately adjacent thereto.

(4) The disconnecting means for the tap conductors is installed at a readily accessible location complying with one of the following:

a. Outside of a building or structure

b. Inside, nearest the point of entrance of the tap conductors

c. Where installed in accordance with 230.6, nearest the point of entrance of the tap conductors

240.24 Location in or on Premises.

(A) Accessibility. Switches containing fuses and circuit breakers shall be readily accessible and installed so that the center of the grip of the operating handle of the switch or circuit breaker, when in its highest position, is not more than 2.0 m (6 ft 7 in.) above the floor or working platform, unless one of the following applies:

(1) For busways, as provided in 368.17(C).

(2) For supplementary overcurrent protection, as described in 240.10.

(3) For overcurrent devices, as described in 225.40 and 230.92.

(4) For overcurrent devices adjacent to utilization equipment that they supply, access shall be permitted to be by portable means.

Exception: The use of a tool shall be permitted to access overcurrent devices located within listed industrial control panels or similar enclosures.

(B) Occupancy. Each occupant shall have ready access to all overcurrent devices protecting the conductors supplying that occupancy, unless otherwise permitted in 240.24(B)(1) and (B)(2).

(1) Service and Feeder Overcurrent Devices. Where electric service and electrical maintenance are provided by the building management and where these are under continuous building management supervision, the service overcurrent devices and feeder overcurrent devices supplying more than one occupancy shall be permitted to be accessible only to authorized management personnel in the following:

(1) Multiple-occupancy buildings

(2) Guest rooms or guest suites

(2) Branch-Circuit Overcurrent Devices. Where electric service and electrical maintenance are provided by the building management and where these are under continuous building management supervision, the branch-circuit overcurrent devices supplying any guest rooms or guest suites without permanent provisions for cooking shall be permitted to be accessible only to authorized management personnel.

(C) Not Exposed to Physical Damage. Overcurrent devices shall be located where they will not be exposed to physical damage.

Informational Note: See 110.11, Deteriorating Agents.

(D) Not in Vicinity of Easily Ignitible Material. Overcurrent devices shall not be located in the vicinity of easily ignitible material, such as in clothes closets.

(E) Not Located in Bathrooms. In dwelling units, dormitories, and guest rooms or guest suites, overcurrent devices, other than supplementary overcurrent protection, shall not be located in bathrooms.

(F) Not Located over Steps. Overcurrent devices shall not be located over steps of a stairway.

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.

Informational Note No. 2: See NFPA 780-2014, *Standard for the Installation of Lightning Protection Systems*, for information on installation of grounding and bonding for lightning protection systems.

(2) Grounding of Electrical Equipments. Normally noncurrent-carrying conductive materials enclosing electrical

conductors or equipment, or forming part of such equipment, shall be connected to earth so as to limit the voltage to ground on these materials.

(3) Bonding of Electrical Equipment. Normally non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

(4) Bonding of Electrically Conductive Materials and Other Equipment. Normally non-current-carrying electrically conductive materials that are likely to become energized shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

(5) Effective Ground-Fault Current Path. Electrical equipment and wiring and other electrically conductive material likely to become energized shall be installed in a manner that creates a low-impedance circuit facilitating the operation of the overcurrent device or ground detector for high-impedance grounded systems. It shall be capable of safely carrying the maximum ground-fault current likely to be imposed on it from any point on the wiring system where a ground fault may occur to the electrical supply source. The earth shall not be considered as an effective ground-fault current path.

(B) Underground Systems.

(1) Grounding Electrical Equipment. Non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth in a manner that will limit the voltage imposed by lightning or unintentional contact with higher-voltage lines and limit the voltage to ground on these materials.

> Informational Note: See NFPA 780-2014, *Standard for the Installation of Lightning Protection Systems*, for information on installation of grounding and bonding for lightning protection systems.

(2) Bonding of Electrical Equipment. Non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the supply system grounded equipment in a manner that creates a low-impedance path for ground-fault current that is capable of carrying the maximum fault current likely to be imposed on it.

(3) Bonding of Electrically Conductive Materials and Other Equipment. Electrically conductive materials that are likely to become energized shall be connected together and to the supply system grounded equipment in a manner that creates a low-impedance path for ground-fault current that is capable of carrying the maximum fault current likely to be imposed on it.

(4) Path for Fault Current. Electrical equipment, wiring, and other electrically conductive material likely to become energized shall be installed in a manner that creates a low-impedance circuit from any point on the wiring system to the electrical supply source to facilitate the operation of overcurrent devices should a second ground fault from a different phase occur on the wiring system. The earth shall not be considered as an effective fault-current path.

250.8 Connection of Grounding and Bonding Equipment.

(A) Permitted Methods. Equipment grounding conductors, grounding electrode conductors, and bonding jumpers shall be connected by one or more of the following means:

(1) Listed pressure connectors

(2) Terminal bars

(3) Pressure connectors listed as grounding and bonding equipment

(4) Exothermic welding process

(5) Machine screw-type fasteners that engage not less than two threads or are secured with a nut

(6) Thread-forming machine screws that engage not less than two threads in the enclosure

(7) Connections that are part of a listed assembly

(8) Other listed means

(B) Methods Not Permitted. Connection devices or fittings that depend solely on solder shall not be used.

250.52 Grounding Electrodes.

(A) Electrodes Permitted for Grounding.

(1) Metal Underground Water Pipe. A metal underground water pipe in direct contact with the earth for 3.0 m (10 ft) or more (including any metal well casing bonded to the pipe) and electrically continuous (or made electrically continuous by bonding around insulating joints or insulating pipe) to the points of connection of the grounding electrode conductor and the bonding conductor(s) or jumper(s), if installed.

(2) Metal In-ground Support Structure(s). One or more metal in-ground support structure(s) in direct contact with the earth vertically for 3.0 m (10 ft) or more, with or without concrete encasement. If multiple metal in-ground support structures are present at a building or a structure, it shall be permissible to bond only one into the grounding electrode system.

> Informational Note: Metal in-ground support structures include, but are not limited to, pilings, casings, and other structural metal.

(3) Concrete-Encased Electrode. A concrete-encased electrode shall consist of at least 6.0 m (20 ft) of either (1) or (2):

(1) One or more bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of not less than 13 mm ($^1/_2$ in.) in diameter, installed in one continuous 6.0 m (20 ft) length, or if in multiple pieces connected together by the usual steel tie wires, exothermic welding, welding, or other effective means to create a 6.0 m (20 ft) or greater length; or

(2) Bare copper conductor not smaller than 4 AWG

Metallic components shall be encased by at least 50 mm (2 in.) of concrete and shall be located horizontally within that portion of a concrete foundation or footing that is in direct contact with the earth or within vertical foundations or struc-

tural components or members that are in direct contact with the earth. If multiple concrete-encased electrodes are present at a building or structure, it shall be permissible to bond only one into the grounding electrode system.

Informational Note: Concrete installed with insulation, vapor barriers, films or similar items separating the concrete from the earth is not considered to be in "direct contact" with the earth.

(4) Ground Ring. A ground ring encircling the building or structure, in direct contact with the earth, consisting of at least 6.0 m (20 ft) of bare copper conductor not smaller than 2 AWG.

(5) Rod and Pipe Electrodes. Rod and pipe electrodes shall not be less than 2.44 m (8 ft) in length and shall consist of the following materials.

(a) Grounding electrodes of pipe or conduit shall not be smaller than metric designator 21 (trade size $^{3}/_{4}$) and, where of steel, shall have the outer surface galvanized or otherwise metal-coated for corrosion protection.

(b) Rod-type grounding electrodes of stainless steel and copper or zinc coated steel shall be at least 15.87 mm ($^{5}/_{8}$ in.) in diameter, unless listed.

(6) Other Listed Electrodes. Other listed grounding electrodes shall be permitted.

(7) Plate Electrodes. Each plate electrode shall expose not less than 0.186 m^2 (2 ft^2) of surface to exterior soil. Electrodes of bare or electrically conductive coated iron or steel plates shall be at least 6.4 mm ($^{1}/_{4}$ in.) in thickness. Solid, uncoated electrodes of nonferrous metal shall be at least 1.5 mm (0.06 in.) in thickness.

(8) Other Local Metal Underground Systems or Structures. Other local metal underground systems or structures such as piping systems, underground tanks, and underground metal well casings that are not bonded to a metal water pipe.

(B) Not Permitted for Use as Grounding Electrodes. The following systems and materials shall not be used as grounding electrodes:

(1) Metal underground gas piping systems

(2) Aluminum

(3) The structures and structural reinforcing steel described in 680.26(B)(1) and (B)(2)

Informational Note: See 250.104(B) for bonding requirements of gas piping.

250.54 Auxiliary Grounding Electrodes. One or more grounding electrodes shall be permitted to be connected to the equipment grounding conductors specified in 250.118 and shall not be required to comply with the electrode bonding requirements of 250.50 or 250.53(C) or the resistance requirements of 250.53(A)(2) Exception, but the earth shall not be used as an effective ground-fault current path as specified in 250.4(A)(5) and 250.4(B)(4).

250.64 Grounding Electrode Conductor Installation. Grounding electrode conductors at the service, at each building or structure where supplied by a feeder(s) or branch circuit(s), or at a separately derived system shall be installed as specified in 250.64(A) through (F).

(A) Aluminum or Copper-Clad Aluminum Conductors. Bare aluminum or copper-clad aluminum grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum grounding electrode conductors shall not be terminated within 450 mm (18 in.) of the earth.

(B) Securing and Protection Against Physical Damage. Where exposed, a grounding electrode conductor or its enclosure shall be securely fastened to the surface on which it is carried. Grounding electrode conductors shall be permitted to be installed on or through framing members.

(1) Not Exposed to Physical Damage. A 6 AWG or larger copper or aluminum grounding electrode conductor not exposed to physical damage shall be permitted to be run along the surface of the building construction without metal covering or protection.

(2) Exposed to Physical Damage. A 6 AWG or larger copper or aluminum grounding electrode conductor exposed to physical damage shall be protected in rigid metal conduit (RMC), intermediate metal conduit (IMC), rigid polyvinyl chloride conduit (PVC), reinforced thermosetting resin conduit Type XW (RTRC-XW), electrical metallic tubing (EMT), or cable armor.

(3) Smaller Than 6 AWG. Grounding electrode conductors smaller than 6 AWG shall be protected in RMC, IMC, PVC, RTRC-XW, EMT, or cable armor.

(4) In Contact with the Earth. Grounding electrode conductors and grounding electrode bonding jumpers in contact with the earth shall not be required to comply with 300.5, but shall be buried or otherwise protected if subject to physical damage.

(C) Continuous. Except as provided in 250.30(A)(5) and (A)(6), 250.30(B)(1), and 250.68(C), grounding electrode conductor(s) shall be installed in one continuous length without a splice or joint. If necessary, splices or connections shall be made as permitted in (1) through (4):

(1) Splicing of the wire-type grounding electrode conductor shall be permitted only by irreversible compression-type connectors listed as grounding and bonding equipment or by the exothermic welding process.

(2) Sections of busbars shall be permitted to be connected together to form a grounding electrode conductor.

(3) Bolted, riveted, or welded connections of structural metal frames of buildings or structures.

(4) Threaded, welded, brazed, soldered or bolted-flange connections of metal water piping.

(D) Building or Structure with Multiple Disconnecting Means in Separate Enclosures. If a building or structure is supplied by a service or feeder with two or more disconnecting means in separate enclosures, the grounding electrode connections shall be made in accordance with 250.64(D)(1),250.64(D)(2), or 250.64(D)(3).

(1) Common Grounding Electrode Conductor and Taps. A common grounding electrode conductor and grounding electrode conductor taps shall be installed. The common

grounding electrode conductor shall be sized in accordance with 250.66, based on the sum of the circular mil area of the largest ungrounded conductor(s) of each set of conductors that supplies the disconnecting means. If the service-entrance conductors connect directly to the overhead service conductors, service drop, underground service conductors, or service lateral, the common grounding electrode conductor shall be sized in accordance with Table 250.66, note 1.

A grounding electrode conductor tap shall extend to the inside of each disconnecting means enclosure. The grounding electrode conductor taps shall be sized in accordance with 250.66 for the largest service-entrance or feeder conductor serving the individual enclosure. The tap conductors shall be connected to the common grounding electrode conductor by one of the following methods in such a manner that the common grounding electrode conductor remains without a splice or joint:

(1) Exothermic welding.

(2) Connectors listed as grounding and bonding equipment.

(3) Connections to an aluminum or copper busbar not less than 6 mm thick × 50 mm wide ($^1/_4$ in. thick × 2 in. wide) and of sufficient length to accommodate the number of terminations necessary for the installation. The busbar shall be securely fastened and shall be installed in an accessible location. Connections shall be made by a listed connector or by the exothermic welding process. If aluminum busbars are used, the installation shall comply with 250.64(A).

(2) Individual Grounding Electrode Conductors. A grounding electrode conductor shall be connected between the grounding electrode system and one or more of the following, as applicable:

(1) Grounded conductor in each service equipment disconnecting means enclosure

(2) Equipment grounding conductor installed with the feeder

(3) Supply-side bonding jumper

Each grounding electrode conductor shall be sized in accordance with 250.66 based on the service-entrance or feeder conductor(s) supplying the individual disconnecting means.

(3) Common Location. A grounding electrode conductor shall be connected in a wireway or other accessible enclosure on the supply side of the disconnecting means to one or more of the following, as applicable:

(1) Grounded service conductor(s)

(2) Equipment grounding conductor installed with the feeder

(3) Supply-side bonding jumper

The connection shall be made with exothermic welding or a connector listed as grounding and bonding equipment. The grounding electrode conductor shall be sized in accordance with 250.66 based on the service-entrance or feeder conductor(s) at the common location where the connection is made.

(E) Raceways and Enclosures for Grounding Electrode Conductors.

(1) General. Ferrous metal raceways and enclosures for grounding electrode conductors shall be electrically continuous from the point of attachment to cabinets or equipment to the grounding electrode and shall be securely fastened to the ground clamp or fitting. Ferrous metal raceways and enclosures shall be bonded at each end of the raceway or enclosure to the grounding electrode or grounding electrode conductor to create an electrically parallel path. Nonferrous metal raceways and enclosures shall not be required to be electrically continuous.

(2) Methods. Bonding shall be in compliance with 250.92(B) and ensured by one of the methods in 250.92(B)(2) through (B)(4).

(3) Size. The bonding jumper for a grounding electrode conductor raceway or cable armor shall be the same size as, or larger than, the enclosed grounding electrode conductor.

(4) Wiring Methods. If a raceway is used as protection for a grounding electrode conductor, the installation shall comply with the requirements of the appropriate raceway article.

(F) Installation to Electrode(s). Grounding electrode conductor(s) and bonding jumpers interconnecting grounding electrodes shall be installed in accordance with (1), (2), or (3). The grounding electrode conductor shall be sized for the largest grounding electrode conductor required among all the electrodes connected to it.

(1) The grounding electrode conductor shall be permitted to be run to any convenient grounding electrode available in the grounding electrode system where the other electrode(s), if any, is connected by bonding jumpers that are installed in accordance with 250.53(C).

(2) Grounding electrode conductor(s) shall be permitted to be run to one or more grounding electrode(s) individually.

(3) Bonding jumper(s) from grounding electrode(s) shall be permitted to be connected to an aluminum or copper busbar not less than 6 mm thick × 50 mm wide ($^1/_4$ in. thick × 2 in wide.) and of sufficient length to accommodate the number of terminations necessary for the installation. The busbar shall be securely fastened and shall be installed in an accessible location. Connections shall be made by a listed connector or by the exothermic welding process. The grounding electrode conductor shall be permitted to be run to the busbar. Where aluminum busbars are used, the installation shall comply with 250.64(A).

250.66 Size of Alternating-Current Grounding Electrode Conductor. The size of the grounding electrode conductor at the service, at each building or structure where supplied by a feeder(s) or branch circuit(s), or at a separately derived system of a grounded or ungrounded ac system shall not be less than given in Table 250.66, except as permitted in 250.66(A) through (C).

(A) Connections to a Rod, Pipe, or Plate Electrode(s). If the grounding electrode conductor or bonding jumper connected to a single or multiple rod, pipe, or plate electrode(s), or any combination thereof, as described in 250.52(A)(5) or (A)(7), does not extend on to other types of electrodes that require a larger size conductor, the grounding electrode conductor shall not be required to be larger than 6 AWG copper wire or 4 AWG aluminum wire.

(B) Connections to Concrete-Encased Electrodes. If the grounding electrode conductor or bonding jumper connected to a single or multiple concrete-encased electrode(s), as described in 250.52(A)(3), does not extend on to other types of electrodes that require a larger size of conductor, the grounding electrode conductor shall not be required to be larger than 4 AWG copper wire.

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).

(C) Connections to Ground Rings. If the grounding electrode conductor or bonding jumper connected to a ground ring, as described in 250.52(A)(4), does not extend on to other types of electrodes that require a larger size of conductor, the grounding electrode conductor shall not be required to be larger than the conductor used for the ground ring.

250.92 Services.

(A) Bonding of Equipment for Services. The normally non–current-carrying metal parts of equipment indicated in 250.92(A)(1) and (A)(2) shall be bonded together.

(1) All raceways, cable trays, cablebus framework, auxiliary gutters, or service cable armor or sheath that enclose, contain, or support service conductors, except as permitted in 250.80

(2) All enclosures containing service conductors, including meter fittings, boxes, or the like, interposed in the service raceway or armor

(B) Method of Bonding at the Service. Bonding jumpers meeting the requirements of this article shall be used around impaired connections, such as reducing washers or oversized, concentric, or eccentric knockouts. Standard locknuts or bushings shall not be the only means for the bonding required by this section but shall be permitted to be installed to make a mechanical connection of the raceway(s).

Electrical continuity at service equipment, service raceways, and service conductor enclosures shall be ensured by one of the following methods:

(1) Bonding equipment to the grounded service conductor in a manner provided in 250.8

(2) Connections utilizing threaded couplings or threaded hubs on enclosures if made up wrenchtight

(3) Threadless couplings and connectors if made up tight for metal raceways and metal-clad cables

(4) Other listed devices, such as bonding-type locknuts, bushings, or bushings with bonding jumpers

250.97 Bonding for Over 250 Volts. For circuits of over 250 volts to ground, the electrical continuity of metal raceways and cables with metal sheaths that contain any conductor other than service conductors shall be ensured by one or more of the methods specified for services in 250.92(B), except for (B)(1).

Exception: Where oversized, concentric, or eccentric knockouts are not encountered, or where a box or enclosure with concentric or eccentric knockouts is listed to provide a reliable bonding connection, the following methods shall be permitted:

(1) Threadless couplings and connectors for cables with metal sheaths

(2) Two locknuts, on rigid metal conduit or intermediate metal conduit, one inside and one outside of boxes and cabinets

(3) Fittings with shoulders that seat firmly against the box or cabinet, such as electrical metallic tubing connectors, flexible metal conduit connectors, and cable connectors, with one locknut on the inside of boxes and cabinets

(4) Listed fittings

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

(B) Multiconductor Cable. Where the conditions of maintenance and supervision ensure that only qualified persons service the installation, one or more insulated conductors in a multiconductor cable, at the time of installation, shall be permitted to be permanently identified as equipment grounding conductors at each end and at every point where the conductors are accessible by one of the following means:

(1) Stripping the insulation from the entire exposed length.

(2) Coloring the exposed insulation green.

(3) Marking the exposed insulation with green tape or green adhesive labels. Identification shall encircle the conductor.

(C) Flexible Cord. Equipment grounding conductors in flexible cords shall be insulated and shall have a continuous outer finish that is either green or green with one or more yellow stripes.

250.120 Equipment Grounding Conductor Installation. An equipment grounding conductor shall be installed in accordance with 250.120(A), (B), and (C).

(A) Raceway, Cable Trays, Cable Armor, Cablebus, or Cable Sheaths. Where it consists of a raceway, cable tray, cable armor, cablebus framework, or cable sheath or where it is a wire within a raceway or cable, it shall be installed in accordance with the applicable provisions in this *Code* using fittings for joints and terminations approved for use with the type raceway or cable used. All connections, joints, and fittings shall be made tight using suitable tools.

Informational Note: See the UL guide information on FHIT systems for equipment grounding conductors installed in a raceway that are part of an electrical circuit protective system or a fire-rated cable listed to maintain circuit integrity.

(B) Aluminum and Copper-Clad Aluminum Conductors. Equipment grounding conductors of bare or insulated aluminum or copper-clad aluminum shall be permitted. Bare conductors shall not come in direct contact with masonry or the earth or where subject to corrosive conditions. Aluminum or copper-clad aluminum conductors shall not be terminated within 450 mm (18 in.) of the earth.

(C) Equipment Grounding Conductors Smaller Than 6 AWG. Where not routed with circuit conductors as permitted in 250.130(C) and 250.134(B) Exception No. 2, equipment grounding conductors smaller than 6 AWG shall be protected from physical damage by an identified raceway or cable armor unless installed within hollow spaces of the framing members of buildings or structures and where not subject to physical damage.

250.122 Size of Equipment Grounding Conductors.

(A) General. Copper, aluminum, or copper-clad aluminum equipment grounding conductors of the wire type shall not be smaller than shown in Table 250.122, but in no case shall they be required to be larger than the circuit conductors supplying the equipment. Where a cable tray, a raceway, or a cable armor or sheath is used as the equipment grounding conductor, as provided in 250.118 and 250.134(A), it shall comply with 250.4(A)(5) or (B)(4).

Equipment grounding conductors shall be permitted to be sectioned within a multiconductor cable, provided the combined circular mil area complies with Table 250.122.

(B) Increased in Size. Where ungrounded conductors are increased in size from the minimum size that has sufficient ampacity for the intended installation, wire-type equipment grounding conductors, where installed, shall be increased in size proportionately, according to the circular mil area of the ungrounded conductors.

(C) Multiple Circuits. Where a single equipment grounding conductor is run with multiple circuits in the same raceway, cable, or cable tray, it shall be sized for the largest overcurrent device protecting conductors in the raceway, cable, or cable tray. Equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c).

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1200
6000	800	1200

Note: Where necessary to comply with 250.4(A)(5) or (B)(4), the equipment grounding conductor shall be sized larger than given in this table.

*See installation restrictions in 250.120.

(D) Motor Circuits. Equipment grounding conductors for motor circuits shall be sized in accordance with (D)(1) or (D)(2).

(1) General. The equipment grounding conductor size shall not be smaller than determined by 250.122(A) based on the rating of the branch-circuit short-circuit and ground-fault protective device.

(2) Instantaneous-Trip Circuit Breaker and Motor Short-Circuit Protector. Where the overcurrent device is an instantaneous-trip circuit breaker or a motor short-circuit protector, the equipment grounding conductor shall be sized not smaller than that given by 250.122(A) using the maximum permitted rating of a dual element time-delay fuse selected for branch-circuit short-circuit and ground-fault protection in accordance with 430.52(C)(1), Exception No. 1.

(E) Flexible Cord and Fixture Wire. The equipment grounding conductor in a flexible cord with the largest circuit conductor 10 AWG or smaller, and the equipment grounding conductor used with fixture wires of any size in accordance with 240.5, shall not be smaller than 18 AWG copper and shall not be smaller than the circuit conductors. The equipment grounding conductor in a flexible cord with a circuit conductor larger than 10 AWG shall be sized in accordance with Table 250.122.

(F) Conductors in Parallel. For circuits of parallel conductors as permitted in 310.10(H), the equipment grounding conductor shall be installed in accordance with (1) or (2).

(1) Conductor Installations in Raceways, Auxiliary Gutters, or Cable Trays.

a. *Single Raceway or Cable Tray.* If conductors are installed in parallel in the same raceway or cable tray, a single wire-type conductor shall be permitted as the equipment grounding conductor. The wire-type equipment grounding conductor shall be sized in accordance with 250.122, based on the overcurrent protective device for the feeder or branch circuit. Wire-type equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c). Metal raceways or auxiliary gutters in accordance with 250.118 or cable trays complying with 392.60(B) shall be permitted as the equipment grounding conductor.

b. *Multiple Raceways.* If conductors are installed in parallel in multiple raceways, wire-type equipment grounding conductors, where used, shall be installed in parallel in each raceway. The equipment grounding conductor installed in each raceway shall be sized in compliance with 250.122 based on the overcurrent protective device for the feeder or branch circuit. Metal raceways or auxiliary gutters in accordance with 250.118 or cable trays complying with 392.60(B) shall be permitted as the equipment grounding conductor.

(2) Multiconductor Cables.

a. If multiconductor cables are installed in parallel, the equipment grounding conductor(s) in each cable shall be connected in parallel.

b. If multiconductor cables are installed in parallel in the same raceway, auxiliary gutter, or cable tray, a single equipment grounding conductor that is sized in accordance with 250.122 shall be permitted in combination with the equipment grounding conductors provided within the multiconductor cables and shall all be connected together.

c. Equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c). Cable trays complying with 392.60(B), metal raceways in accordance with 250.118, or auxiliary gutters shall be permitted as the equipment grounding conductor.

d. Except as provided in 250.122(F)(2)(b) for raceway or cable tray installations, the equipment grounding conductor in each multiconductor cable shall be sized in accordance with 250.122 based on the overcurrent protective device for the feeder or branch circuit.

(G) Feeder Taps. Equipment grounding conductors run with feeder taps shall not be smaller than shown in Table 250.122 based on the rating of the overcurrent device ahead of the feeder but shall not be required to be larger than the tap conductors.

250.134 Equipment Fastened in Place or Connected by Permanent Wiring Methods (Fixed) — Grounding. Unless grounded by connection to the grounded circuit conductor as permitted by 250.32, 250.140, and 250.142, non–current-car-

rying metal parts of equipment, raceways, and other enclosures, if grounded, shall be connected to an equipment grounding conductor by one of the methods specified in 250.134(A) or (B).

(A) Equipment Grounding Conductor Types. By connecting to any of the equipment grounding conductors permitted by 250.118.

(B) With Circuit Conductors. By connecting to an equipment grounding conductor contained within the same raceway, cable, or otherwise run with the circuit conductors.

Exception No. 1: As provided in 250.130(C), the equipment grounding conductor shall be permitted to be run separately from the circuit conductors.

Exception No. 2: For dc circuits, the equipment grounding conductor shall be permitted to be run separately from the circuit conductors.

Informational Note No. 1: See 250.102 and 250.168 for equipment bonding jumper requirements.

Informational Note No. 2: See 400.10 for use of cords for fixed equipment.

250.136 Equipment Considered Grounded. Under the conditions specified in 250.136(A) and (B), the normally non–current-carrying metal parts of the equipment shall be considered grounded.

(A) Equipment Secured to Grounded Metal Supports. Electrical equipment secured to and in electrical contact with a metal rack or structure provided for its support and connected to an equipment grounding conductor by one of the means indicated in 250.134. The structural metal frame of a building shall not be used as the required equipment grounding conductor for ac equipment.

(B) Metal Car Frames. Metal car frames supported by metal hoisting cables attached to or running over metal sheaves or drums of elevator machines that are connected to an equipment grounding conductor by one of the methods indicated in 250.134.

250.162 Direct-Current Circuits and Systems to Be Grounded. Direct-current circuits and systems shall be grounded as provided for in 250.162(A) and (B).

(A) Two-Wire, Direct-Current Systems. A 2-wire, dc system supplying premises wiring and operating at greater than 60 volts but not greater than 300 volts shall be grounded.

Exception No. 1: A system equipped with a ground detector and supplying only industrial equipment in limited areas shall not be required to be grounded where installed adjacent to or integral with the source of supply.

Exception No. 2: A rectifier-derived dc system supplied from an ac system complying with 250.20 shall not be required to be grounded.

Exception No. 3: Direct-current fire alarm circuits having a maximum current of 0.030 ampere as specified in Article 760, Part III, shall not be required to be grounded.

(B) Three-Wire, Direct-Current Systems. The neutral conductor of all 3-wire, dc systems supplying premises wiring shall be grounded.

250.164 Point of Connection for Direct-Current Systems.

(A) Off-Premises Source. Direct-current systems to be grounded and supplied from an off-premises source shall have the grounding connection made at one or more supply stations. A grounding connection shall not be made at individual services or at any point on the premises wiring.

(B) On-Premises Source. Where the dc system source is located on the premises, a grounding connection shall be made at one of the following:

(1) The source

(2) The first system disconnection means or overcurrent device

(3) By other means that accomplish equivalent system protection and that utilize equipment listed and identified for the use

250.166 Size of the Direct-Current Grounding Electrode Conductor. The size of the grounding electrode conductor for a dc system shall be as specified in 250.166(A) and (B), except as permitted by 250.166(C) through (E). The grounding electrode conductor for a dc system shall meet the sizing requirements in this section but shall not be required to be larger than 3/0 copper or 250 kcmil aluminum.

(A) Not Smaller Than the Neutral Conductor. Where the dc system consists of a 3-wire balancer set or a balancer winding with overcurrent protection as provided in 445.12(D), the grounding electrode conductor shall not be smaller than the neutral conductor and not smaller than 8 AWG copper or 6 AWG aluminum.

(B) Not Smaller Than the Largest Conductor. Where the dc system is other than as in 250.166(A), the grounding electrode conductor shall not be smaller than the largest conductor supplied by the system, and not smaller than 8 AWG copper or 6 AWG aluminum.

(C) Connected to Rod, Pipe, or Plate Electrodes. Where connected to rod, pipe, or plate electrodes as in 250.52(A)(5) or (A)(7), that portion of the grounding electrode conductor that is the sole connection to the grounding electrode shall not be required to be larger than 6 AWG copper wire or 4 AWG aluminum wire.

(D) Connected to a Concrete-Encased Electrode. Where connected to a concrete-encased electrode as in 250.52(A)(3), that portion of the grounding electrode conductor that is the sole connection to the grounding electrode shall not be required to be larger than 4 AWG copper wire.

(E) Connected to a Ground Ring. Where connected to a ground ring as in 250.52(A)(4), that portion of the grounding electrode conductor that is the sole connection to the grounding electrode shall not be required to be larger than the conductor used for the ground ring.

250.167 Direct-Current Ground-Fault Detection.

(A) Ungrounded Systems. Ground-fault detection systems shall be required for ungrounded systems.

(B) Grounded Systems. Ground-fault detection shall be permitted for grounded systems.

(C) Marking. Direct-current systems shall be legibly marked to indicate the grounding type at the dc source or the first disconnecting means of the system. The marking shall be of sufficient durability to withstand the environment involved.

Informational Note: *NFPA 70E*-2015 identifies four dc grounding types in detail.

250.168 Direct-Current System Bonding Jumper. For direct-current systems that are to be grounded, an unspliced bonding jumper shall be used to connect the equipment grounding conductor(s) to the grounded conductor at the source or the first system disconnecting means where the system is grounded. The size of the bonding jumper shall not be smaller than the system grounding electrode conductor specified in 250.166 and shall comply with the provisions of 250.28(A), (B), and (C).

ARTICLE 300
General Requirements for Wiring Methods and Materials

300.3 Conductors.

(A) Single Conductors. Single conductors specified in Table 310.104(A) shall only be installed where part of a recognized wiring method of Chapter 3.

Exception: Individual conductors shall be permitted where installed as separate overhead conductors in accordance with 225.6.

(B) Conductors of the Same Circuit. All conductors of the same circuit and, where used, the grounded conductor and all equipment grounding conductors and bonding conductors shall be contained within the same raceway, auxiliary gutter, cable tray, cablebus assembly, trench, cable, or cord, unless otherwise permitted in accordance with 300.3(B)(1)through (B)(4).

(1) Paralleled Installations. Conductors shall be permitted to be run in parallel in accordance with the provisions of 310.10(H). The requirement to run all circuit conductors within the same raceway, auxiliary gutter, cable tray, trench, cable, or cord shall apply separately to each portion of the paralleled installation, and the equipment grounding conductors shall comply with the provisions of 250.122. Parallel runs in cable tray shall comply with the provisions of 392.20(C).

Exception: Conductors installed in nonmetallic raceways run underground shall be permitted to be arranged as isolated phase, neutral, and grounded conductor installations. The raceways shall be installed in close proximity, and the isolated phase, neutral, and grounded conductors shall comply with the provisions of 300.20(B).

(2) Grounding and Bonding Conductors. Equipment grounding conductors shall be permitted to be installed outside a raceway or cable assembly where in accordance with the provisions of 250.130(C) for certain existing installations or in accordance with 250.134(B), Exception No. 2, for dc circuits. Equipment bonding conductors shall be permitted to be installed on the outside of raceways in accordance with 250.102(E).

(3) Nonferrous Wiring Methods. Conductors in wiring methods with a nonmetallic or other nonmagnetic sheath, where run in different raceways, auxiliary gutters, cable trays, trenches, cables, or cords, shall comply with the provisions of 300.20(B). Conductors in single-conductor Type MI cable with a nonmagnetic sheath shall comply with the provisions of 332.31. Conductors of single-conductor Type MC cable with a nonmagnetic sheath shall comply with the provisions of 330.31, 330.116, and 300.20(B).

(4) Column-Width Panelboard Enclosures. Where an auxiliary gutter runs between a column-width panelboard and a pull box, and the pull box includes neutral terminations, the neutral conductors of circuits supplied from the panelboard shall be permitted to originate in the pull box.

(C) Conductors of Different Systems.

(1) 1000 Volts, Nominal, or Less. Conductors of ac and dc circuits, rated 1000 volts, nominal, or less, shall be permitted to occupy the same equipment wiring enclosure, cable, or raceway. All conductors shall have an insulation rating equal to at least the maximum circuit voltage applied to any conductor within the enclosure, cable, or raceway.

Secondary wiring to electric-discharge lamps of 1000 volts or less, if insulated for the secondary voltage involved, shall be permitted to occupy the same luminaire, sign, or outline lighting enclosure as the branch-circuit conductors.

Informational Note No. 1: See 725.136(A) for Class 2 and Class 3 circuit conductors.

Informational Note No. 2: See 690.4(B) for photovoltaic source and output circuits.

(2) Over 1000 Volts, Nominal. Conductors of circuits rated over 1000 volts, nominal, shall not occupy the same equipment wiring enclosure, cable, or raceway with conductors of circuits rated 1000 volts, nominal, or less unless otherwise permitted in 300.3(C)(2)(a) through 300.3(C)(2)(d).

(a) Primary leads of electric-discharge lamp ballasts insulated for the primary voltage of the ballast, where contained within the individual wiring enclosure, shall be permitted to occupy the same luminaire, sign, or outline lighting enclosure as the branch-circuit conductors.

(b) Excitation, control, relay, and ammeter conductors used in connection with any individual motor or starter shall be permitted to occupy the same enclosure as the motor-circuit conductors.

(c) In motors, transformers, switchgear, switchboards, control assemblies, and similar equipment, conductors of different voltage ratings shall be permitted.

(d) In manholes, if the conductors of each system are permanently and effectively separated from the conductors of the other systems and securely fastened to racks, insulators, or other approved supports, conductors of different voltage ratings shall be permitted.

Conductors having nonshielded insulation and operating at different voltage levels shall not occupy the same enclosure, cable, or raceway.

300.4 Protection Against Physical Damage. Where subject to physical damage, conductors, raceways, and cables shall be protected.

> Informational Note: Minor damage to a raceway, cable armor, or cable insulation does not necessarily violate the integrity of either the contined conductors or the conductors' insulation.

(A) Cables and Raceways Through Wood Members.

(1) Bored Holes. In both exposed and concealed locations, where a cable- or raceway-type wiring method is installed through bored holes in joists, rafters, or wood members, holes shall be bored so that the edge of the hole is not less than 32 mm ($1^1/_4$ in.) from the nearest edge of the wood member. Where this distance cannot be maintained, the cable or raceway shall be protected from penetration by screws or nails by a steel plate(s) or bushing(s), at least 1.6 mm ($^1/_{16}$ in.) thick, and of appropriate length and width installed to cover the area of the wiring.

Exception No. 1: Steel plates shall not be required to protect rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, or electrical metallic tubing.

Exception No. 2: A listed and marked steel plate less than 1.6 mm ($^1/_{16}$ in.) thick that provides equal or better protection against nail or screw penetration shall be permitted.

(2) Notches in Wood. Where there is no objection because of weakening the building structure, in both exposed and concealed locations, cables or raceways shall be permitted to be laid in notches in wood studs, joists, rafters, or other wood members where the cable or raceway at those points is protected against nails or screws by a steel plate at least 1.6 mm ($^1/_{16}$ in.) thick, and of appropriate length and width, installed to cover the area of the wiring. The steel plate shall be installed before the building finish is applied.

Exception No. 1: Steel plates shall not be required to protect rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, or electrical metallic tubing.

Exception No. 2: A listed and marked steel plate less than 1.6 mm ($^1/_{16}$ in.) thick that provides equal or better protection against nail or screw penetration shall be permitted.

(B) Nonmetallic-Sheathed Cables and Electrical Nonmetallic Tubing Through Metal Framing Members.

(1) Nonmetallic-Sheathed Cable. In both exposed and concealed locations where nonmetallic-sheathed cables pass through either factory- or field-punched, cut, or drilled slots or holes in metal members, the cable shall be protected by listed bushings or listed grommets covering all metal edges that are securely fastened in the opening prior to installation of the cable.

(2) Nonmetallic-Sheathed Cable and Electrical Nonmetallic Tubing. Where nails or screws are likely to penetrate nonmetallic-sheathed cable or electrical nonmetallic tubing, a steel sleeve, steel plate, or steel clip not less than 1.6 mm ($^1/_{16}$ in.) in thickness shall be used to protect the cable or tubing.

Exception: A listed and marked steel plate less than 1.6 mm ($^1/_{16}$ in.) thick that provides equal or better protection against nail or screw penetration shall be permitted.

(C) Cables Through Spaces Behind Panels Designed to Allow Access. Cables or raceway-type wiring methods, installed behind panels designed to allow access, shall be supported according to their applicable articles.

(D) Cables and Raceways Parallel to Framing Members and Furring Strips. In both exposed and concealed locations, where a cable- or raceway-type wiring method is installed parallel to framing members, such as joists, rafters, or studs, or is installed parallel to furring strips, the cable or raceway shall be installed and supported so that the nearest outside surface of the cable or raceway is not less than 32 mm ($1^1/_4$ in.) from the nearest edge of the framing member or furring strips where nails or screws are likely to penetrate. Where this distance cannot be maintained, the cable or raceway shall be protected from penetration by nails or screws by a steel plate, sleeve, or equivalent at least 1.6 mm ($^1/_{16}$ in.) thick.

Exception No. 1: Steel plates, sleeves, or the equivalent shall not be required to protect rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, or electrical metallic tubing.

Exception No. 2: For concealed work in finished buildings, or finished panels for prefabricated buildings where such supporting is impracticable, it shall be permissible to fish the cables between access points.

Exception No. 3: A listed and marked steel plate less than 1.6 mm ($^1/_{16}$ in.) thick that provides equal or better protection against nail or screw penetration shall be permitted.

(E) Cables, Raceways, or Boxes Installed in or Under Roof Decking. A cable, raceway, or box, installed in exposed or concealed locations under metal-corrugated sheet roof decking, shall be installed and supported so there is not less than 38 mm ($1^1/_2$ in.) measured from the lowest surface of the roof decking to the top of the cable, raceway, or box. A cable, raceway, or box shall not be installed in concealed locations in metal-corrugated, sheet decking-type roof.

> Informational Note: Roof decking material is often repaired or replaced after the initial raceway or cabling and roofing installation and may be penetrated by the screws or other mechanical devices designed to provide "hold down" strength of the waterproof membrane or roof insulating material.

Exception: Rigid metal conduit and intermediate metal conduit shall not be required to comply with 300.4(E).

(F) Cables and Raceways Installed in Shallow Grooves. Cable- or raceway-type wiring methods installed in a groove, to be covered by wallboard, siding, paneling, carpeting, or similar finish, shall be protected by 1.6 mm ($^1/_{16}$ in.) thick steel plate, sleeve, or equivalent or by not less than 32-mm ($1^1/_4$-in.) free space for the full length of the groove in which the cable or raceway is installed.

Exception No. 1: Steel plates, sleeves, or the equivalent shall not be required to protect rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, or electrical metallic tubing.

Exception No. 2: A listed and marked steel plate less than 1.6 mm ($^1/_{16}$ in.) thick that provides equal or better protection against nail or screw penetration shall be permitted.

(G) Insulated Fittings. Where raceways contain 4 AWG or larger insulated circuit conductors, and these conductors enter a cabinet, a box, an enclosure, or a raceway, the conductors shall be protected by an identified fitting providing a smoothly rounded insulating surface, unless the conductors are separated from the fitting or raceway by identified insulating material that is securely fastened in place.

Exception: Where threaded hubs or bosses that are an integral part of a cabinet, box, enclosure, or raceway provide a smoothly rounded or flared entry for conductors.

Conduit bushings constructed wholly of insulating material shall not be used to secure a fitting or raceway. The insulating fitting or insulating material shall have a temperature rating not less than the insulation temperature rating of the installed conductors.

(H) Structural Joints. A listed expansion/deflection fitting or other approved means shall be used where a raceway crosses a structural joint intended for expansion, contraction or deflection, used in buildings, bridges, parking garages, or other structures.

300.7 Raceways Exposed to Different Temperatures.

(A) Sealing. Where portions of a raceway or sleeve are known to be subjected to different temperatures, and where condensation is known to be a problem, as in cold storage areas of buildings or where passing from the interior to the exterior of a building, the raceway or sleeve shall be filled with an approved material to prevent the circulation of warm air to a colder section of the raceway or sleeve. An explosion-proof seal shall not be required for this purpose.

(B) Expansion, Expansion-Deflection, and Deflection Fittings. Raceways shall be provided with expansion, expansion-deflection, or deflection fittings where necessary to compensate for thermal expansion, deflection, and contraction.

Informational Note: Table 352.44 and Table 355.44 provide the expansion information for polyvinyl chloride (PVC) and for reinforced thermosetting resin conduit (RTRC), respectively. A nominal number for steel conduit can be determined by multiplying the expansion length in Table 352.44 by 0.20. The coefficient of expansion for steel electrical metallic tubing, intermediate metal conduit, and rigid metal conduit is 1.170×10^{-5} (0.0000117 mm per mm of conduit for each °C in temperature change) [0.650×10^{-5} (0.0000065 in. per inch of conduit for each °F in temperature change)].

A nominal number for aluminum conduit and aluminum electrical metallic tubing can be determined by multiplying the expansion length in Table 352.44 by 0.40. The coefficient of expansion for aluminum electrical metallic tubing and aluminum rigid metal conduit is 2.34×10^{-5} (0.0000234 mm per mm of conduit for each °C in temperature change) [1.30×10^{-5} (0.000013 in. per inch of conduit for each °F in temperature change)].

300.8 Installation of Conductors with Other Systems. Raceways or cable trays containing electrical conductors shall not contain any pipe, tube, or equal for steam, water, air, gas, drainage, or any service other than electrical.

300.9 Raceways in Wet Locations Abovegrade. Where raceways are installed in wet locations abovegrade, the interior of these raceways shall be considered to be a wet location. Insulated conductors and cables installed in raceways in wet locations abovegrade shall comply with 310.10(C).

ARTICLE 310
Conductors for General Wiring

310.10 Uses Permitted. The conductors described in 310.104 shall be permitted for use in any of the wiring methods covered in Chapter 3 and as specified in their respective tables or as permitted elsewhere in this *Code*.

(A) Dry Locations. Insulated conductors and cables used in dry locations shall be any of the types identified in this *Code*.

(B) Dry and Damp Locations. Insulated conductors and cables used in dry and damp locations shall be Types FEP, FEPB, MTW, PFA, RHH, RHW, RHW-2, SA, THHN, THW, THW-2, THHW, THWN, THWN-2, TW, XHH, XHHW, XHHW-2, Z, or ZW.

(C) Wet Locations. Insulated conductors and cables used in wet locations shall comply with one of the following:

(1) Be moisture-impervious metal-sheathed

(2) Be types MTW, RHW, RHW-2, TW, THW, THW-2, THHW, THWN, THWN-2, XHHW, XHHW-2, or ZW

(3) Be of a type listed for use in wet locations

(D) Locations Exposed to Direct Sunlight. Insulated conductors or cables used where exposed to direct rays of the sun shall comply with (D)(1) or (D)(2):

(1) Conductors and cables shall be listed, or listed and marked, as being sunlight resistant

(2) Conductors and cables shall be covered with insulating material, such as tape or sleeving, that is listed, or listed and marked, as being sunlight resistant

(H) Conductors in Parallel.

(1) General. Aluminum, copper-clad aluminum, or copper conductors, for each phase, polarity, neutral, or grounded circuit shall be permitted to be connected in parallel (electrically joined at both ends) only in sizes 1/0 AWG and larger where installed in accordance with 310.10(H)(2) through (H)(6).

Exception No. 1: Conductors in sizes smaller than 1/0 AWG shall be permitted to be run in parallel to supply control power to indicating instruments, contactors, relays, solenoids, and similar control devices, or for frequencies of 360 Hz and higher, provided all of the following apply:

(a) They are contained within the same raceway or cable.

(b) The ampacity of each individual conductor is sufficient to carry the entire load current shared by the parallel conductors.

(c) The overcurrent protection is such that the ampacity of each individual conductor will not be exceeded if one or more of the parallel conductors become inadvertently disconnected.

Exception No. 2: Under engineering supervision, 2 AWG and 1 AWG grounded neutral conductors shall be permitted to be installed in parallel for existing installations.

Informational Note to Exception No. 2: Exception No. 2 can be used to alleviate overheating of neutral conductors in

existing installations due to high content of triplen harmonic currents.

(2) Conductor and Installation Characteristics. The paralleled conductors in each phase, polarity, neutral, grounded circuit conductor, equipment grounding conductor, or equipment bonding jumper shall comply with all of the following:

(1) Be the same length.

(2) Consist of the same conductor material.

(3) Be the same size in circular mil area.

(4) Have the same insulation type.

(5) Be terminated in the same manner.

(3) Separate Cables or Raceways. Where run in separate cables or raceways, the cables or raceways with conductors shall have the same number of conductors and shall have the same electrical characteristics. Conductors of one phase, polarity, neutral, grounded circuit conductor, or equipment grounding conductor shall not be required to have the same physical characteristics as those of another phase, polarity, neutral, grounded circuit conductor, or equipment grounding conductor.

(4) Ampacity Adjustment. Conductors installed in parallel shall comply with the provisions of 310.15(B)(3)(a).

(5) Equipment Grounding Conductors. Where parallel equipment grounding conductors are used, they shall be sized in accordance with 250.122. Sectioned equipment grounding conductors smaller than 1/0 AWG shall be permitted in multiconductor cables, if the combined circular mil area of the sectioned equipment grounding conductors in each cable complies with 250.122.

(6) Bonding Jumpers. Where parallel equipment bonding jumpers or supply-side bonding jumpers are installed in raceways, they shall be sized and installed in accordance with 250.102.

310.15 Ampacities for Conductors Rated 0–2000 Volts.

(A) General.

(1) Tables or Engineering Supervision. Ampacities for conductors shall be permitted to be determined by tables as provided in 310.15(B) or under engineering supervision, as provided in 310.15(C).

Informational Note No. 1: Ampacities provided by this section do not take voltage drop into consideration. See 210.19(A), Informational Note No. 4, for branch circuits and 215.2(A), Informational Note No. 2, for feeders.

Informational Note No. 2: For the allowable ampacities of Type MTW wire, see Table 13.5.1 in NFPA 79-2015, *Electrical Standard for Industrial Machinery*.

(2) Selection of Ampacity. Where more than one ampacity applies for a given circuit length, the lowest value shall be used.

Exception: Where different ampacities apply to portions of a circuit, the higher ampacity shall be permitted to be used if the total portion(s) of the circuit with lower ampacity does not exceed the lesser of 3.0 m (10 ft) or 10 percent of the total circuit.

Informational Note: See 110.14(C) for conductor temperature limitations due to termination provisions.

(3) Temperature Limitation of Conductors. No conductor shall be used in such a manner that its operating temperature exceeds that designated for the type of insulated conductor involved. In no case shall conductors be associated together in such a way, with respect to type of circuit, the wiring method employed, or the number of conductors, that the limiting temperature of any conductor is exceeded.

Informational Note No. 1: The temperature rating of a conductor [see Table 310.104(A) and Table 310.104(C)] is the maximum temperature, at any location along its length, that the conductor can withstand over a prolonged time period without serious degradation. The allowable ampacity tables, the ampacity tables of Article 310 and the ampacity tables of Informative Annex B, the ambient temperature correction factors in 310.15(B)(2), and the notes to the tables provide guidance for coordinating conductor sizes, types, allowable ampacities, ampacities, ambient temperatures, and number of associated conductors. The principal determinants of operating temperature are as follows:

(1) Ambient temperature — ambient temperature may vary along the conductor length as well as from time to time.
(2) Heat generated internally in the conductor as the result of load current flow, including fundamental and harmonic currents.
(3) The rate at which generated heat dissipates into the ambient medium. Thermal insulation that covers or surrounds conductors affects the rate of heat dissipation.
(4) Adjacent load-carrying conductors — adjacent conductors have the dual effect of raising the ambient temperature and impeding heat dissipation.

Informational Note No. 2: Refer to 110.14(C) for the temperature limitation of terminations.

(B) Tables. Ampacities for conductors rated 0 to 2000 volts shall be as specified in the Allowable Ampacity Table 310.15(B)(16) through Table 310.15(B)(19), and Ampacity Table 310.15(B)(20) and Table 310.15(B)(21) as modified by 310.15(B)(1) through (B)(7).

The temperature correction and adjustment factors shall be permitted to be applied to the ampacity for the temperature rating of the conductor, if the corrected and adjusted ampacity does not exceed the ampacity for the temperature rating of the termination in accordance with the provisions of 110.14(C).

Informational Note: Table 310.15(B)(16) through Table 310.15(B)(19) are application tables for use in determining conductor sizes on loads calculated in accordance with Article 220. Allowable ampacities result from consideration of one or more of the following:

(1) Temperature compatibility with connected equipment, especially the connection points.
(2) Coordination with circuit and system overcurrent protection.
(3) Compliance with the requirements of product listings or certifications. See 110.3(B).
(4) Preservation of the safety benefits of established industry practices and standardized procedures.

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

Table 310.15(B)(2)(b) Ambient Temperature Correction Factors Based on 40°C (104°F)

For ambient temperatures other than 40°C (104°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	150°C	200°C	250°C	
10 or less	1.58	1.26	1.13	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.11	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.09	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.07	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.04	1.04	1.03	1.02	78–86
31–35	1.12	1.07	1.02	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91-100	—	—	—	0.67	0.79	0.85	195-212
101-110	—	—	—	0.60	0.75	0.82	213-230
111-120	—	—	—	0.52	0.71	0.79	231-248
121-130	—	—	—	0.43	0.66	0.76	249-266
131-140	—	—	—	0.30	0.61	0.72	267-284
141-160	—	—	—	—	0.50	0.65	285-320
161-180	—	—	—	—	0.35	0.58	321-356
181-200	—	—	—	—	—	0.49	357-392
201-225	—	—	—	—	—	0.35	393-437

(1) General. For explanation of type letters used in tables and for recognized sizes of conductors for the various conductor insulations, see Table 310.104(A) and Table 310.104(B). For installation requirements, see 310.1 through 310.15(A)(3) and the various articles of this *Code*. For flexible cords, see Table 400.4, Table 400.5(A)(1), and Table 400.5(A)(2).

(2) Ambient Temperature Correction Factors. Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(2)(a) or Table 310.15(B)(2)(b), or shall be permitted to be calculated using the following equation:

[310.15(B)(2)]

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}}$$

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the tables

T_c = temperature rating of conductor (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

(3) Adjustment Factors.

(a) More than Three Current-Carrying Conductors. Where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables are installed without maintaining spacing for a continuous length longer than 600 mm (24 in.) and are not installed in raceways, the allowable ampacity of each conductor shall be reduced as shown in Table 310.15(B)(3)(a). Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Where conductors of different systems, as provided in 300.3, are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(B)(3)(a) shall apply only to the number of power and lighting conductors (Articles 210, 215, 220, and 230).

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Informational Note No. 2: See 366.23for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.

(1) Where conductors are installed in cable trays, the provisions of 392.80 shall apply.

(2) Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).

(3) Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conduc-

tors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(4) Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:

a. The cables do not have an overall outer jacket.

b. Each cable has not more than three current-carrying conductors.

c. The conductors are 12 AWG copper.

d. Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on "bridle rings."

Exception to (4): If cables meeting the requirements in 310.15(B)(3)(4)a through c with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

Table 310.15(B)(3)(a) Adjustment Factors for More Than Three Current-Carrying Conductors

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, including spare conductors. The count shall be adjusted in accordance with 310.15(B)(5) and (6). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

(b) Raceway Spacing. Spacing between raceways shall be maintained.

(c) Raceways and Cables Exposed to Sunlight on Rooftops. Where raceways or cables are exposed to direct sunlight on or above rooftops, raceways or cables shall be installed a minimum distance above the roof to the bottom of the raceway or cable of 23 mm ($^7/_8$ in.). Where the distance above the roof to the bottom of the raceway is less than 23 mm ($^7/_8$ in.), a temperature adder of 33°C (60°F) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(2)(a) or Table 310.15(B)(2)(b).

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Informational Note: One source for the ambient temperatures in various locations is the ASHRAE *Handbook — Fundamentals.*

(4) Bare or Covered Conductors. Where bare or covered conductors are installed with insulated conductors, the temperature rating of the bare or covered conductor shall be equal to the lowest temperature rating of the insulated conductors for the purpose of determining ampacity.

(5) Neutral Conductor.

(a) A neutral conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to be counted when applying the provisions of 310.15(B)(3)(a).

(b) In a 3-wire circuit consisting of two phase conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system, a common conductor carries approximately the same current as the line-to-neutral load currents of the other conductors and shall be counted when applying the provisions of 310.15(B)(3)(a).

(c) On a 4-wire, 3-phase wye circuit where the major portion of the load consists of nonlinear loads, harmonic currents are present in the neutral conductor; the neutral conductor shall therefore be considered a current-carrying conductor.

(6) Grounding or Bonding Conductor. A grounding or bonding conductor shall not be counted when applying the provisions of 310.15(B)(3)(a).

(7) Single-Phase Dwelling Services and Feeders. For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240-volt system shall be permitted to be sized in accordance with 310.15(B)(7)(1) through (4).

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, single-phase feeder conductors consisting of 2 ungrounded conductors and the neutral conductor from a 208Y/120 volt system shall be permitted to be sized in accordance with 310.15(B)(7)(1) through (3).

(1) For a service rated 100 through 400 amperes, the service conductors supplying the entire load associated with a one-family dwelling, or the service conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the service rating.

(2) For a feeder rated 100 through 400 amperes, the feeder conductors supplying the entire load associated with a one-family dwelling, or the feeder conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the feeder rating.

(3) In no case shall a feeder for an individual dwelling unit be required to have an ampacity greater than that specified in 310.15(B)(7)(1) or (2).

(4) Grounded conductors shall be permitted to be sized smaller than the ungrounded conductors, if the requirements of 220.61 and 230.42 for service conductors or the requirements of 215.2 and 220.61 for feeder conductors are met.

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.

Where correction or adjustment factors are required by 310.15(B)(2) or (3), they shall be permitted to be applied to the ampacity associated with the temperature rating of the conductor.

Informational Note No. 1: The service or feeder ratings addressed by this section are based on the standard ampacity ratings from 240.6(A).

Informational Note No. 2: See Example D7 in Annex D.

(C) Engineering Supervision. Under engineering supervision, conductor ampacities shall be permitted to be calculated by means of the following general equation:

[310.15(C)]

$$I = \sqrt{\frac{T_c - T_a}{R_{dc}(1 + Y_c)R_{ca}}} \times 10^3 \text{ amperes}$$

where:

T_c = conductor temperature in degrees Celsius (°C)

T_a = ambient temperature in degrees Celsius (°C)

R_{dc} = dc resistance of 305 mm (1 ft) of conductor in microohms at temperature, T_c

Y_c = component ac resistance resulting from skin effect and proximity effect

R_{ca} = effective thermal resistance between conductor and surrounding ambient

ARTICLE 312
Cabinets, Cutout Boxes, and Meter Socket Enclosures

312.2 Damp and Wet Locations. In damp or wet locations, surface-type enclosures within the scope of this article shall be placed or equipped so as to prevent moisture or water from entering and accumulating within the cabinet or cutout box, and shall be mounted so there is at least 6-mm ($^1/_4$-in.) airspace between the enclosure and the wall or other supporting surface. Enclosures installed in wet locations shall be weath-

erproof. For enclosures in wet locations, raceways or cables entering above the level of uninsulated live parts shall use fittings listed for wet locations.

Exception: Nonmetallic enclosures shall be permitted to be installed without the airspace on a concrete, masonry, tile, or similar surface.

Informational Note: For protection against corrosion, see 300.6.

312.8 Switch and Overcurrent Device Enclosures. The wiring space within enclosures for switches and overcurrent devices shall be permitted for other wiring and equipment subject to limitations for specific equipment as provided in (A) and (B).

(A) Splices, Taps, and Feed-Through Conductors. The wiring space of enclosures for switches or overcurrent devices shall be permitted for conductors feeding through, spliced, or tapping off to other enclosures, switches, or overcurrent devices where all of the following conditions are met:

(1) The total of all conductors installed at any cross section of the wiring space does not exceed 40 percent of the cross-sectional area of that space.

(2) The total area of all conductors, splices, and taps installed at any cross section of the wiring space does not exceed 75 percent of the cross-sectional area of that space.

(3) A warning label complying with 110.21(B) is applied to the enclosure that identifies the closest disconnecting means for any feed-through conductors.

(B) Power Monitoring Equipment. The wiring space of enclosures for switches or overcurrent devices shall be permitted to contain power monitoring equipment where all of the following conditions are met:

(1) The power monitoring equipment is identified as a field installable accessory as part of the listed equipment, or is a listed kit evaluated for field installation in switch or overcurrent device enclosures.

(2) The total area of all conductors, splices, taps, and equipment at any cross section of the wiring space does not exceed 75 percent of the cross-sectional area of that space.

ARTICLE 314
Outlet, Device, Pull, and Junction Boxes; Conduit Bodies; Fittings; and Handhole Enclosures

314.15 Damp or Wet Locations. In damp or wet locations, boxes, conduit bodies, outlet box hoods, and fittings shall be placed or equipped so as to prevent moisture from entering or accumulating within the box, conduit body, or fitting. Boxes, conduit bodies, outlet box hoods, and fittings installed in wet locations shall be listed for use in wet locations. Approved drainage openings not smaller than 3 mm ($^1/_8$ in.) and not larger than 6 mm ($^1/_4$ in.) in diameter shall be permitted to be installed in the field in boxes or conduit bodies listed for use in damp or wet locations. For installation of listed drain fittings, larger openings are permitted to be installed in the field in accordance with manufacturer's instructions.

Informational Note No. 1: For boxes in floors, see 314.27(B).

Informational Note No. 2: For protection against corrosion, see 300.6.

314.16 Number of Conductors in Outlet, Device, and Junction Boxes, and Conduit Bodies. Boxes and conduit bodies shall be of an approved 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.

Informational Note: For volume requirements of motor or generator terminal housings, see 430.12.

Boxes and conduit bodies enclosing conductors 4 AWG or larger shall also comply with the provisions of 314.28.

(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). Where a box is provided with one or more securely installed barriers, the volume shall be apportioned to each of the resulting spaces. Each barrier, if not marked with its volume, shall be considered to take up 8.2 cm^3 ($^1/_2$ in^3) if metal, and 16.4 cm^3 (1.0 in^3) if nonmetallic.

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

(2) Other Boxes. Boxes 1650 cm^3 (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(s). 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.

(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. Each space within a box installed with a barrier shall be calculated separately.

(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.

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

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 × 1 1/4)	round/octagonal	205	12.5	8	7	6	5	5	5	2
100 × 38	(4 × 1 1/2)	round/octagonal	254	15.5	10	8	7	6	6	5	3
100 × 54	(4 × 2 1/8)	round/octagonal	353	21.5	14	12	10	9	8	7	4
100 × 32	(4 × 1 1/4)	square	295	18.0	12	10	9	8	7	6	3
100 × 38	(4 × 1 1/2)	square	344	21.0	14	12	10	9	8	7	4
100 × 54	(4 × 2 1/8)	square	497	30.3	20	17	15	13	12	10	6
120 × 32	(4 11/16 × 1 1/4)	square	418	25.5	17	14	12	11	10	8	5
120 × 38	(4 11/16 × 1 1/2)	square	484	29.5	19	16	14	13	11	9	5
120 × 54	(4 11/16 × 2 1/8)	square	689	42.0	28	24	21	18	16	14	8
75 × 50 × 38	(3 × 2 × 1 1/2)	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
75 × 50 × 57	(3 × 2 × 2 1/4)	device	172	10.5	7	6	5	4	4	3	2
75 × 50 × 65	(3 × 2 × 2 1/2)	device	205	12.5	8	7	6	5	5	4	2
75 × 50 × 70	(3 × 2 × 2 3/4)	device	230	14.0	9	8	7	6	5	4	2
75 × 50 × 90	(3 × 2 × 3 1/2)	device	295	18.0	12	10	9	8	7	6	3
100 × 54 × 38	(4 × 2 1/8 × 1 1/2)	device	169	10.3	6	5	5	4	4	3	2
100 × 54 × 48	(4 × 2 1/8 × 1 7/8)	device	213	13.0	8	7	6	5	5	4	2
100 × 54 × 54	(4 × 2 1/8 × 2 1/8)	device	238	14.5	9	8	7	6	5	4	2
95 × 50 × 65	(3 3/4 × 2 × 2 1/2)	masonry box/gang	230	14.0	9	8	7	6	5	4	2
95 × 50 × 90	(3 3/4 × 2 × 3 1/2)	masonry box/gang	344	21.0	14	12	10	9	8	7	4
min. 44.5 depth	FS — single cover/gang (1 3/4)		221	13.5	9	7	6	6	5	4	2
min. 60.3 depth	FD — single cover/gang (2 3/8)		295	18.0	12	10	9	8	7	6	3
min. 44.5 depth	FS — multiple cover/gang (1 3/4)		295	18.0	12	10	9	8	7	6	3
min. 60.3 depth	FD — multiple cover/gang (2 3/8)		395	24.0	16	13	12	10	9	8	4

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

they enter a box from a domed luminaire or similar canopy and terminate within that box.

(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.

A clamp assembly that incorporates a cable termination for the cable conductors shall be listed and marked for use with specific nonmetallic boxes. Conductors that originate within the clamp assembly shall be included in conductor fill calculations covered in 314.16(B)(1) as though they entered from outside the box. The clamp assembly shall not require a fill allowance, but the volume of the portion of the assembly that remains within the box after installation shall be excluded from the box volume as marked in 314.16(A)(2).

(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.

(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.

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

(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.

(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.

(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.

(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 an approved size to provide free space for all conductors enclosed in the conduit body.

ARTICLE 334
Nonmetallic-Sheathed Cable: Types NM, NMC, and NMS

334.30 Securing and Supporting. Nonmetallic-sheathed cable shall be supported and secured by staples; cable ties listed and identified for securement and support; or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1.4 m ($4^1/_2$ ft) and within 300 mm (12 in.) of every cable entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings. Flat cables shall not be stapled on edge.

Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

(A) Horizontal Runs Through Holes and Notches. In other than vertical runs, cables installed in accordance with 300.4 shall be considered to be supported and secured where such support does not exceed 1.4-m ($4^1/_2$-ft) intervals and the nonmetallic-sheathed cable is securely fastened in place by an approved means within 300 mm (12 in.) of each box, cabinet, conduit body, or other nonmetallic-sheathed cable termination.

Informational Note: See 314.17(C) for support where nonmetallic boxes are used.

(B) Unsupported Cables. Nonmetallic-sheathed cable shall be permitted to be unsupported where the cable:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impracticable.

(2) Is not more than 1.4 m ($4^1/_2$ ft) from the last point of cable support to the point of connection to a luminaire or other piece of electrical equipment and the cable and point of connection are within an accessible ceiling in one-, two-, or multifamily dwellings.

(C) Wiring Device Without a Separate Outlet Box. A wiring device identified for the use, without a separate outlet box, and incorporating an integral cable clamp shall be permitted where the cable is secured in place at intervals not exceeding 1.4 m ($4^1/_2$ ft) and within 300 mm (12 in.) from the wiring device wall opening, and there shall be at least a 300 mm (12 in.) loop of unbroken cable or 150 mm (6 in.) of a cable end available on the interior side of the finished wall to permit replacement.

ARTICLE 338
Service-Entrance Cable: Types SE and USE

Part I. General

338.1 Scope. This article covers the use, installation, and construction specifications of service-entrance cable.

338.2 Definitions.

Service-Entrance Cable. A single conductor or multiconductor assembly provided with or without an overall covering, primarily used for services, and of the following types:

Type SE. Service-entrance cable having a flame-retardant, moisture-resistant covering.

Type USE. Service-entrance cable, identified for underground use, having a moisture-resistant covering, but not required to have a flame-retardant covering.

338.6 Listing Requirements. Type SE and USE cables and associated fittings shall be listed.

Part II. Installation

338.10 Uses Permitted.

(A) Service-Entrance Conductors. Service-entrance cable shall be permitted to be used as service-entrance conductors and shall be installed in accordance with 230.6, 230.7, and Parts II, III, and IV of Article 230.

(B) Branch Circuits or Feeders.

(1) Grounded Conductor Insulated. Type SE service-entrance cables shall be permitted in wiring systems where all of the circuit conductors of the cable are of the thermoset or thermoplastic type.

(2) Use of Uninsulated Conductor. Type SE service-entrance cable shall be permitted for use where the insulated conductors are used for circuit wiring and the uninsulated conductor is used only for equipment grounding purposes.

Exception: In existing installations, uninsulated conductors shall be permitted as a grounded conductor in accordance with 250.32 and 250.140, where the uninsulated grounded conductor of the cable originates in service equipment, and with 225.30 through 225.40.

(3) Temperature Limitations. Type SE service-entrance cable used to supply appliances shall not be subject to conductor temperatures in excess of the temperature specified for the type of insulation involved.

(4) Installation Methods for Branch Circuits and Feeders.

(a) *Interior Installations.* In addition to the provisions of this article, Type SE service-entrance cable used for interior wiring shall comply with the installation requirements of Part II of Article 334, excluding 334.80.

For Type SE cable with ungrounded conductor sizes 10 AWG and smaller, where installed in thermal insulation, the ampacity shall be in accordance with 60°C (140°F) conductor temperature rating. The maximum conductor temperature rating shall be permitted to be used for ampacity adjustment and correction purposes, if the final derated ampacity does not exceed that for a 60°C (140°F) rated conductor.

Informational Note No. 1: See 310.15(A)(3) for temperature limitation of conductors.

Informational Note No. 2: For the installation of main power feeder conductors in dwelling units refer to 310.15(B)(7).

(b) *Exterior Installations.* In addition to the provisions of this article, service-entrance cable used for feeders or branch circuits, where installed as exterior wiring, shall be installed in accordance with Part I of Article 225. The cable shall be supported in accordance with 334.30. Type USE cable installed as underground feeder and branch circuit cable shall comply with Part II of Article 340.

Exception: Single-conductor Type USE and multi-rated USE conductors shall not be subject to the ampacity limitations of Part II of Article 340.

338.12 Uses Not Permitted.

(A) Service-Entrance Cable. Service-entrance cable (SE) shall not be used under the following conditions or in the following locations:

(1) Where subject to physical damage unless protected in accordance with 230.50(B)

(2) Underground with or without a raceway

(3) For exterior branch circuits and feeder wiring unless the installation complies with the provisions of Part I of Article 225 and is supported in accordance with 334.30 or is used as messenger-supported wiring as permitted in Part II of Article 396

(B) Underground Service-Entrance Cable. Underground service-entrance cable (USE) shall not be used under the following conditions or in the following locations:

(1) For interior wiring

(2) For aboveground installations except where USE cable emerges from the ground and is terminated in an enclosure at an outdoor location and the cable is protected in accordance with 300.5(D)

(3) As aerial cable unless it is a multiconductor cable identified for use aboveground and installed as messenger-supported wiring in accordance with 225.10 and Part II of Article 396

338.24 Bending Radius. Bends in Types USE and SE cable shall be so made that the cable will not be damaged. The radius of the curve of the inner edge of any bend, during or after installation, shall not be less than five times the diameter of the cable.

Part III. Construction

338.100 Construction Specifications. Cabled, single-conductor, Type USE constructions recognized for underground use shall be permitted to have a bare copper conductor cabled with the assembly. Type USE single, parallel, or cabled conductor assemblies recognized for underground use shall be permitted to have a bare copper concentric conductor applied. These constructions shall not require an outer overall covering.

Informational Note: See 230.41, Exception, item (2), for directly buried, uninsulated service-entrance conductors.

Type SE or USE cable containing two or more conductors shall be permitted to have one conductor uninsulated.

338.120 Marking. Service-entrance cable shall be marked as required in 310.120. Cable with the neutral conductor smaller than the ungrounded conductors shall be so marked.

ARTICLE 340
Underground Feeder and Branch-Circuit Cable: Type UF

Part I. General

340.1 Scope. This article covers the use, installation, and construction specifications for underground feeder and branch-circuit cable, Type UF.

340.2 Definition.

Underground Feeder and Branch-Circuit Cable, Type UF. A factory assembly of one or more insulated conductors with an integral or an overall covering of nonmetallic material suitable for direct burial in the earth.

340.6 Listing Requirements. Type UF cable and associated fittings shall be listed.

Part II. Installation

340.10 Uses Permitted. Type UF cable shall be permitted as follows:

(1) For use underground, including direct burial in the earth. For underground requirements, see 300.5.

(2) As single-conductor cables. Where installed as single-conductor cables, all conductors of the feeder grounded conductor or branch circuit, including the grounded conductor and equipment grounding conductor, if any, shall be installed in accordance with 300.3.

(3) For wiring in wet, dry, or corrosive locations under the recognized wiring methods of this *Code*.

(4) Installed as nonmetallic-sheathed cable. Where so installed, the installation and conductor requirements shall comply with Parts II and III of Article 334 and shall be of the multiconductor type.

(5) For solar photovoltaic systems in accordance with 690.31.

(6) As single-conductor cables as the nonheating leads for heating cables as provided in 424.43.

(7) Supported by cable trays. Type UF cable supported by cable trays shall be of the multiconductor type.

Informational Note: See 310.15(A)(3) for temperature limitation of conductors.

340.12 Uses Not Permitted. Type UF cable shall not be used as follows:

(1) As service-entrance cable

(2) In commercial garages
(3) In theaters and similar locations
(4) In motion picture studios
(5) In storage battery rooms
(6) In hoistways or on elevators or escalators
(7) In hazardous (classified) locations, except as specifically permitted by other articles in this *Code*
(8) Embedded in poured cement, concrete, or aggregate, except where embedded in plaster as nonheating leads where permitted in 424.43
(9) Where exposed to direct rays of the sun, unless identified as sunlight resistant
(10) Where subject to physical damage
(11) As overhead cable, except where installed as messenger-supported wiring in accordance with Part II of Article 396

340.24 Bending Radius. Bends in Type UF cable shall be so made that the cable is not damaged. The radius of the curve of the inner edge of any bend shall not be less than five times the diameter of the cable.

340.80 Ampacity. The ampacity of Type UF cable shall be that of 60°C (140°F) conductors in accordance with 310.15.

Part III. Construction Specifications

340.104 Conductors. The conductors shall be sizes 14 AWG copper or 12 AWG aluminum or copper-clad aluminum through 4/0 AWG.

340.108 Equipment Grounding Conductor. In addition to the insulated conductors, the cable shall be permitted to have an insulated or bare equipment grounding conductor.

340.112 Insulation. The conductors of Type UF shall be one of the moisture-resistant types listed in Table 310.104(A) that is suitable for branch-circuit wiring or one that is identified for such use. Where installed as a substitute wiring method for NM cable, the conductor insulation shall be rated 90°C (194°F).

340.116 Sheath. The overall covering shall be flame retardant; moisture, fungus, and corrosion resistant; and suitable for direct burial in the earth.

ARTICLE 360
Flexible Metallic Tubing: Type FMT

Part I. General

360.1 Scope. This article covers the use, installation, and construction specifications for flexible metallic tubing (FMT) and associated fittings.

360.2 Definition.

Flexible Metallic Tubing (FMT). A metal raceway that is circular in cross section, flexible, and liquidtight without a nonmetallic jacket.

360.6 Listing Requirements. FMT and associated fittings shall be listed.

Part II. Installation

360.10 Uses Permitted. FMT shall be permitted to be used for branch circuits as follows:

(1) In dry locations
(2) Where concealed
(3) In accessible locations
(4) For system voltages of 1000 volts maximum

360.12 Uses Not Permitted. FMT shall not be used as follows:

(1) In hoistways
(2) In storage battery rooms
(3) In hazardous (classified) locations unless otherwise permitted under other articles in this *Code*
(4) Underground for direct earth burial, or embedded in poured concrete or aggregate
(5) Where subject to physical damage
(6) In lengths over 1.8 m (6 ft)

360.20 Size.

(A) Minimum. FMT smaller than metric designator 16 (trade size $^{1}/_{2}$) shall not be used.

Exception No. 1: FMT of metric designator 12 (trade size $^{3}/_{8}$) shall be permitted to be installed in accordance with 300.22(B) and (C).

Exception No. 2: FMT of metric designator 12 (trade size $^{3}/_{8}$) shall be permitted in lengths not in excess of 1.8 m (6 ft) as part of a listed assembly or for luminaires. See 410.117(C).

(B) Maximum. The maximum size of FMT shall be metric designator 21 (trade size $^{3}/_{4}$).

Informational Note: See 300.1(C) for the metric designators and trade sizes. These are for identification purposes only and do not relate to actual dimensions.

360.22 Number of Conductors.

(A) FMT — Metric Designators 16 and 21 (Trade Sizes $^{1}/_{2}$ and $^{3}/_{4}$). The number of conductors in metric designators 16 (trade size $^{1}/_{2}$) and 21 (trade size $^{3}/_{4}$) shall not exceed that permitted by the percentage fill specified in Table 1, Chapter 9.

Cables shall be permitted to be installed where such use is not prohibited by the respective cable articles. The number of cables shall not exceed the allowable percentage fill specified in Table 1, Chapter 9.

(B) FMT — Metric Designator 12 (Trade Size $^{3}/_{8}$). The number of conductors in metric designator 12 (trade size $^{3}/_{8}$) shall not exceed that permitted in Table 348.22.

360.24 Bends.

(A) Infrequent Flexing Use. When FMT is infrequently flexed in service after installation, the radii of bends measured to the inside of the bend shall not be less than specified in Table 360.24(A).

Table 360.24(A) Minimum Radii for Flexing Use

Metric Designator	Trade Size	Minimum Radii for Flexing Use	
		mm	in.
12	3/8	254.0	10
16	1/2	317.5	12 1/2
21	3/4	444.5	17 1/2

(B) Fixed Bends. Where FMT is bent for installation purposes and is not flexed or bent as required by use after installation, the radii of bends measured to the inside of the bend shall not be less than specified in Table 360.24(B).

Table 360.24(B) Minimum Radii for Fixed Bends

Metric Designator	Trade Size	Minimum Radii for Fixed Bends	
		mm	in.
12	3/8	88.9	3 1/2
16	1/2	101.6	4
21	3/4	127.0	5

360.56 Splices and Taps. Splices and taps shall be made in accordance with 300.15.

360.60 Grounding. FMT shall be permitted as an equipment grounding conductor where installed in accordance with 250.118(7).

Part III. Construction Specifications

360.120 Marking. FMT shall be marked according to 110.21.

ARTICLE 404
Switches

404.8 Accessibility and Grouping.

(A) Location. All switches and circuit breakers used as switches shall be located so that they may be operated from a readily accessible place. They shall be installed such that the center of the grip of the operating handle of the switch or circuit breaker, when in its highest position, is not more than 2.0 m (6 ft 7 in.) above the floor or working platform.

Exception No. 1: On busway installations, fused switches and circuit breakers shall be permitted to be located at the same level as the busway. Suitable means shall be provided to operate the handle of the device from the floor.

Exception No. 2: Switches and circuit breakers installed adjacent to motors, appliances, or other equipment that they supply shall be permitted to be located higher than 2.0 m (6 ft 7 in.) and to be accessible by portable means.

Exception No. 3: Hookstick operable isolating switches shall be permitted at greater heights.

(B) Voltage Between Adjacent Devices. A snap switch shall not be grouped or ganged in enclosures with other snap switches, receptacles, or similar devices, unless they are arranged so that the voltage between adjacent devices does not exceed 300 volts, or unless they are installed in enclosures equipped with identified, securely installed barriers between adjacent devices.

(C) Multipole Snap Switches. A multipole, general-use snap switch shall not be permitted to be fed from more than a single circuit unless it is listed and marked as a two-circuit or three-circuit switch.

Informational Note: See 210.7 for disconnect requirements where more than one circuit supplies a switch.

SE 400
SOLAR THERMAL, AUXILIARY SYSTEMS AND STORAGE BATTERIES

ARTICLE 422
Appliances

422.13 Storage-Type Water Heaters. A fixed storage-type water heater that has a capacity of 450 L (120 gal) or less shall be considered a continuous load for the purposes of sizing branch circuits.

Informational Note: For branch-circuit rating, see 422.10.

422.61 Marking of Heating Elements. All heating elements that are rated over one ampere, replaceable in the field, and a part of an appliance shall be legibly marked with the ratings in volts and amperes, or in volts and watts, or with the manufacturer's part number.

ARTICLE 424
Fixed Electric Space-Heating Equipment

424.20 Thermostatically Controlled Switching Devices.

(A) Serving as Both Controllers and Disconnecting Means. Thermostatically controlled switching devices and combination thermostats and manually controlled switches shall be permitted to serve as both controllers and disconnecting means, provided they meet all of the following conditions:

(1) Provided with a marked "off" position

(2) Directly open all ungrounded conductors when manually placed in the "off" position

(3) Designed so that the circuit cannot be energized automatically after the device has been manually placed in the "off" position

(4) Located as specified in 424.19

(B) Thermostats That Do Not Directly Interrupt All Ungrounded Conductors. Thermostats that do not directly interrupt all ungrounded conductors and thermostats that operate remote-control circuits shall not be required to meet the requirements of 424.20(A). These devices shall not be permitted as the disconnecting means.

424.100 Scope. Low-voltage fixed electric space-heating equipment shall consist of an isolating power supply, low-voltage heaters, and associated equipment that are all identified for use in dry locations.

Article 427
Fixed Electric Heating Equipment for Pipelines and Vessels

Part I. General

427.1 Scope. The requirements of this article shall apply to electrically energized heating systems and the installation of these systems used with pipelines or vessels or both.

Informational Note: For further information, see ANSI/IEEE 515-2011, Standard for the Testing, Design, Installation and Maintenance of Electrical Resistance Trace Heating for Industrial Applications; ANSI/IEEE 844-2000, Recommended Practice for Electrical Impedance, Induction, and Skin Effect Heating of Pipelines and Vessels; and ANSI/NECA 202-2013, Standard for Installing and Maintaining Industrial Heat Tracing Systems.

427.2 Definitions.

Impedance Heating System. A system in which heat is generated in a pipeline or vessel wall by causing current to flow through the pipeline or vessel wall by direct connection to an ac voltage source from a dual-winding transformer.

Induction Heating System. A system in which heat is generated in a pipeline or vessel wall by inducing current and hysteresis effect in the pipeline or vessel wall from an external isolated ac field source.

Pipeline. A length of pipe including pumps, valves, flanges, control devices, strainers, and/or similar equipment for conveying fluids.

Resistance Heating Element. A specific separate element to generate heat that is applied to the pipeline or vessel externally or internally.

Informational Note: Tubular heaters, strip heaters, heating cable, heating tape, heating blankets, and immersion heaters are examples of resistance heaters.

Skin-Effect Heating System. A system in which heat is generated on the inner surface of a ferromagnetic envelope attached to a pipeline or vessel, or both.

Informational Note: Typically, an electrically insulated conductor is routed through and connected to the envelope at the other end. The envelope and the electrically insulated conductor are connected to an ac voltage source from a dual-winding transformer.

Vessel. A container such as a barrel, drum, or tank for holding fluids or other material.

427.3 Application of Other Articles. Cord-connected pipe heating assemblies intended for specific use and identified as suitable for this use shall be installed according to Article 422.

427.4 Continuous Load. Fixed electric heating equipment for pipelines and vessels shall be considered continuous load.

Part II. Installation

427.10 General. Equipment for pipeline and vessel electric heating shall be identified as being suitable for (1) the chemical, thermal, and physical environment and (2) installation in accordance with the manufacturer's drawings and instructions.

427.11 Use. Electric heating equipment shall be installed in such a manner as to be afforded protection from physical damage.

427.12 Thermal Protection. External surfaces of pipeline and vessel heating equipment that operate at temperatures exceeding 60°C (140°F) shall be physically guarded, isolated, or thermally insulated to protect against contact by personnel in the area.

427.13 Identification. The presence of electrically heated pipelines, vessels, or both, shall be evident by the posting of appropriate caution signs or markings at intervals not exceeding 6 m (20 ft) along the pipeline or vessel and on or adjacent to equipment in the piping system that requires periodic servicing.

Part III. Resistance Heating Elements

427.14 Secured. Heating element assemblies shall be secured to the surface being heated by means other than the thermal insulation.

427.15 Not in Direct Contact. Where the heating element is not in direct contact with the pipeline or vessel being heated, means shall be provided to prevent overtemperature of the heating element unless the design of the heater assembly is such that its temperature limitations will not be exceeded.

427.16 Expansion and Contraction. Heating elements and assemblies shall not be installed where they bridge expansion joints unless provisions are made for expansion and contraction.

427.17 Flexural Capability. Where installed on flexible pipelines, the heating elements and assemblies shall have a flexural capability that is compatible with the pipeline.

427.18 Power Supply Leads.

(A) Nonheating Leads. Power supply nonheating leads (cold leads) for resistance elements shall be suitable for the temperature encountered. Not less than 150 mm (6 in.) of nonheating leads shall be provided within the junction box. Preassembled factory-supplied and field-assembled nonheating leads on approved heaters shall be permitted to be shortened if the markings specified in 427.20 are retained.

(B) Power Supply Leads Protection. Nonheating power supply leads shall be protected where they emerge from electrically heated pipeline or vessel heating units by rigid metal conduit, intermediate metal conduit, electrical metallic tubing, or other raceways identified as suitable for the application.

(C) Interconnecting Leads. Interconnecting nonheating leads connecting portions of the heating system shall be permitted to be covered by thermal insulation in the same manner as the heaters.

427.19 Electrical Connections.

(A) Nonheating Interconnections. Nonheating interconnections, where required under thermal insulation, shall be made with insulated connectors identified as suitable for this use.

(B) Circuit Connections. Splices and terminations outside the thermal insulation shall be installed in a box or fitting in accordance with 110.14 and 300.15.

427.20 Marking. Each factory-assembled heating unit shall be legibly marked within 75 mm (3 in.) of an end of the nonheating leads with the permanent identification symbol, catalog number, and ratings in volts and watts or in volts and amperes.

427.22 Ground-Fault Protection of Equipment. Ground-fault protection of equipment shall be provided for electric heat tracing and heating panels. This requirement shall not apply in industrial establishments where there is alarm indication of ground faults and the following conditions apply:

(1) Conditions of maintenance and supervision ensure that only qualified persons service the installed systems.

(2) Continued circuit operation is necessary for safe operation of equipment or processes.

427.23 Grounded Conductive Covering. Electric heating equipment shall be listed and have a grounded conductive covering in accordance with 427.23(A) or (B). The conductive covering shall provide an effective ground path for equipment protection.

(A) Heating Wires or Cables. Heating wires or cables shall have a grounded conductive covering that surrounds the heating element and bus wires, if any, and their electrical insulation.

(B) Heating Panels. Heating panels shall have a grounded conductive covering over the heating element and its electrical insulation on the side opposite the side attached to the surface to be heated.

Part IV. Impedance Heating

427.25 Personnel Protection. All accessible external surfaces of the pipeline, vessel, or both, being heated shall be physically guarded, isolated, or thermally insulated (with a weatherproof jacket for outside installations) to protect against contact by personnel in the area.

427.26 Isolation Transformer. A dual-winding transformer with a grounded shield between the primary and secondary windings shall be used to isolate the distribution system from the heating system.

427.27 Voltage Limitations. The secondary winding of the isolation transformer connected to the pipeline or vessel being heated shall not have an output voltage greater than 30 volts ac.

Exception No. 1: In industrial establishments, the isolation transformer connected to the pipeline or vessel being heated shall be permitted to have an output voltage greater than 30 but not more than 80 volts ac to ground where all of the following conditions apply:

(1) Conditions of guarding, maintenance, and supervision ensure that only qualified persons have access to the installed systems.

(2) Ground-fault protection of equipment is provided.

Exception No. 2: In industrial establishments, the isolation transformer connected to the pipeline or vessel being heated shall be permitted to have an output voltage not greater than 132 volts ac to ground where all of the following conditions apply:

(1) Conditions of guarding, maintenance, and supervision ensure that only qualified persons service the installed systems.

(2) Ground-fault protection of equipment is provided.

(3) The pipeline or vessel being heated is completely enclosed in a grounded metal enclosure.

(4) The transformer secondary connections to the pipeline or vessel being heated are completely enclosed in a grounded metal mesh or metal enclosure.

427.28 Induced Currents. All current-carrying components shall be installed in accordance with 300.20.

427.29 Grounding. The pipeline, vessel, or both, that is being heated and operating at a voltage greater than 30 but not more than 80 shall be grounded at designated points.

427.30 Secondary Conductor Sizing. The ampacity of the conductors connected to the secondary of the transformer shall be at least 100 percent of the total load of the heater.

Part V. Induction Heating

427.35 Scope. This part covers the installation of line frequency induction heating equipment and accessories for pipelines and vessels.

Informational Note: See Article 665 for other applications.

427.36 Personnel Protection. Induction coils that operate or may operate at a voltage greater than 30 volts ac shall be enclosed in a nonmetallic or split metallic enclosure, isolated, or made inaccessible by location to protect personnel in the area.

427.37 Induced Current. Induction coils shall be prevented from inducing circulating currents in surrounding metallic equipment, supports, or structures by shielding, isolation, or insulation of the current paths. Stray current paths shall be bonded to prevent arcing.

Part VI. Skin-Effect Heating

427.45 Conductor Ampacity. The ampacity of the electrically insulated conductor inside the ferromagnetic envelope shall be permitted to exceed the values given in Article 310, provided it is identified as suitable for this use.

427.46 Pull Boxes. Pull boxes for pulling the electrically insulated conductor in the ferromagnetic envelope shall be permitted to be buried under the thermal insulation, provided their locations are indicated by permanent markings on the insulation jacket surface and on drawings. For outdoor installations, pull boxes shall be of watertight construction.

427.47 Single Conductor in Enclosure. The provisions of 300.20 shall not apply to the installation of a single conductor in a ferromagnetic envelope (metal enclosure).

427.48 Grounding. The ferromagnetic envelope shall be grounded at both ends, and, in addition, it shall be permitted to be grounded at intermediate points as required by its design. The ferromagnetic envelope shall be bonded at all joints to ensure electrical continuity.

The provisions of 250.30 shall not apply to the installation of skin-effect heating systems.

Informational Note: See Article 250 for grounding methods.

Part VII. Control and Protection

427.55 Disconnecting Means.

(A) Switch or Circuit Breaker. Means shall be provided to simultaneously disconnect all fixed electric pipeline or vessel heating equipment from all ungrounded conductors. The branch-circuit switch or circuit breaker, where readily accessible to the user of the equipment, shall be permitted to serve as the disconnecting means. The disconnecting means shall be of the indicating type and shall be capable of being locked in the open (off) position. The disconnecting means shall be installed in accordance with 110.25.

(B) Cord-and-Plug-Connected Equipment. The factory-installed attachment plug of cord-and-plug-connected equipment rated 20 amperes or less and 150 volts or less to ground shall be permitted to be the disconnecting means.

427.56 Controls.

(A) Temperature Control with "Off" Position. Temperature-controlled switching devices that indicate an "off" position and that interrupt line current shall open all ungrounded conductors when the control device is in this "off" position. These devices shall not be permitted to serve as the disconnecting means unless capable of being locked in the open position.

(B) Temperature Control Without "Off" Position. Temperature controlled switching devices that do not have an "off" position shall not be required to open all ungrounded conductors and shall not be permitted to serve as the disconnecting means.

(C) Remote Temperature Controller. Remote controlled temperature-actuated devices shall not be required to meet the requirements of 427.56(A) and (B). These devices shall not be permitted to serve as the disconnecting means.

(D) Combined Switching Devices. Switching devices consisting of combined temperature-actuated devices and manually controlled switches that serve both as the controllers and the disconnecting means shall comply with all the following conditions:

(1) Open all ungrounded conductors when manually placed in the "off" position

(2) Be designed so that the circuit cannot be energized automatically if the device has been manually placed in the "off" position

(3) Be capable of being locked in the open position

427.57 Overcurrent Protection. Heating equipment shall be considered protected against overcurrent where supplied by a branch circuit as specified in 210.18 and 210.23.

450.3 Overcurrent Protection. Overcurrent protection of transformers shall comply with 450.3(A), (B), or (C). As used in this section, the word transformer shall mean a transformer or polyphase bank of two or more single-phase transformers operating as a unit.

Informational Note No. 1: See 240.4, 240.21, 240.100, and 240.101 for overcurrent protection of conductors.

Informational Note No. 2: Nonlinear loads can increase heat in a transformer without operating its overcurrent protective device.

(A) Transformers Over 1000 Volts, Nominal. Overcurrent protection shall be provided in accordance with Table 450.3(A).

(B) Transformers 1000 Volts, Nominal, or Less. Overcurrent protection shall be provided in accordance with Table 450.3(B).

Exception: Where the transformer is installed as a motor control circuit transformer in accordance with 430.72(C)(1) through (C)(5).

(C) Voltage (Potential) Transformers. Voltage (potential) transformers installed indoors or enclosed shall be protected with primary fuses.

Informational Note: For protection of instrument circuits including voltage transformers, see 408.52.

ARTICLE 480
Storage Batteries

480.1 Scope. This article applies to all stationary installations of storage batteries.

Informational Note: The following standards are frequently referenced for the installation of stationary batteries:

(1) IEEE 484, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*
(2) IEEE 485, *Recommended Practice for Sizing Vented Lead-Acid Storage Batteries for Stationary Applications*
(3) IEEE 1145, *Recommended Practice for Installation and Maintenance of Nickel-Cadmium Batteries for Photovoltaic (PV) Systems*
(4) IEEE 1187, *Recommended Practice for Installation Design, and Installation of Valve-Regulated Lead-Acid Batteries for Stationary Applications*
(5) IEEE 1375, *IEEE Guide for the Protection of Stationary Battery Systems*
(6) IEEE 1578, *Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management*
(7) IEEE 1635/ASHRAE 21, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*
(8) UL 1973, *Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications*
(9) UL Subject 2436, *Outline of Investigation for Spill Containment for Stationary Lead Acid Battery Systems*
(10) UL 1989, *Standard for Standby Batteries*

Table 450.3(A) Maximum Rating or Setting of Overcurrent Protection for Transformers Over 1000 Volts (as a Percentage of Transformer-Rated Current)

		Primary Protection Over 1000 Volts		Secondary Protection (See Note 2.)		
				Over 1000 Volts		1000 Volts or Less
Location Limitations	Transformer Rated Impedance	Circuit Breaker (See Note 4.)	Fuse Rating	Circuit Breaker (See Note 4.)	Fuse Rating	Circuit Breaker or Fuse Rating
Any location	Not more than 6%	600% (See Note 1.)	300% (See Note 1.)	300% (See Note 1.)	250% (See Note 1.)	125% (See Note 1.)
	More than 6% and not more than 10%	400% (See Note 1.)	300% (See Note 1.)	250% (See Note 1.)	225% (See Note 1.)	125% (See Note 1.)
Supervised locations only (See Note 3.)	Any	300% (See Note 1.)	250% (See Note 1.)	Not required	Not required	Not required
	Not more than 6%	600%	300%	300% (See Note 5.)	250% (See Note 5.)	250% (See Note 5.)
	More than 6% and not more than 10%	400%	300%	250% (See Note 5.)	225% (See Note 5.)	250% (See Note 5.)

Notes:

1. Where the required fuse rating or circuit breaker setting does not correspond to a standard rating or setting, a higher rating or setting that does not exceed the following shall be permitted:
   a. The next higher standard rating or setting for fuses and circuit breakers 1000 volts and below, or
   b. The next higher commercially available rating or setting for fuses and circuit breakers above 1000 volts.
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. If both circuit breakers and fuses are used as the overcurrent device, the total of the device ratings shall not exceed that allowed for fuses.
3. A supervised location is a location where conditions of maintenance and supervision ensure that only qualified persons monitor and service the transformer installation.
4. Electronically actuated fuses that may be set to open at a specific current shall be set in accordance with settings for circuit breakers.
5. A transformer equipped with a coordinated thermal overload protection by the manufacturer shall be permitted to have separate secondary protection omitted.

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.

480.2 Definitions.

Cell. The basic electrochemical unit, characterized by an anode and a cathode, used to receive, store, and deliver electrical energy.

Container. A vessel that holds the plates, electrolyte, and other elements of a single unit in a battery.

> Informational Note: A container may be single-cell or multi-cell and is sometimes referred to in the industry as a "jar."

Electrolyte. The medium that provides the ion transport mechanism between the positive and negative electrodes of a cell.

Intercell Connector. An electrically conductive bar or cable used to connect adjacent cells.

Intertier Connector. An electrical conductor used to connect two cells on different tiers of the same rack or different shelves of the same rack.

Nominal Voltage (Battery or Cell). The value assigned to a cell or battery of a given voltage class for the purpose of convenient designation. The operating voltage of the cell or battery may vary above or below this value.

> Informational Note: The most common nominal cell voltages are 2 volts per cell for the lead-acid systems, 1.2 volts per cell for alkali systems, and 3.6 to 3.8 volts per cell for

Li-ion systems. Nominal voltages might vary with different chemistries.

Sealed Cell or Battery. A cell or battery that has no provision for the routine addition of water or electrolyte or for external measurement of electrolyte specific gravity and might contain pressure relief venting.

Storage Battery. A battery comprised of one or more rechargeable cells of the lead-acid, nickel-cadmium, or other rechargeable electrochemical types.

Terminal. That part of a cell, container, or battery to which an external connection is made (commonly identified as post, pillar, pole, or terminal post).

480.3 Equipment. Storage batteries and battery management equipment shall be listed. This requirement shall not apply to lead-acid batteries.

480.4 Battery and Cell Terminations.

(A) Corrosion Prevention. Where mating dissimilar metals, antioxidant material suitable for the battery connection shall be used where recommended by the battery manufacturer.

Informational Note: The battery manufacturer's installation and instruction manual can be used for guidance for acceptable materials.

(B) Intercell and Intertier Conductors and Connections. The ampacity of field-assembled intercell and intertier connectors and conductors shall be of such cross-sectional area that the temperature rise under maximum load conditions and at maximum ambient temperature shall not exceed the safe operating temperature of the conductor insulation or of the material of the conductor supports.

Informational Note: Conductors sized to prevent a voltage drop exceeding 3 percent of maximum anticipated load, and where the maximum total voltage drop to the furthest point of connection does not exceed 5 percent, may not be appropriate for all battery applications. IEEE 1375-2003, *Guide for the Protection of Stationary Battery Systems*, provides guidance for overcurrent protection and associated cable sizing.

(C) Battery Terminals. Electrical connections to the battery, and the cable(s) between cells on separate levels or racks, shall not put mechanical strain on the battery terminals. Terminal plates shall be used where practicable.

Informational Note: Conductors are commonly pre-formed to eliminate stress on battery terminations. Fine stranded cables may also eliminate the stress on battery terminations. See the manufacturer's instructions for guidance.

480.5 Wiring and Equipment Supplied from Batteries. Wiring and equipment supplied from storage batteries shall be subject to the applicable provisions of this *Code* applying to wiring and equipment operating at the same voltage, unless otherwise permitted by 480.6.

480.6 Overcurrent Protection for Prime Movers. Overcurrent protection shall not be required for conductors from a battery with a voltage of 60 volts dc or less if the battery provides power for starting, ignition, or control of prime movers. Section 300.3 shall not apply to these conductors.

480.7 DC Disconnect Methods.

(A) Disconnecting Means. A disconnecting means shall be provided for all ungrounded conductors derived from a stationary battery system with a voltage over 60 volts dc. A disconnecting means shall be readily accessible and located within sight of the battery system.

Informational Note: See 240.21(H) for information on the location of the overcurrent device for battery conductors.

(B) Remote Actuation. Where a disconnecting means, located in accordance with 480.7(A), is provided with remote controls to activate the disconnecting means and the controls for the disconnecting means are not located within sight of the stationary battery system, the disconnecting means shall be capable of being locked in the open position, in accordance with 110.25, and the location of the controls shall be field marked on the disconnecting means.

(C) Busway. Where a DC busway system is installed, the disconnecting means shall be permitted to be incorporated into the busway.

(D) Notification. The disconnecting means shall be legibly marked in the field. A label with the marking shall be placed in a conspicuous location near the battery if a disconnecting means is not provided. The marking shall be of sufficient durability to withstand the environment involved and shall include the following:

(1) Nominal battery voltage

(2) Maximum available short-circuit current derived from the stationary battery system

(3) Date the short-circuit current calculation was performed

(4) The battery disconnecting means shall be marked in accordance with 110.16.

Informational Note No. 1: Battery equipment suppliers can provide information about short-circuit current on any particular battery model.

Informational Note No. 2: The available short-circuit current marking(s) addressed in 480.7(D)(2) is related to required short-circuit current ratings of equipment. NFPA 70E-2015, *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.

480.8 Insulation of Batteries. Batteries constructed of an electrically conductive container shall have insulating support if a voltage is present between the container and ground.

480.9 Battery Support Systems. For battery chemistries with corrosive electrolyte, the structure that supports the battery shall be resistant to deteriorating action by the electrolyte. Metallic structures shall be provided with nonconducting support members for the cells, or shall be constructed with a continuous insulating material. Paint alone shall not be considered as an insulating material.

The terminals of all cells or multi-cell units shall be readily accessible for readings, inspection, and cleaning where required by the equipment design. One side of transparent

battery containers shall be readily accessible for inspection of the internal components.

480.10 Battery Locations. Battery locations shall conform to 480.10(A), (B), and (C).

(A) Ventilation. Provisions appropriate to the battery technology shall be made for sufficient diffusion and ventilation of gases from the battery, if present, to prevent the accumulation of an explosive mixture.

Informational Note No. 1: See NFPA 1-2015, *Fire Code*, Chapter 52, for ventilation considerations for specific battery chemistries.

Informational Note No. 2: Some battery technologies do not require ventilation.

Informational Note No. 3: For additional information on the ventilation of stationary battery systems, see *IEEE Std 1635-2012/ASHRAE Guideline 21-2012 Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*.

(B) Live Parts. Guarding of live parts shall comply with 110.27.

(C) Spaces About Battery Systems. Spaces about battery systems shall comply with 110.26. Working space shall be measured from the edge of the battery cabinet, racks, or trays.

For battery racks, there shall be a minimum clearance of 25 mm (1 in.) between a cell container and any wall or structure on the side not requiring access for maintenance. Battery stands shall be permitted to contact adjacent walls or structures, provided that the battery shelf has a free air space for not less than 90 percent of its length.

Informational Note: Additional space is often needed to accommodate battery hoisting equipment, tray removal, or spill containment.

(D) Top Terminal Batteries. Where top terminal batteries are installed on tiered racks or on shelves of battery cabinets, working space in accordance with the battery manufacturer's instructions shall be provided between the highest point on a cell and the row, shelf, or ceiling above that point.

Informational Note: IEEE 1187-2013, *IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Batteries for Stationary Applications*, provides guidance for top clearance of valve-regulated lead-acid batteries, which are commonly used in battery cabinets.

(E) Egress. A personnel door(s) intended for entrance to, and egress from, rooms designated as battery rooms shall open in the direction of egress and shall be equipped with listed panic hardware.

(F) Piping in Battery Rooms. Gas piping shall not be permitted in dedicated battery rooms.

(G) Illumination. Illumination shall be provided for working spaces containing battery systems. The lighting outlets shall not be controlled by automatic means only. Additional lighting outlets shall not be required where the work space is illuminated by an adjacent light source. The location of luminaires shall not:

(1) Expose personnel to energized battery components while performing maintenance on the luminaires in the battery space; or

(2) Create a hazard to the battery upon failure of the luminaire.

480.11 Vents.

(A) Vented Cells. Each vented cell shall be equipped with a flame arrester.

Informational Note: A flame arrester prevents destruction of the cell due to ignition of gases within the cell by an external spark or flame.

(B) Sealed Cells. Where the battery is constructed such that an excessive accumulation of pressure could occur within the cell during operation, a pressure-release vent shall be provided.

SE500
PHOTOVOLTAIC SYSTEMS, ENERGY STORAGE SYSTEMS AND ENERGY MANAGEMENT SYSTEMS

600.2 Definitions.

Photovoltaic (PV) Powered Sign. A complete sign powered by solar energy consisting of all components and subassemblies for installation either as an off-grid stand-alone, on-grid interactive, or non-grid interactive system.

600.34 Photovoltaic (PV) Powered Sign. All field wiring of components and subassemblies for an off-grid stand-alone, on-grid interactive, or non-grid interactive PV installation shall be installed in accordance with Article 690, as applicable, 600.34, and the PV powered sign installation instructions.

(A) Equipment. Inverters, motor generators, PV modules, PV panels, ac PV modules, dc combiners, dc-ac converters, and charge controllers intended for use in PV powered sign systems shall be listed for PV application.

(B) Wiring. Wiring from a photovoltaic panel or wiring external to the PV sign body shall be:

(1) Listed, labeled, and suitable for photovoltaic applications

(2) Routed to closely follow the sign body or enclosure

(3) As short as possible and secured at intervals not exceeding 0.91 m (3 ft)

(4) Protected where subject to physical damage

(C) Flexible Cords and Cables. Flexible cords and cables shall comply with Article 400 and be identified as extra hard usage, rated for outdoor use, and water and sunlight resistant.

(D) Grounding. Grounding a PV powered sign shall comply with Article 690, Part V and 600.7.

(E) Disconnecting Means. The disconnecting means for a PV powered sign shall comply with Article 690, Part III and 600.6.

(F) Battery Compartments. Battery compartments shall require a tool to open.

680.81 Equipment Approval. Lifts shall be listed, labeled, and identified for swimming pool and spa use.

Exception No. 1: Lifts where the battery is removed for charging at another location and the battery is rated less

than or equal to the low-voltage contact limit shall not be required to be listed or labeled.

Exception No. 2: Solar-operated or solar-recharged lifts where the solar panel is attached to the lift and the battery is rated less than or equal to 24 volts shall not be required to be listed or labeled.

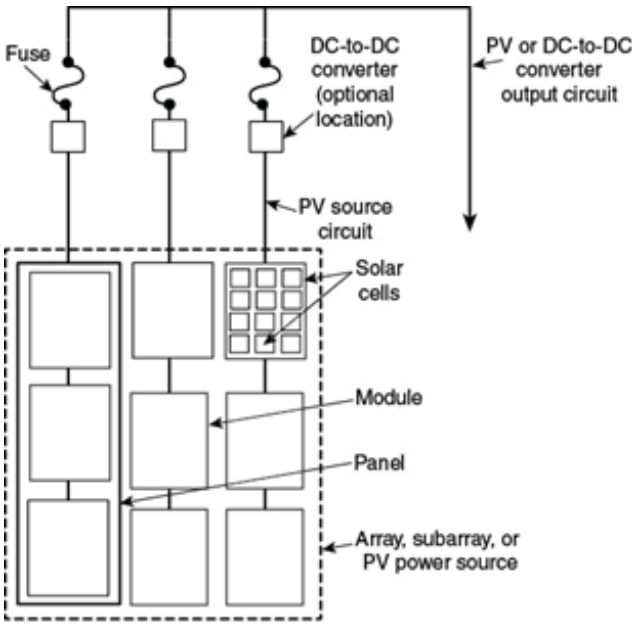
Exception No. 3: Lifts that are supplied from a source not exceeding the low-voltage contact limit and supplied by listed transformers or power supplies that comply with 680.23(A)(2) shall not be required to be listed or labeled.

ARTICLE 690
Solar Photovoltaic (PV) Systems

Part I. General

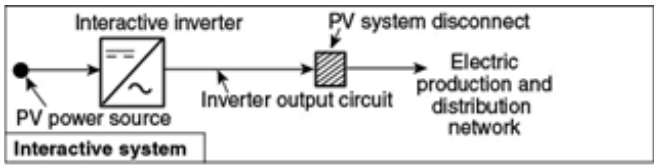
690.1 Scope. This article applies to solar PV systems, other than those covered by Article 691, including the array circuit(s), inverter(s), and controller(s) for such systems. *[See Figure 690.1(a) and Figure 690.1(b).]* The systems covered by this article may be interactive with other electrical power production sources or stand-alone or both, and may or may not be connected to energy storage systems such as batteries. These PV systems may have ac or dc output for utilization.

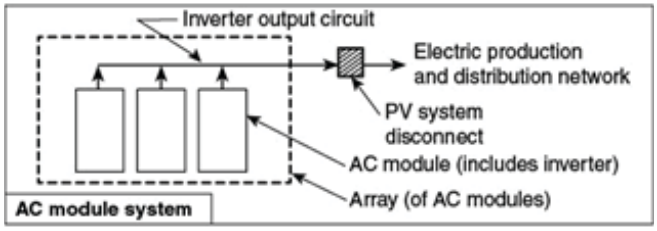
Informational Note: Article 691 covers the installation of large-scale PV electric supply stations.

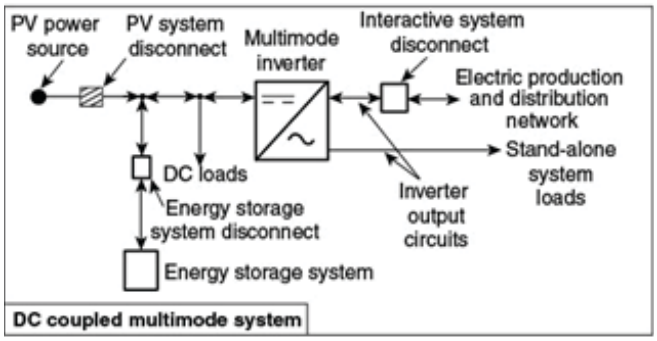


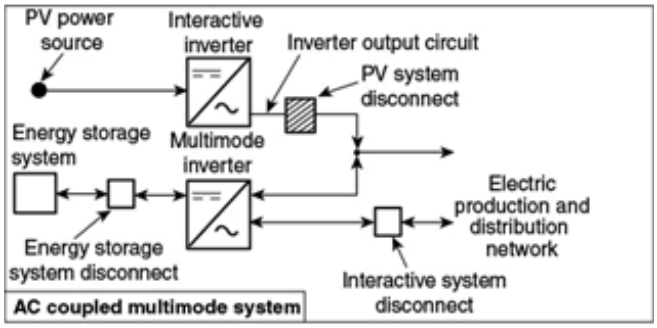
Notes:
(1) These diagrams are intended to be a means of identification for PV power source components, circuits, and connections that make up the PV power source.
(2) Custom PV power source designs occur, and some components are optional.

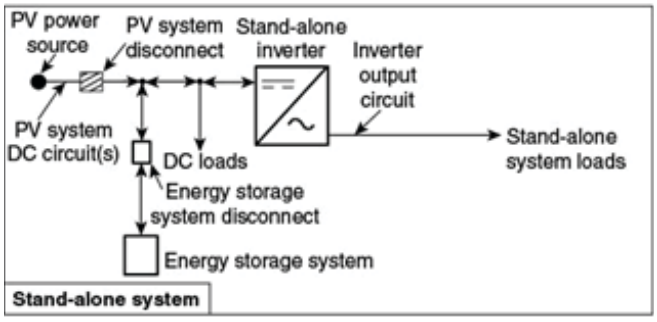
Figure 690.1(a)
Identification of PV Power Source Components.











Notes:
(1) These diagrams are intended to be a means of identification for PV system components, circuits, and connections.
(2) The PV system disconnect in these diagrams separates the PV system from all other systems.
(3) Not all disconnecting means required by Article 690, Part III are shown.
(4) System grounding and equipment grounding are not shown. See Article 690, Part V.
(5) Custom designs occur in each configuration, and some components are optional.

Figure 690.1(b)
Identification of PV System Components in Common Configurations.

690.2 Definitions.

Alternating-Current (ac) Module (Alternating-Current Photovoltaic Module). A complete, environmentally protected unit consisting of solar cells, optics, inverter, and other components, exclusive of tracker, designed to generate ac power when exposed to sunlight.

Array. A mechanically integrated assembly of module(s) or panel(s) with a support structure and foundation, tracker, and other components, as required, to form a dc or ac power-producing unit.

Bipolar Photovoltaic Array. A dc PV array that has two outputs, each having opposite polarity to a common reference point or center tap.

DC-to-DC Converter. A device installed in the PV source circuit or PV output circuit that can provide an output dc voltage and current at a higher or lower value than the input dc voltage and current.

DC-to-DC Converter Output Circuit. Circuit conductors between the dc-to-dc converter source circuit(s) and the inverter or dc utilization equipment.

DC-to-DC Converter Source Circuit. Circuits between dc-to-dc converters and from dc-to-dc converters to the common connection point(s) of the dc system.

Direct-Current (dc) Combiner. A device used in the PV source and PV output circuits to combine two or more dc circuit inputs and provide one dc circuit output.

Diversion Charge Controller. Equipment that regulates the charging process of a battery by diverting power from energy storage to direct-current or alternating-current loads or to an interconnected utility service.

Electrical Production and Distribution Network. A power production, distribution, and utilization system, such as a utility system and connected loads, that is external to and not controlled by the PV power system.

Functional Grounded PV System. A PV system that has an electrical reference to ground that is not solidly grounded.

> Informational Note: A functional grounded PV system is often connected to ground through a fuse, circuit breaker, resistance device, non-isolated grounded ac circuit, or electronic means that is part of a listed ground-fault protection system. Conductors in these systems that are normally at ground potential may have voltage to ground during fault conditions.

Generating Capacity. The sum of parallel-connected inverter maximum continuous output power at 40°C in kilowatts.

Interactive System. A PV system that operates in parallel with and may deliver power to an electrical production and distribution network.

Interactive Inverter Output Circuit. The conductors between the interactive inverter and the service equipment or another electrical power production and distribution network.

Inverter. Equipment that is used to change voltage level or waveform, or both, of electrical energy. Commonly, an inverter [also known as a power conditioning unit (PCU) or power conversion system (PCS)] is a device that changes dc input to an ac output. Inverters may also function as battery chargers that use alternating current from another source and convert it into direct current for charging batteries.

Inverter Input Circuit. Conductors connected to the dc input of an inverter.

Inverter Output Circuit. Conductors connected to the ac output of an inverter.

Module. A complete, environmentally protected unit consisting of solar cells, optics, and other components, exclusive of tracker, designed to generate dc power when exposed to sunlight.

Monopole Subarray. A PV subarray that has two conductors in the output circuit, one positive (+) and one negative (-). Two monopole PV subarrays are used to form a bipolar PV array.

Multimode Inverter. Equipment having the capabilities of both the interactive inverter and the stand-alone inverter.

Panel. A collection of modules mechanically fastened together, wired, and designed to provide a field-installable unit.

Photovoltaic Output Circuit. Circuit conductors between the PV source circuit(s) and the inverter or dc utilization equipment.

Photovoltaic Power Source. An array or aggregate of arrays that generates dc power at system voltage and current.

Photovoltaic Source Circuit. Circuits between modules and from modules to the common connection point(s) of the dc system.

Photovoltaic System DC Circuit. Any dc conductor supplied by a PV power source, including PV source circuits, PV output circuits, dc-to-dc converter source circuits, or dc-to-dc converter output circuits.

Solar Cell. The basic PV device that generates electricity when exposed to light.

Stand-Alone System. A solar PV system that supplies power independently of an electrical production and distribution network.

Subarray. An electrical subset of a PV array.

690.4 General Requirements.

(A) Photovoltaic Systems. Photovoltaic systems shall be permitted to supply a building or other structure in addition to any other electrical supply system(s).

(B) Equipment. Inverters, motor generators, PV modules, PV panels, ac modules, dc combiners, dc-to-dc converters, and charge controllers intended for use in PV systems shall be listed or field labeled for the PV application.

(C) Qualified Personnel. The installation of equipment and all associated wiring and interconnections shall be performed only by qualified persons.

> Informational Note: See Article 100 for the definition of *qualified person.*

(D) Multiple PV Systems. Multiple PV systems shall be permitted to be installed in or on a single building or structure.

Where the PV systems are remotely located from each other, a directory in accordance with 705.10 shall be provided at each PV system disconnecting means.

(E) Locations Not Permitted. PV system equipment and disconnecting means shall not be installed in bathrooms.

690.6 Alternating-Current (ac) Modules.

(A) Photovoltaic Source Circuits. The requirements of Article 690 pertaining to PV source circuits shall not apply to ac modules. The PV source circuit, conductors, and inverters shall be considered as internal wiring of an ac module.

(B) Inverter Output Circuit. The output of an ac module shall be considered an inverter output circuit.

Part II. Circuit Requirements

690.7 Maximum Voltage. The maximum voltage of PV system dc circuits shall be the highest voltage between any two circuit conductors or any conductor and ground. PV system dc circuits on or in one- and two-family dwellings shall be permitted to have a maximum voltage of 600 volts or less. PV system dc circuits on or in other types of buildings shall be permitted to have a maximum voltage of 1000 volts or less. Where not located on or in buildings, listed dc PV equipment, rated at a maximum voltage of 1500 volts or less, shall not be required to comply with Parts II and III of Article 490.

(A) Photovoltaic Source and Output Circuits. In a dc PV source circuit or output circuit, the maximum PV system voltage for that circuit shall be calculated in accordance with one of the following methods:

Informational Note: One source for lowest-expected, ambient temperature design data for various locations is the chapter titled Extreme Annual Mean Minimum Design Dry Bulb Temperature found in the *ASHRAE Handbook — Fundamentals*, 2013. These temperature data can be used to calculate maximum voltage.

(1) **Instructions in listing or labeling of the module:** The sum of the PV module–rated open-circuit voltage of the series-connected modules corrected for the lowest expected ambient temperature using the open-circuit voltage temperature coefficients in accordance with the instructions included in the listing or labeling of the module

(2) **Crystalline and multicrystalline modules:** For crystalline and multicrystalline silicon modules, the sum of the PV module–rated open-circuit voltage of the series-connected modules corrected for the lowest expected ambient temperature using the correction factor provided in Table 690.7(A)

(3) **PV systems of 100 kW or larger:** For PV systems with a generating capacity of 100 kW or greater, a documented and stamped PV system design, using an industry standard method and provided by a licensed professional electrical engineer, shall be permitted.

Informational Note: One industry standard method for calculating maximum voltage of a PV system is published by Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*.

The maximum voltage shall be used to determine the voltage rating of conductors, cables, disconnects, overcurrent devices, and other equipment.

Table 690.7(A) Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules

Correction Factors for Ambient Temperatures Below 25°C (77°F). (Multiply the rated open-circuit voltage by the appropriate correction factor shown below.)

Ambient Temperature (°C)	Factor	Ambient Temperature (°F)
24 to 20	1.02	76 to 68
19 to 15	1.04	67 to 59
14 to 10	1.06	58 to 50
9 to 5	1.08	49 to 41
4 to 0	1.10	40 to 32
–1 to –5	1.12	31 to 23
–6 to –10	1.14	22 to 14
–11 to –15	1.16	13 to 5
–16 to –20	1.18	4 to –4
–21 to –25	1.20	–5 to –13
–26 to –30	1.21	–14 to –22
–31 to –35	1.23	–23 to –31
–36 to –40	1.25	–32 to –40

(B) DC-to-DC Converter Source and Output Circuits. In a dc-to-dc converter source and output circuit, the maximum voltage shall be calculated in accordance with 690.7(B)(1) or (B)(2).

(1) Single DC-to-DC Converter. For circuits connected to the output of a single dc-to-dc converter, the maximum voltage shall be the maximum rated voltage output of the dc-to-dc converter.

(2) Two or More Series Connected DC-to-DC Converters. For circuits connected to the output of two or more series-connected dc-to-dc converters, the maximum voltage shall be determined in accordance with the instructions included in the listing or labeling of the dc-to-dc converter. If these instructions do not state the rated voltage of series-connected dc-to-dc converters, the maximum voltage shall be the sum of the maximum rated voltage output of the dc-to-dc converters in series.

(C) Bipolar Source and Output Circuits. For 2-wire dc circuits connected to bipolar PV arrays, the maximum voltage shall be the highest voltage between the 2-wire circuit conductors where one conductor of the 2-wire circuit is connected to the functional ground reference (center tap). To prevent overvoltage in the event of a ground-fault or arc-fault, the array shall be isolated from the ground reference and isolated into two 2-wire circuits.

690.8 Circuit Sizing and Current.

(A) Calculation of Maximum Circuit Current. The maximum current for the specific circuit shall be calculated in accordance with 690.8(A)(1) through (A)(6).

Informational Note: Where the requirements of 690.8(A)(1) and (B)(1) are both applied, the resulting multiplication factor is 156 percent.

(1) Photovoltaic Source Circuit Currents. The maximum current shall be calculated by one of the following methods:

(1) The sum of parallel-connected PV module–rated short-circuit currents multiplied by 125 percent

(2) For PV systems with a generating capacity of 100 kW or greater, a documented and stamped PV system design, using an industry standard method and provided by a licensed professional electrical engineer, shall be permitted. The calculated maximum current value shall be based on the highest 3-hour current average resulting from the simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method shall not be less than 70 percent of the value calculated using 690.8(A)(1)(1).

Informational Note: One industry standard method for calculating maximum current of a PV system is available from Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

(2) Photovoltaic Output Circuit Currents. The maximum current shall be the sum of parallel source circuit maximum currents as calculated in 690.8(A)(1).

(3) Inverter Output Circuit Current. The maximum current shall be the inverter continuous output current rating.

(4) Stand-Alone Inverter Input Circuit Current. The maximum current shall be the stand-alone continuous inverter input current rating when the inverter is producing rated power at the lowest input voltage.

(5) DC-to-DC Converter Output Current. The maximum current shall be the dc-to-dc converter continuous output current rating.

(6) DC-to-DC Converter Output Circuit Current. The maximum current shall be the sum of parallel connected dc-to-dc converter source circuit currents as calculated in 690.8(A)(5).

(B) Conductor Ampacity. PV system currents shall be considered to be continuous. Circuit conductors shall be sized to carry not less than the larger of 690.8(B)(1) or (B)(2) or where protected by a listed adjustable electronic overcurrent protective device in accordance 690.9(B)(3), not less than the current in 690.8(B)(3).

(1) Before Application of Adjustment and Correction Factors. One hundred twenty-five percent of the maximum currents calculated in 690.8(A) before the application of adjustment and correction factors.

Exception: Circuits containing an assembly, together with its overcurrent device(s), that is listed for continuous operation at 100 percent of its rating shall be permitted to be used at 100 percent of its rating.

(2) After Application of Adjustment and Correction Factors. The maximum currents calculated in 690.8(A) after the application of adjustment and correction factors.

(3) Adjustable Electronic Overcurrent Protective Device. The rating or setting of an adjustable electronic overcurrent protective device installed in accordance with 240.6.

(C) Systems with Multiple Direct-Current Voltages. For a PV power source that has multiple output circuit voltages and employs a common-return conductor, the ampacity of the common-return conductor shall not be less than the sum of the ampere ratings of the overcurrent devices of the individual output circuits.

(D) Sizing of Module Interconnection Conductors. Where a single overcurrent device is used to protect a set of two or more parallel-connected module circuits, the ampacity of each of the module interconnection conductors shall not be less than the sum of the rating of the single overcurrent device plus 125 percent of the short-circuit current from the other parallel-connected modules.

690.9 Overcurrent Protection.

(A) Circuits and Equipment. PV system dc circuit and inverter output conductors and equipment shall be protected against overcurrent. Overcurrent protective devices shall not be required for circuits with sufficient ampacity for the highest available current. Circuits connected to current limited supplies (e.g., PV modules, dc-to-dc converters, interactive inverter output circuits) and also connected to sources having higher current availability (e.g., parallel strings of modules, utility power) shall be protected at the higher current source connection.

Exception: An overcurrent device shall not be required for PV modules or PV source circuit or dc-to-dc converters source circuit conductors sized in accordance with 690.8(B) where one of the following applies:

(1) There are no external sources such as parallel-connected source circuits, batteries, or backfeed from inverters.

(2) The short-circuit currents from all sources do not exceed the ampacity of the conductors and the maximum overcurrent protective device size rating specified for the PV module or dc-to-dc converter.

Informational Note: Photovoltaic system dc circuits are current limited circuits that only need overcurrent protection when connected in parallel to higher current sources. The overcurrent device is often installed at the higher current source end of the circuit.

(B) Overcurrent Device Ratings. Overcurrent devices used in PV system dc circuits shall be listed for use in PV systems. Overcurrent devices, where required, shall be rated in accordance with one of the following:

(1) Not less than 125 percent of the maximum currents calculated in 690.8(A).

(2) An assembly, together with its overcurrent device(s), that is listed for continuous operation at 100 percent of its rating shall be permitted to be used at 100 percent of its rating.

(3) Adjustable electronic overcurrent protective devices rated or set in accordance with 240.6.

Informational Note: Some electronic overcurrent protective devices prevent backfeed current.

(C) Photovoltaic Source and Output Circuits. A single overcurrent protective device, where required, shall be permitted to protect the PV modules and conductors of each source circuit or the conductors of each output circuit. Where single overcurrent protection devices are used to protect PV source or output circuits, all overcurrent devices shall be

placed in the same polarity for all circuits within a PV system. The overcurrent devices shall be accessible but shall not be required to be readily accessible.

Informational Note: Due to improved ground-fault protection required in PV systems by 690.41(B), a single overcurrent protective device in either the positive or negative conductors of a PV system in combination with this ground-fault protection provides adequate overcurrent protection.

(D) Power Transformers. Overcurrent protection for a transformer with a source(s) on each side shall be provided in accordance with 450.3 by considering first one side of the transformer, then the other side of the transformer, as the primary.

Exception: A power transformer with a current rating on the side connected toward the interactive inverter output, not less than the rated continuous output current of the inverter, shall be permitted without overcurrent protection from the inverter.

690.10 Stand-Alone Systems. The wiring system connected to a stand-alone system shall be installed in accordance with 710.15.

690.11 Arc-Fault Circuit Protection (Direct Current). Photovoltaic systems operating at 80 volts dc or greater between any two conductors shall be protected by a listed PV arc-fault circuit interrupter or other system components listed to provide equivalent protection. The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the PV system dc circuits.

Informational Note: Annex A includes the reference for the Photovoltaic DC Arc-Fault Circuit Protection product standard.

Exception: For PV systems not installed on or in buildings, PV output circuits and dc-to-dc converter output circuits that are direct buried, installed in metallic raceways, or installed in enclosed metallic cable trays are permitted without arc-fault circuit protection. Detached structures whose sole purpose is to house PV system equipment shall not be considered buildings according to this exception.

690.12 Rapid Shutdown of PV Systems on Buildings. PV system circuits installed on or in buildings shall include a rapid shutdown function to reduce shock hazard for emergency responders in accordance with 690.12(A) through (D).

Exception: Ground mounted PV system circuits that enter buildings, of which the sole purpose is to house PV system equipment, shall not be required to comply with 690.12.

(A) Controlled Conductors. Requirements for controlled conductors shall apply to PV circuits supplied by the PV system.

(B) Controlled Limits. The use of the term *array boundary* in this section is defined as 305 mm (1 ft) from the array in all directions. Controlled conductors outside the array boundary shall comply with 690.12(B)(1) and inside the array boundary shall comply with 690.12(B)(2).

(1) Outside the Array Boundary. Controlled conductors located outside the boundary or more than 1 m (3 ft) from the point of entry inside a building shall be limited to not more than 30 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

(2) Inside the Array Boundary. The PV system shall comply with one of the following:

(1) The PV array shall be listed or field labeled as a rapid shutdown PV array. Such a PV array shall be installed and used in accordance with the instructions included with the rapid shutdown PV array listing or field labeling.

Informational Note: A listed or field labeled rapid shutdown PV array is evaluated as an assembly or system as defined in the installation instructions to reduce but not eliminate risk of electric shock hazard within a damaged PV array during fire-fighting procedures. These rapid shutdown PV arrays are designed to reduce shock hazards by methods such as limiting access to energized components, reducing the voltage difference between energized components, limiting the electric current that might flow in an electrical circuit involving personnel with increased resistance of the conductive circuit, or by a combination of such methods.

(2) Controlled conductors located inside the boundary or not more than 1 m (3 ft) from the point of penetration of the surface of the building shall be limited to not more than 80 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

(3) PV arrays with no exposed wiring methods, no exposed conductive parts, and installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground shall not be required to comply with 690.12(B)(2).

The requirement of 690.12(B)(2) shall become effective January 1, 2019.

(C) Initiation Device. The initiation device(s) shall initiate the rapid shutdown function of the PV system. The device "off" position shall indicate that the rapid shutdown function has been initiated for all PV systems connected to that device. For one-family and two-family dwellings, an initiation device(s) shall be located at a readily accessible location outside the building.

The rapid shutdown initiation device(s) shall consist of at least one of the following:

(1) Service disconnecting means

(2) PV system disconnecting means

(3) Readily accessible switch that plainly indicates whether it is in the "off" or "on" position

Informational Note: One example of why an initiation device that complies with 690.12(C)(3) would be used is where a PV system is connected to an optional standby system that remains energized upon loss of utility voltage.

Where multiple PV systems are installed with rapid shutdown functions on a single service, the initiation device(s) shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. These initiation device(s)

shall initiate the rapid shutdown of all PV systems with rapid shutdown functions on that service. Where auxiliary initiation devices are installed, these auxiliary devices shall control all PV systems with rapid shutdown functions on that service.

(D) Equipment. Equipment that performs the rapid shutdown functions, other than initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed for providing rapid shutdown protection.

Informational Note: Inverter input circuit conductors often remain energized for up to 5 minutes with inverters not listed for rapid shutdown.

Part III. Disconnecting Means

690.13 Photovoltaic System Disconnecting Means. Means shall be provided to disconnect the PV system from all wiring systems including power systems, energy storage systems, and utilization equipment and its associated premises wiring.

(A) Location. The PV system disconnecting means shall be installed at a readily accessible location.

Informational Note: PV systems installed in accordance with 690.12 address the concerns related to energized conductors entering a building.

(B) Marking. Each PV system disconnecting means shall plainly indicate whether in the open (off) or closed (on) position and be permanently marked "PV SYSTEM DISCONNECT" or equivalent. Additional markings shall be permitted based upon the specific system configuration. For PV system disconnecting means where the line and load terminals may be energized in the open position, the device shall be marked with the following words or equivalent:

WARNING
ELECTRIC SHOCK HAZARD
TERMINALS ON THE LINE AND LOAD SIDES
MAY BE ENERGIZED IN THE OPEN POSITION

The warning sign(s) or label(s) shall comply with 110.21(B).

(C) Suitable for Use. If the PV system is connected to the supply side of the service disconnecting means as permitted in 230.82(6), the PV system disconnecting means shall be listed as suitable for use as service equipment.

(D) Maximum Number of Disconnects. Each PV system disconnecting means shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. A single PV system disconnecting means shall be permitted for the combined ac output of one or more inverters or ac modules in an interactive system.

Informational Note: This requirement does not limit the number of PV systems connected to a service as permitted in 690.4(D). This requirement allows up to six disconnecting means to disconnect a single PV system. For PV systems where all power is converted through interactive inverters, a dedicated circuit breaker, in 705.12(B)(1), is an example of a single PV system disconnecting means.

(E) Ratings. The PV system disconnecting means shall have ratings sufficient for the maximum circuit current available short-circuit current, and voltage that is available at the terminals of the PV system disconnect.

(F) Type of Disconnect.

(1) Simultaneous Disconnection. The PV system disconnecting means shall simultaneously disconnect the PV system conductors of the circuit from all conductors of other wiring systems. The PV system disconnecting means shall be an externally operable general-use switch or circuit breaker, or other approved means. A dc PV system disconnecting means shall be marked for use in PV systems or be suitable for backfeed operation.

(2) Devices Marked "Line" and "Load." Devices marked with "line" and "load" shall not be permitted for backfeed or reverse current.

(3) DC-Rated Enclosed Switches, Open-Type Switches, and Low-Voltage Power Circuit Breakers. DC-rated, enclosed switches, open-type switches, and low-voltage power circuit breakers shall be permitted for backfeed operation.

690.15 Disconnection of Photovoltaic Equipment. Isolating devices shall be provided to isolate PV modules, ac PV modules, fuses, dc-to-dc converters, inverters, and charge controllers from all conductors that are not solidly grounded. An equipment disconnecting means or a PV system disconnecting means shall be permitted in place of an isolating device. Where the maximum circuit current is greater than 30 amperes for the output circuit of a dc combiner or the input circuit of a charge controller or inverter, an equipment disconnecting means shall be provided for isolation. Where a charge controller or inverter has multiple input circuits, a single equipment disconnecting means shall be permitted to isolate the equipment from the input circuits.

Informational Note: The purpose of these isolating devices are for the safe and convenient replacement or service of specific PV system equipment without exposure to energized conductors.

(A) Location. Isolating devices or equipment disconnecting means shall be installed in circuits connected to equipment at a location within the equipment, or within sight and within 3 m (10 ft) of the equipment. An equipment disconnecting means shall be permitted to be remote from the equipment where the equipment disconnecting means can be remotely operated from within 3 m (10 ft) of the equipment.

(B) Interrupting Rating. An equipment disconnecting means shall have an interrupting rating sufficient for the maximum short-circuit current and voltage that is available at the terminals of the equipment. An isolating device shall not be required to have an interrupting rating.

(C) Isolating Device. An isolating device shall not be required to simultaneously disconnect all current-carrying conductors of a circuit. The isolating device shall be one of the following:

(1) A connector meeting the requirements of 690.33 and listed and identified for use with specific equipment

(2) A finger safe fuse holder

(3) An isolating switch that requires a tool to open

(4) An isolating device listed for the intended application

An isolating device shall be rated to open the maximum circuit current under load or be marked "Do Not Disconnect Under Load" or "Not for Current Interrupting."

(D) Equipment Disconnecting Means. An equipment disconnecting means shall simultaneously disconnect all current-carrying conductors that are not solidly grounded of the circuit to which it is connected. An equipment disconnecting means shall be externally operable without exposing the operator to contact with energized parts, shall indicate whether in the open (off) or closed (on) position, and shall be lockable in accordance with 110.25. An equipment disconnecting means shall be one of the following devices:

(1) A manually operable switch or circuit breaker

(2) A connector meeting the requirements of 690.33(E)(1)

(3) A load break fused pull out switch

(4) A remote-controlled circuit breaker that is operable locally and opens automatically when control power is interrupted

For equipment disconnecting means, other than those complying with 690.33, where the line and load terminals can be energized in the open position, the device shall be marked in accordance with the warning in 690.13(B).

Part IV. Wiring Methods

690.31 Methods Permitted.

(A) Wiring Systems. All raceway and cable wiring methods included in this *Code*, other wiring systems and fittings specifically listed for use on PV arrays, and wiring as part of a listed system shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

Where PV source and output circuits operating at voltages greater than 30 volts are installed in readily accessible locations, circuit conductors shall be guarded or installed in Type MC cable or in raceway. For ambient temperatures exceeding 30°C (86°F), conductor ampacities shall be corrected in accordance with Table 690.31(A).

Table 690.31(A) Correction Factors

Ambient Temperature (°C)	Temperature Rating of Conductor				Ambient Temperature (°F)
	60°C (140°F)	75°C (167°F)	90°C (194°F)	150°C (221°F)	
30	1.00	1.00	1.00	1.00	86
31-35	0.91	0.94	0.96	0.97	87-95
36-40	0.82	0.88	0.91	0.93	96-104
41-45	0.71	0.82	0.87	0.89	105-113
46-50	0.58	0.75	0.82	0.86	114-122
51-55	0.41	0.67	0.76	0.82	123-131
56-60	—	0.58	0.71	0.77	132-140
61-70	—	0.33	0.58	0.68	141-158
71-80	—	—	0.41	0.58	159-176

(B) Identification and Grouping. PV source circuits and PV output circuits shall not be contained in the same raceway, cable tray, cable, outlet box, junction box, or similar fitting as conductors, feeders, branch circuits of other non-PV systems, or inverter output circuits, unless the conductors of the different systems are separated by a partition. PV system circuit conductors shall be identified and grouped as required by 690.31(B)(1) through (2). The means of identification shall be permitted by separate color coding, marking tape, tagging, or other approved means.

(1) Identification. PV system circuit conductors shall be identified at all accessible points of termination, connection, and splices.

The means of identification shall be permitted by separate color coding, marking tape, tagging, or other approved means. Only solidly grounded PV system circuit conductors, in accordance with 690.41(A)(5), shall be marked in accordance with 200.6.

Exception: Where the identification of the conductors is evident by spacing or arrangement, further identification shall not be required.

(2) Grouping. Where the conductors of more than one PV system occupy the same junction box or raceway with a removable cover(s), the ac and dc conductors of each system shall be grouped separately by cable ties or similar means at least once and shall then be grouped at intervals not to exceed 1.8 m (6 ft).

Exception: The requirement for grouping shall not apply if the circuit enters from a cable or raceway unique to the circuit that makes the grouping obvious.

(C) Single-Conductor Cable.

(1) General. Single-conductor cable Type USE-2 and single-conductor cable listed and identified as photovoltaic (PV) wire shall be permitted in exposed outdoor locations in PV source circuits within the PV array. PV wire shall be installed in accordance with 338.10(B)(4)(b) and 334.30.

(2) Cable Tray. PV source circuits and PV output circuits using single-conductor cable listed and identified as photovoltaic (PV) wire of all sizes, with or without a cable tray marking/rating, shall be permitted in cable trays installed in outdoor locations, provided that the cables are supported at intervals not to exceed 300 mm (12 in.) and secured at intervals not to exceed 1.4 m ($4^1/_2$ft).

Informational Note: Photovoltaic wire and PV cable have a nonstandard outer diameter. Table 1 of Chapter 9 contains the allowable percent of cross section of conduit and tubing for conductors and cables.

(D) Multiconductor Cable. Jacketed multiconductor cable assemblies listed and identified for the application shall be permitted in outdoor locations. The cable shall be secured at intervals not exceeding 1.8 m (6 ft).

(E) Flexible Cords and Cables Connected to Tracking PV Arrays. Flexible cords and flexible cables, where connected to moving parts of tracking PV arrays, shall comply with Article 400 and shall be of a type identified as a hard service cord or portable power cable; they shall be suitable for extra-

hard usage, listed for outdoor use, water resistant, and sunlight resistant. Allowable ampacities shall be in accordance with 400.5. Stranded copper PV wire shall be permitted to be connected to moving parts of tracking PV arrays in accordance with the minimum number of strands specified in Table 690.31(E).

Table 690.31(E) Minimum PV Wire Strands

PV Wire AWG	Minimum Strands
18	17
16-10	19
8-4	49
2	130
1 AWG–1000 MCM	259

(F) Small-Conductor Cables. Single-conductor cables listed for outdoor use that are sunlight resistant and moisture resistant in sizes 16 AWG and 18 AWG shall be permitted for module interconnections where such cables meet the ampacity requirements of 400.5. Section 310.15 shall be used to determine the cable ampacity adjustment and correction factors.

(G) Photovoltaic System Direct Current Circuits on or in a Building. Where PV system dc circuits run inside a building, they shall be contained in metal raceways, Type MC metal-clad cable that complies with 250.118(10), or metal enclosures from the point of penetration of the surface of the building to the first readily accessible disconnecting means. The disconnecting means shall comply with 690.13(B) and (C) and 690.15(A) and (B). The wiring methods shall comply with the additional installation requirements in 690.31(G)(1) through (4).

(1) Embedded in Building Surfaces. Where circuits are embedded in built-up, laminate, or membrane roofing materials in roof areas not covered by PV modules and associated equipment, the location of circuits shall be clearly marked using a marking protocol that is approved as being suitable for continuous exposure to sunlight and weather.

(2) Flexible Wiring Methods. Where flexible metal conduit (FMC) smaller than metric designator 21 (trade size $^{3}/_{4}$) or Type MC cable smaller than 25 mm (1 in.) in diameter containing PV power circuit conductors is installed across ceilings or floor joists, the raceway or cable shall be protected by substantial guard strips that are at least as high as the raceway or cable. Where run exposed, other than within 1.8 m (6 ft) of their connection to equipment, these wiring methods shall closely follow the building surface or be protected from physical damage by an approved means.

(3) Marking and Labeling Required. The following wiring methods and enclosures that contain PV system dc circuit conductors shall be marked with the wording WARNING: PHOTOVOLTAIC POWER SOURCE by means of permanently affixed labels or other approved permanent marking:

(1) Exposed raceways, cable trays, and other wiring methods

(2) Covers or enclosures of pull boxes and junction boxes

(3) Conduit bodies in which any of the available conduit openings are unused

(4) Marking and Labeling Methods and Locations. The labels or markings shall be visible after installation. The labels shall be reflective, and all letters shall be capitalized and shall be a minimum height of 9.5 mm ($^{3}/_{8}$ in.) in white on a red background. PV system dc circuit labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels or markings, or between a label and a marking, shall not be more than 3 m (10 ft). Labels required by this section shall be suitable for the environment where they are installed.

(H) Flexible, Fine-Stranded Cables. Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14.

(I) Bipolar Photovoltaic Systems. Where the sum, without consideration of polarity, of the voltages of the two monopole subarrays exceeds the rating of the conductors and connected equipment, monopole subarrays in a bipolar PV system shall be physically separated, and the electrical output circuits from each monopole subarray shall be installed in separate raceways until connected to the inverter. The disconnecting means and overcurrent protective devices for each monopole subarray output shall be in separate enclosures. All conductors from each separate monopole subarray shall be routed in the same raceway. Solidly grounded bipolar PV systems shall be clearly marked with a permanent, legible warning notice indicating that the disconnection of the grounded conductor(s) may result in overvoltage on the equipment.

Exception: Listed switchgear rated for the maximum voltage between circuits and containing a physical barrier separating the disconnecting means for each monopole subarray shall be permitted to be used instead of disconnecting means in separate enclosures.

690.32 Component Interconnections. Fittings and connectors that are intended to be concealed at the time of on-site assembly, where listed for such use, shall be permitted for on-site interconnection of modules or other array components. Such fittings and connectors shall be equal to the wiring method employed in insulation, temperature rise, and fault-current withstand, and shall be capable of resisting the effects of the environment in which they are used.

690.33 Connectors. Connectors, other than those covered by 690.32, shall comply with 690.33(A) through (E).

(A) Configuration. The connectors shall be polarized and shall have a configuration that is noninterchangeable with receptacles in other electrical systems on the premises.

(B) Guarding. The connectors shall be constructed and installed so as to guard against inadvertent contact with live parts by persons.

(C) Type. The connectors shall be of the latching or locking type. Connectors that are readily accessible and that are used in circuits operating at over 30 volts dc or 15 volts ac shall require a tool for opening.

(D) Grounding Member. The grounding member shall be the first to make and the last to break contact with the mating connector.

(E) Interruption of Circuit. Connectors shall be either (1) or (2):

(1) Be rated for interrupting current without hazard to the operator.

(2) Be a type that requires the use of a tool to open and marked "Do Not Disconnect Under Load" or "Not for Current Interrupting."

690.34 Access to Boxes. Junction, pull, and outlet boxes located behind modules or panels shall be so installed that the wiring contained in them can be rendered accessible directly or by displacement of a module(s) or panel(s) secured by removable fasteners and connected by a flexible wiring system.

Part V. Grounding and Bonding

690.41 System Grounding.

(A) PV System Grounding Configurations. One or more of the following system grounding configurations shall be employed:

(1) 2-wire PV arrays with one functional grounded conductor

(2) Bipolar PV arrays according to 690.7(C) with a functional ground reference (center tap)

(3) PV arrays not isolated from the grounded inverter output circuit

(4) Ungrounded PV arrays

(5) Solidly grounded PV arrays as permitted in 690.41(B) Exception

(6) PV systems that use other methods that accomplish equivalent system protection in accordance with 250.4(A) with equipment listed and identified for the use

(B) Ground-Fault Protection. DC PV arrays shall be provided with dc ground-fault protection meeting the requirements of 690.41(B)(1) and (2) to reduce fire hazards.

Exception: PV arrays with not more than two PV source circuits and with all PV system dc circuits not on or in buildings shall be permitted without ground-fault protection where solidly grounded.

(1) Ground-Fault Detection. The ground fault protective device or system shall detect ground fault(s) in the PV array dc current–carrying conductors and components, including any functional grounded conductors, and be listed for providing PV ground-fault protection.

(2) Isolating Faulted Circuits. The faulted circuits shall be isolated by one of the following methods:

(1) The current-carrying conductors of the faulted circuit shall be automatically disconnected.

(2) The inverter or charge controller fed by the faulted circuit shall automatically cease to supply power to output circuits and isolate the PV system dc circuits from the ground reference in a functional grounded system.

690.42 Point of System Grounding Connection. Systems with a ground-fault protective device in accordance with 690.41(B) shall have any current-carrying conductor-to-ground connection made by the ground-fault protective device. For solidly grounded PV systems, the dc circuit grounding connection shall be made at any single point on the PV output circuit.

690.43 Equipment Grounding and Bonding. Exposed non–current-carrying metal parts of PV module frames, electrical equipment, and conductor enclosures of PV systems shall be grounded in accordance with 250.134 or 250.136(A), regardless of voltage. Equipment grounding conductors and devices shall comply with 690.43(A) through (C).

(A) Photovoltaic Module Mounting Systems and Devices. Devices and systems used for mounting PV modules that are also used for bonding module frames shall be listed, labeled, and identified for bonding PV modules. Devices that mount adjacent PV modules shall be permitted to bond adjacent PV modules.

(B) Equipment Secured to Grounded Metal Supports. Devices listed, labeled, and identified for bonding and grounding the metal parts of PV systems shall be permitted to bond the equipment to grounded metal supports. Metallic support structures shall have identified bonding jumpers connected between separate metallic sections or shall be identified for equipment bonding and shall be connected to the equipment grounding conductor.

(C) With Circuit Conductors. Equipment grounding conductors for the PV array and support structure (where installed) shall be contained within the same raceway, cable, or otherwise run with the PV array circuit conductors when those circuit conductors leave the vicinity of the PV array.

690.45 Size of Equipment Grounding Conductors. Equipment grounding conductors for PV source and PV output circuits shall be sized in accordance with 250.122. Where no overcurrent protective device is used in the circuit, an assumed overcurrent device rated in accordance with 690.9(B)shall be used when applying Table 250.122. Increases in equipment grounding conductor size to address voltage drop considerations shall not be required. An equipment grounding conductor shall not be smaller than 14 AWG.

690.46 Array Equipment Grounding Conductors. For PV modules, equipment grounding conductors smaller than 6 AWG shall comply with 250.120(C).

690.47 Grounding Electrode System.

(A) Buildings or Structures Supporting a PV Array. A building or structure supporting a PV array shall have a grounding electrode system installed in accordance with Part III of Article 250.

PV array equipment grounding conductors shall be connected to the grounding electrode system of the building or structure supporting the PV array in accordance with Part VII of Article 250. This connection shall be in addition to any other equipment grounding conductor requirements in 690.43(C). The PV array equipment grounding conductors shall be sized in accordance with 690.45.

For PV systems that are not solidly grounded, the equipment grounding conductor for the output of the PV system, connected to associated distribution equipment, shall be per-

mitted to be the connection to ground for ground-fault protection and equipment grounding of the PV array.

For solidly grounded PV systems, as permitted in 690.41(A)(5), the grounded conductor shall be connected to a grounding electrode system by means of a grounding electrode conductor sized in accordance with 250.166.

Informational Note: Most PV systems installed in the past decade are actually functional grounded systems rather than solidly grounded systems as defined in this *Code*. For functional grounded PV systems with an interactive inverter output, the ac equipment grounding conductor is connected to associated grounded ac distribution equipment. This connection is often the connection to ground for ground-fault protection and equipment grounding of the PV array.

(B) Additional Auxiliary Electrodes for Array Grounding. Grounding electrodes shall be permitted to be installed in accordance with 250.52 and 250.54 at the location of ground- and roof-mounted PV arrays. The electrodes shall be permitted to be connected directly to the array frame(s) or structure. The grounding electrode conductor shall be sized according to 250.66. The structure of a ground-mounted PV array shall be permitted to be considered a grounding electrode if it meets the requirements of 250.52. Roof mounted PV arrays shall be permitted to use the metal frame of a building or structure if the requirements of 250.52(A)(2) are met.

690.50 Equipment Bonding Jumpers. Equipment bonding jumpers, if used, shall comply with 250.120(C).

Part VI. Marking

690.51 Modules. Modules shall be marked with identification of terminals or leads as to polarity, maximum overcurrent device rating for module protection, and with the following ratings:

(1) Open-circuit voltage

(2) Operating voltage

(3) Maximum permissible system voltage

(4) Operating current

(5) Short-circuit current

(6) Maximum power

690.52 Alternating-Current Photovoltaic Modules. Alternating-current modules shall be marked with identification of terminals or leads and with identification of the following ratings:

(1) Nominal operating ac voltage

(2) Nominal operating ac frequency

(3) Maximum ac power

(4) Maximum ac current

(5) Maximum overcurrent device rating for ac module protection

690.53 Direct-Current Photovoltaic Power Source. A permanent label for the dc PV power source indicating the information specified in (1) through (3) shall be provided by the installer at dc PV system disconnecting means and at each dc equipment disconnecting means required by 690.15. Where a disconnecting means has more than one dc PV power source, the values in 690.53(1) through (3) shall be specified for each source.

(1) Maximum voltage

Informational Note to (1): See 690.7 for voltage.

(2) Maximum circuit current

Informational Note to (2): See 690.8(A) for calculation of maximum circuit current.

(3) Maximum rated output current of the charge controller or dc-to-dc converter (if installed)

690.54 Interactive System Point of Interconnection. All interactive system(s) points of interconnection with other sources shall be marked at an accessible location at the disconnecting means as a power source and with the rated ac output current and the nominal operating ac voltage.

690.55 Photovoltaic Systems Connected to Energy Storage Systems. The PV system output circuit conductors shall be marked to indicate the polarity where connected to energy storage systems.

690.56 Identification of Power Sources.

(A) Facilities with Stand-Alone Systems. Any structure or building with a PV power system that is not connected to a utility service source and is a stand-alone system shall have a permanent plaque or directory installed on the exterior of the building or structure at a readily visible location. The plaque or directory shall indicate the location of system disconnecting means and that the structure contains a stand-alone electrical power system.

(B) Facilities with Utility Services and PV Systems. Plaques or directories shall be installed in accordance with 705.10.

(C) Facilities with Rapid Shutdown. Buildings with PV systems shall have permanent labels as described in 690.56(C)(1) through (C)(3).

(1) Rapid Shutdown Type. The type of PV system rapid shutdown shall be labeled as described in 690.56(C)(1)(a) or (1)(b):

(a) For PV systems that shut down the array and conductors leaving the array:

SOLAR PV SYSTEM IS EQUIPPED
WITH RAPID SHUTDOWN.
TURN RAPID SHUTDOWN SWITCH TO
THE "OFF" POSITION TO SHUT DOWN PV
SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY.

The title "SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN" shall utilize capitalized characters with a minimum height of 9.5 mm ($^3/_8$ in.) in black on yellow background, and the remaining characters shall be capitalized with a minimum height of 4.8 mm ($^3/_{16}$ in.) in black on white background. [*See Figure 690.56(C)(1)(a).*]

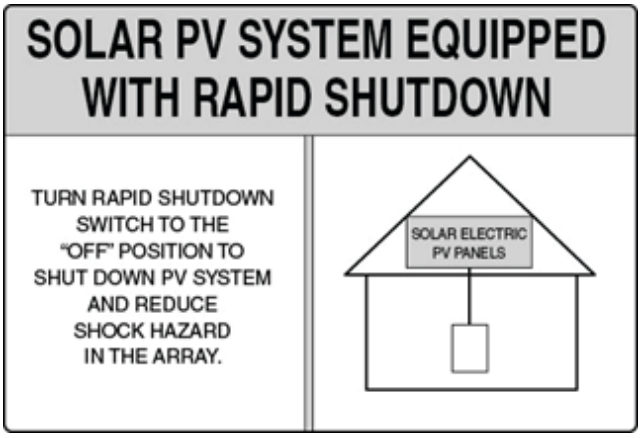


Figure 690.56(C)(1)(a)
Label for PV Systems that Shut Down the Array and the Conductors Leaving the Array.

(b) For PV systems that only shut down conductors leaving the array:

SOLAR PV SYSTEM IS EQUIPPED
WITH RAPID SHUTDOWN.
TURN RAPID SHUTDOWN SWITCH TO
THE "OFF" POSITION TO SHUT DOWN
CONDUCTORS OUTSIDE THE ARRAY. CONDUCTORS
IN ARRAY REMAIN ENERGIZED IN SUNLIGHT.

The title "SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN" shall utilize capitalized characters with a minimum height of 9.5 mm ($^3/_8$ in.) in white on red background, and the remaining characters shall be capitalized with a minimum height of 4.8 mm ($^3/_{16}$ in.) in black on white background. [*See Figure 690.56(C)(1)(b).*]

The labels in 690.56(C)(1)(a) and (b) shall include a simple diagram of a building with a roof. The diagram shall have sections in red to signify sections of the PV system that are not shut down when the rapid shutdown switch is operated.

The rapid shutdown label in 690.56(C)(1) shall be located on or no more than 1 m (3 ft) from the service disconnecting means to which the PV systems are connected and shall indicate the location of all identified rapid shutdown switches if not at the same location.

(2) Building with More Than One Rapid Shutdown Type. For buildings that have PV systems with a rapid shutdown type and a PV system with no rapid shutdown, a detailed plan view diagram of the roof shall be provided showing each different PV system and a dotted line around areas that remain energized after the rapid shutdown switch is operated.

(3) Rapid Shutdown Switch. A rapid shutdown switch shall have a label located on or no more than 1 m (3 ft) from the switch that includes the following wording:

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

The label shall be reflective, with all letters capitalized and having a minimum height of 9.5 mm ($^3/_8$ in.), in white on red background.

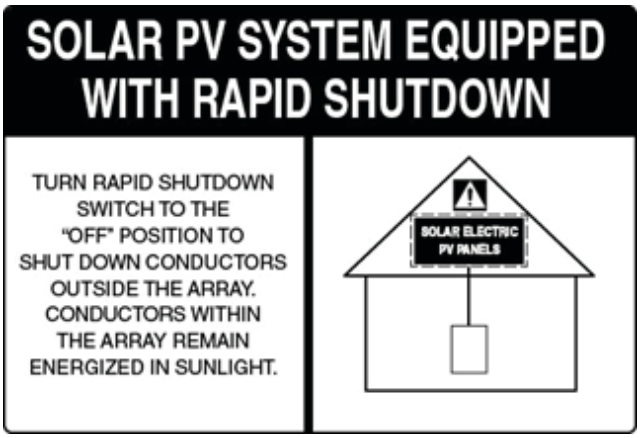


Figure 690.56(C)(1)(b)
Label for PV Systems that Shut Down the Conductors Leaving the Array Only.

Part VII. Connection to Other Sources

690.59 Connection to Other Sources. PV systems connected to other sources shall be installed in accordance with Parts I and II of Article 705.

Part VIII. Energy Storage Systems

690.71 General. An energy storage system connected to a PV system shall be installed in accordance with Article 706.

690.72 Self-Regulated PV Charge Control. The PV source circuit shall be considered to comply with the requirements of 706.23 if:

(1) The PV source circuit is matched to the voltage rating and charge current requirements of the interconnected battery cells and,

(2) The maximum charging current multiplied by 1 hour is less than 3 percent of the rated battery capacity expressed in ampere-hours or as recommended by the battery manufacturer

ARTICLE 691
Large-Scale Photovoltaic (PV) Electric Power Production Facility

691.1 Scope. This article covers the installation of large-scale PV electric power production facilities with a generating capacity of no less than 5000 kW, and not under exclusive utility control.

Informational Note No. 1: Facilities covered by this article have specific design and safety features unique to large-scale PV facilities and are operated for the sole purpose of providing electric supply to a system operated by a regulated utility for the transfer of electric energy.

Informational Note No. 2: Section 90.2(B)(5) includes information about utility-owned properties not covered under this *Code*. For additional information on electric supply stations, see ANSI/IEEE C2-2012, *National Electrical Safety Code*.

691.2 Definitions.

Electric Supply Stations. Locations containing the generating stations and substations, including their associated generator, storage battery, transformer, and switchgear areas.

Generating Capacity. The sum of the parallel-connected inverter rated maximum continuous output power at 40°C in kilowatts (kW).

Generating Station. A plant wherein electric energy is produced by conversion from some other form of energy (e.g., chemical, nuclear, solar, wind, mechanical, or hydraulic) by means of suitable apparatus.

691.4 Special Requirements for Large-Scale PV Electric Supply Stations. Large-scale PV electric supply stations shall be accessible only to authorized personnel and comply with the following:

(1) Electrical circuits and equipment shall be maintained and operated only by qualified personnel.

Informational Note: Refer to NFPA 70E-2015, *Standard for Electrical Safety in the Workplace*, for electrical safety requirements.

(2) Access to PV electric supply stations shall be restricted by fencing or other adequate means in accordance with 110.31. Field-applied hazard markings shall be applied in accordance with 110.21(B).

(3) The connection between the PV electric supply station and the system operated by a utility for the transfer of electrical energy shall be through medium- or high-voltage switch gear, substation, switch yard, or similar methods whose sole purpose shall be to safely and effectively interconnect the two systems.

(4) The electrical loads within the PV electric supply station shall only be used to power auxiliary equipment for the generation of the PV power.

(5) Large-scale PV electric supply stations shall not be installed on buildings.

691.5 Equipment Approval. All electrical equipment shall be approved for installation by one of the following:

(1) Listing and labeling

(2) Field labeling

(3) Where products complying with 691.5(1) or (2) are not available, by engineering review validating that the electrical equipment is tested to relevant standards or industry practice

691.6 Engineered Design. Documentation of the electrical portion of the engineered design of the electric supply station shall be stamped and provided upon request of the AHJ. Additional stamped independent engineering reports detailing compliance of the design with applicable electrical standards and industry practice shall be provided upon request of the AHJ. The independent engineer shall be a licensed professional electrical engineer retained by the system owner or installer. This documentation shall include details of conformance of the design with Article 690, and any alternative methods to Article 690, or other articles of this *Code*.

691.7 Conformance of Construction to Engineered Design. Documentation that the construction of the electric supply station conforms to the electrical engineered design shall be provided upon request of the AHJ. Additional stamped independent engineering reports detailing the construction conforms with this *Code*, applicable standards and industry practice shall be provided upon request of the AHJ. The independent engineer shall be a licensed professional electrical engineer retained by the system owner or installer. This documentation, where requested, shall be available prior to commercial operation of the station.

691.8 Direct Current Operating Voltage. For large-scale PV electric supply stations, calculations shall be included in the documentation required in 691.6.

691.9 Disconnection of Photovoltaic Equipment. Isolating devices shall be permitted to be more than 1.8 m (6 ft) from the equipment where written safety procedures and conditions of maintenance and supervision ensure that only qualified persons service the equipment.

Informational Note: For information on lockout/tagout procedures, see NFPA 70E-2015, *Standard for Electrical Safety in the Workplace.*

Buildings whose sole purpose is to house and protect supply station equipment shall not be required to comply with 690.12. Written standard operating procedures shall be available at the site detailing necessary shutdown procedures in the event of an emergency.

691.10 Arc-Fault Mitigation. PV systems that do not comply with the requirements of 690.11 shall include details of fire mitigation plans to address dc arc-faults in the documentation required in 691.6.

691.11 Fence Grounding. Fence grounding requirements and details shall be included in the documentation required in 691.6.

ARTICLE 705
Interconnected Electric Power Production Sources

Part I. General

705.1 Scope. This article covers installation of one or more electric power production sources operating in parallel with a primary source(s) of electricity.

Informational Note: Examples of the types of primary sources include a utility supply or an on-site electric power source(s).

705.2 Definitions.

Interactive Inverter Output Circuit. The conductors between the interactive inverter and the service equipment or another electric power production source, such as a utility, for electrical production and distribution network.

Microgrid Interconnect Device (MID). A device that allows a microgrid system to separate from and reconnect to a primary power source.

Microgrid System. A premises wiring system that has generation, energy storage, and load(s), or any combination thereof, that includes the ability to disconnect from and parallel with the primary source.

Informational Note: The application of Article 705 to microgrid systems is limited by the exclusions in 90.2(B)(5) related to electric utilities.

Multimode Inverter. Equipment having the capabilities of both the interactive inverter and the stand-alone inverter.

Power Production Equipment. The generating source, and all distribution equipment associated with it, that generates electricity from a source other than a utility supplied service.

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

705.3 Other Articles. Interconnected electric power production sources shall comply with this article and also with the applicable requirements of the articles in Table 705.3.

Table 705.3 Other Articles

Equipment/System	Article
Generators	445
Solar photovoltaic systems	690
Fuel cell systems	692
Wind electric systems	694
Emergency systems	700
Legally required standby systems	701
Optional standby systems	702
Energy storage systems	706
Stand-alone systems	710
DC microgids	712

705.6 Equipment Approval. All equipment shall be approved for the intended use. Interactive inverters for interconnection to systems interactive equipment intended to operate in parallel with the electric power system including, but not limited to, interactive inverters, engine generators, energy storage equipment, and wind turbines shall be listed and or field labeled for the intended use of interconnection service.

705.8 System Installation. Installation of one or more electrical power production sources operating in parallel with a primary source(s) of electricity shall be performed only by qualified persons.

Informational Note: See Article 100 for the definition of *Qualified Person.*

705.10 Directory. A permanent plaque or directory denoting the location of all electric power source disconnecting means on or in the premises shall be installed at each service equipment location and at the location(s) of the system disconnect(s) for all electric power production sources capable of being interconnected. The marking shall comply with 110.21(B).

Exception: Installations with large numbers of power production sources shall be permitted to be designated by groups.

705.12 Point of Connection. The output of an interconnected electric power source shall be connected as specified in 705.12(A)or (B).

(A) Supply Side. An electric power production source shall be permitted to be connected to the supply side of the service disconnecting means as permitted in 230.82(6). The sum of the ratings of all overcurrent devices connected to power production sources shall not exceed the rating of the service.

(B) Load Side. The output of an interconnected electric power source shall be permitted to be connected to the load side of the service disconnecting means of the other source(s) at any distribution equipment on the premises. Where distribution equipment, including switchgear, switchboards, or panelboards, is fed simultaneously by a primary source(s) of electricity and one or more other power source(s), and where this distribution equipment is capable of supplying multiple branch circuits or feeders, or both, the interconnecting provisions for other power sources shall comply with 705.12(B)(1) through (B)(5).

(1) Dedicated Overcurrent and Disconnect. Each source interconnection of one or more power sources installed in one system shall be made at a dedicated circuit breaker or fusible disconnecting means.

(2) Bus or Conductor Ampere Rating. One hundred twenty-five percent of the power source output circuit current shall be used in ampacity calculations for the following:

(1) Feeders. Where the power source output connection is made to a feeder at a location other than the opposite end of the feeder from the primary source overcurrent device, that portion of the feeder on the load side of the power source output connection shall be protected by one of the following:

a. The feeder ampacity shall be not less than the sum of the primary source overcurrent device and 125 percent of the power source output circuit current.

b. An overcurrent device on the load side of the power source connection shall be rated not greater than the ampacity of the feeder.

(2) Taps. In systems where power source output connections are made at feeders, any taps shall be sized based on the sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the feeder conductors as calculated in 240.21(B).

(3) Busbars. One of the methods that follows shall be used to determine the ratings of busbars in panelboards.

a. The sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

b. Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the

power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:
POWER SOURCE OUTPUT CONNECTION —
DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B).

(c) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

WARNING:
THIS EQUIPMENT FED BY MULTIPLE SOURCES.
TOTAL RATING OF ALL OVERCURRENT DEVICES,
EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE,
SHALL NOT EXCEED AMPACITY OF BUSBAR.

The warning sign(s) or label(s) shall comply with 110.21(B).

(d) A connection at either end, but not both ends, of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

(e) Connections shall be permitted on multiple-ampacity busbars where designed under engineering supervision that includes available fault current and busbar load calculations.

(3) Marking. Equipment containing overcurrent devices in circuits supplying power to a busbar or conductor supplied from multiple sources shall be marked to indicate the presence of all sources.

(4) Suitable for Backfeed. Circuit breakers, if backfed, shall be suitable for such operation.

Informational Note: Fused disconnects, unless otherwise marked, are suitable for backfeeding.

(5) Fastening. Listed plug-in-type circuit breakers backfed from electric power sources that are listed and identified as interactive shall be permitted to omit the additional fastener normally required by 408.36(D) for such applications.

705.14 Output Characteristics. The output of a generator or other electric power production source operating in parallel with an electrical supply system shall be compatible with the voltage, wave shape, and frequency of the system to which it is connected.

Informational Note: The term compatible does not necessarily mean matching the primary source wave shape.

705.16 Interrupting and Short-Circuit Current Rating. Consideration shall be given to the contribution of fault currents from all interconnected power sources for the interrupting and short-circuit current ratings of equipment on interactive systems.

705.20 Disconnecting Means, Sources. Means shall be provided to disconnect all ungrounded conductors of an electric power production source(s) from all other conductors.

705.21 Disconnecting Means, Equipment. Means shall be provided to disconnect power production equipment, such as interactive inverters or transformers associated with a power production source, from all ungrounded conductors of all sources of supply. Equipment intended to be operated and maintained as an integral part of a power production source exceeding 1000 volts shall not be required to have a disconnecting means.

705.22 Disconnect Device. The disconnecting means for ungrounded conductors shall consist of a manual or power operated switch(es) or circuit breaker(s) that complies with the following:

(1) Located where readily accessible

(2) Externally operable without exposing the operator to contact with live parts and, if power operated, of a type that is opened by hand in the event of a power-supply failure

(3) Plainly indicate whether in the open (off) or closed (on) position

(4) Have ratings sufficient for the maximum circuit current, available short-circuit current, and voltage that is available at the terminals

(5) Where the line and load terminals are capable of being energized in the open position, marked in accordance with the warning in 690.13(B)

Informational Note: In parallel generation systems, some equipment, including knife blade switches and fuses, is likely to be energized from both directions. See 240.40.

(6) Simultaneously disconnect all ungrounded conductors of the circuit

(7) Be lockable in the open (off) position in accordance with 110.25

705.23 Interactive System Disconnecting Means. A readily accessible means shall be provided to disconnect the interactive system from all wiring systems including power systems, energy storage systems, and utilization equipment and its associated premises wiring.

705.30 Overcurrent Protection. Conductors shall be protected in accordance with Article 240. Equipment and conductors connected to more than one electrical source shall have a sufficient number of overcurrent devices located so as to provide protection from all sources.

(A) Solar Photovoltaic Systems. Solar photovoltaic systems shall be protected in accordance with Article 690.

(B) Transformers. Overcurrent protection for a transformer with a source(s) on each side shall be provided in accordance with 450.3 by considering first one side of the transformer, then the other side of the transformer, as the primary.

(C) Fuel Cell Systems. Fuel cell systems shall be protected in accordance with Article 692.

(D) Interactive Inverters. Interactive inverters shall be protected in accordance with 705.65.

(E) Generators. Generators shall be protected in accordance with 705.130.

705.31 Location of Overcurrent Protection. Overcurrent protection for electric power production source conductors, connected to the supply side of the service disconnecting means in accordance with 705.12(A), shall be located within 3 m (10 ft) of the point where the electric power production source conductors are connected to the service.

Informational Note: This overcurrent protection protects against short-circuit current supplied from the primary source(s) of electricity.

Exception: Where the overcurrent protection for the power production source is located more than 3 m (10 ft) from the point of connection for the electric power production source to the service, cable limiters or current-limited circuit breakers for each ungrounded conductor shall be installed at the point where the electric power production conductors are connected to the service.

705.32 Ground-Fault Protection. Where ground-fault protection is used, the output of an interactive system shall be connected to the supply side of the ground-fault protection.

Exception: Connection shall be permitted to be made to the load side of ground-fault protection, if there is ground-fault protection for equipment from all ground-fault current sources.

705.40 Loss of Primary Source. Upon loss of primary source, an electric power production source shall be automatically disconnected from all ungrounded conductors of the primary source and shall not be reconnected until the primary source is restored.

Exception: A listed interactive inverter shall be permitted to automatically cease exporting power upon loss of primary source and shall not be required to automatically disconnect all ungrounded conductors from the primary source. A listed interactive inverter shall be permitted to automatically or manually resume exporting power to the utility once the primary source is restored.

Informational Note No. 1: Risks to personnel and equipment associated with the primary source could occur if an utility interactive electric power production source can operate as an intentional island. Special detection methods are required to determine that a primary source supply system outage has occurred and whether there should be automatic disconnection. When the primary source supply system is restored, special detection methods can be required to limit exposure of power production sources to out-of-phase reconnection.

Informational Note No. 2: Induction-generating equipment on systems with significant capacitance can become self-excited upon loss of the primary source and experience severe overvoltage as a result.

An interactive inverter shall be permitted to operate as a stand-alone system to supply loads that have been disconnected from electrical production and distribution network sources.

705.42 Loss of 3-Phase Primary Source. A 3-phase electric power production source shall be automatically disconnected from all ungrounded conductors of the interconnected systems when one of the phases of that source opens. This requirement shall not be applicable to an electric power production source providing power for an emergency or legally required standby system.

Exception: A listed interactive inverter shall be permitted to automatically cease exporting power when one of the phases of the source opens and shall not be required to automatically disconnect all ungrounded conductors from the primary source. A listed interactive inverter shall be permitted to automatically or manually resume exporting power to the utility once all phases of the source are restored.

705.50 Grounding. Interconnected electric power production sources shall be grounded in accordance with Article 250.

Exception: For direct-current systems connected through an inverter directly to a grounded service, other methods that accomplish equivalent system protection and that utilize equipment listed and identified for the use shall be permitted.

Part II. Interactive Inverters

705.60 Circuit Sizing and Current.

(A) Calculation of Maximum Circuit Current. The maximum current for the specific circuit shall be calculated in accordance with 705.60(A)(1) and (A)(2).

(1) Inverter Input Circuit Currents. The maximum current shall be the maximum rated input current of the inverter.

(2) Inverter Output Circuit Current. The maximum current shall be the inverter continuous output current rating.

(B) Ampacity and Overcurrent Device Ratings. Inverter system currents shall be considered to be continuous. The circuit conductors and overcurrent devices shall be sized to carry not less than 125 percent of the maximum currents as calculated in 705.60(A). The rating or setting of overcurrent devices shall be permitted in accordance with 240.4(B) and (C).

Exception: Circuits containing an assembly together with its overcurrent device(s) that is listed for continuous operation at 100 percent of its rating shall be permitted to be utilized at 100 percent of its rating.

705.65 Overcurrent Protection.

(A) Circuits and Equipment. Inverter input circuits, inverter output circuits, and storage battery circuit conductors and equipment shall be protected in accordance with the requirements of Article 240. Circuits connected to more than one

electrical source shall have overcurrent devices located so as to provide overcurrent protection from all sources.

Exception: An overcurrent device shall not be required for circuit conductors sized in accordance with 705.60(B) and located where one of the following applies:

(1) There are no external sources such as parallel-connected source circuits, batteries, or backfeed from inverters.

(2) The short-circuit currents from all sources do not exceed the ampacity of the conductors.

Informational Note: Possible backfeed of current from any source of supply, including a supply through an inverter into the inverter output circuit and inverter source circuits, is a consideration in determining whether adequate overcurrent protection from all sources is provided for conductors and modules.

(B) Power Transformers. Overcurrent protection for a transformer with a source(s) on each side shall be provided in accordance with 450.3 by considering first one side of the transformer, then the other side of the transformer, as the primary.

Exception: A power transformer with a current rating on the side connected toward the interactive inverter output that is not less than the rated continuous output current of the inverter shall be permitted without overcurrent protection from that source.

(C) Conductor Ampacity. Power source output circuit condutors that are connected to feeder, if smaller than the feeder condutors, shall be sized to carry not less than the larger of the current as calculated in 705.60(B) or as calculated in accordance with 240.21(B) based on the over-current device protecting the feeder.

705.70 Interactive Inverters Mounted in Not Readily Accessible Locations. Interactive inverters shall be permitted to be mounted on roofs or other exterior areas that are not readily accessible. These installations shall comply with (1) through (4):

(1) A dc disconnecting means shall be mounted within sight of or in the inverter.

(2) An ac disconnecting means shall be mounted within sight of or in the inverter.

(3) An additional ac disconnecting means for the inverter shall comply with 705.22.

(4) A plaque shall be installed in accordance with 705.10.

705.80 Utility-Interactive Power Systems Employing Energy Storage. Utility-interactive power systems employing energy storage shall also be marked with the maximum operating voltage, including any equalization voltage, and the polarity of the grounded circuit conductor.

705.82 Hybrid Systems. Hybrid systems shall be permitted to be interconnected with interactive inverters.

705.95 Ampacity of Neutral Conductor. The ampacity of the neutral conductors shall comply with either (A) or (B).

(A) Neutral Conductor for Single Phase, 2-Wire Inverter Output. If a single-phase, 2-wire inverter output is connected to the neutral and one ungrounded conductor (only) of a 3-wire system or of a 3-phase, 4-wire, wye-connected system, the maximum load connected between the neutral and any one ungrounded conductor plus the inverter output rating shall not exceed the ampacity of the neutral conductor.

(B) Neutral Conductor for Instrumentation, Voltage, Detection or Phase Detection. A conductor used solely for instrumentation, voltage detection, or phase detection and connected to a single-phase or 3-phase interactive inverter, shall be permitted to be sized at less than the ampacity of the other current-carrying conductors and shall be sized equal to or larger than the equipment grounding conductor.

705.100 Unbalanced Interconnections.

(A) Single Phase. Single-phase inverters for hybrid systems and ac modules in interactive hybrid systems shall be connected to 3-phase power systems in order to limit unbalanced voltages to not more than 3 percent.

Informational Note: For interactive single-phase inverters, unbalanced voltages can be minimized by the same methods that are used for single-phase loads on a 3-phase power system. See ANSI/C84.1-2011, *Electric Power Systems and Equipment — Voltage Ratings (60 Hertz).*

(B) Three Phase. Three-phase inverters and 3-phase ac modules in interactive systems shall have all phases automatically de-energized upon loss of, or unbalanced, voltage in one or more phases unless the interconnected system is designed so that significant unbalanced voltages will not result.

Part III. Generators

705.130 Overcurrent Protection. Conductors shall be protected in accordance with Article 240. Equipment and conductors connected to more than one electrical source shall have overcurrent devices located so as to provide protection from all sources. Generators shall be protected in accordance with 445.12.

705.143 Synchronous Generators. Synchronous generators in a parallel system shall be provided with the necessary equipment to establish and maintain a synchronous condition.

Part IV. Microgrid Systems

705.150 System Operation. Microgrid systems shall be permitted to disconnect from the primary source of power or other interconnected electric power production sources and operate as a separate microgrid system.

705.160 Primary Power Source Connection. Connections to primary power sources that are external to the microgrid system shall comply with the requirements of 705.12.

705.165 Reconnection to Primary Power Source. Microgrid systems that reconnect to primary power sources shall be provided with the necessary equipment to establish a synchronous transition.

705.170 Microgrid Interconnect Devices (MID). Microgrid interconnect devices shall comply with the following:

(1) Be required for any connection between a microgrid system and a primary power source

(2) Be listed or field labeled for the application

(3) Have sufficient number of overcurrent devices located to provide overcurrent protection from all sources

Informational Note: MID functionality is often incorporated in an interactive or multimode inverter, energy storage system, or similar device identified for interactive operation.

Article 706
Energy Storage Systems

Part I. General

706.1 Scope. This article applies to all permanently installed energy storage systems (ESS) operating at over 50 volts ac or 60 volts dc that may be stand-alone or interactive with other electric power production sources.

Informational Note: The following standards are frequently referenced for the installation of energy storage systems:

(1) NFPA 111-2013, *Standard on Stored Electrical Energy Emergency and Standby Systems*

(2) IEEE 484-2008, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*

(3) IEEE 485-1997, *Recommended Practice for Sizing Vented Lead-Acid Storage Batteries for Stationary Applications*

(4) IEEE 1145-2007, *Recommended Practice for Installation and Maintenance of Nickel-Cadmium Batteries for Photovoltaic (PV) Systems*

(5) IEEE 1187-2002, *Recommended Practice for Installation Design, and Installation of Valve-Regulated Lead-Acid Batteries for Stationary Applications*

(6) IEEE 1578-2007, *Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management*

(7) IEEE 1635/ASHRAE 21-2012, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*

(8) UL 810A, *Electrochemical Capacitors*

(9) UL 1973, *Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications*

(10) UL 1989, *Standard for Standby Batteries*

(11) UL Subject 2436, Spill Containment For Stationary Lead Acid Battery Systems

(12) UL Subject 9540, *Safety of Energy Storage Systems and Equipment*

706.2 Definitions.

Battery. Two or more cells connected together electrically in series, in parallel, or a combination of both to provide the required operating voltage and current levels.

Cell. The basic electrochemical unit, characterized by an anode and a cathode, used to receive, store, and deliver electrical energy.

Container. A vessel that holds the plates, electrolyte, and other elements of a single unit, comprised of one or more cells, in a battery. It can be referred to as a jar or case.

Diversion Charge Controller. Equipment that regulates the charging process of an ESS by diverting power from energy storage to direct-current or alternating-current loads or to an interconnected utility service.

Electrolyte. The medium that provides the ion transport mechanism between the positive and negative electrodes of a cell.

Energy Storage System (ESS). One or more components assembled together capable of storing energy for use at a future time. ESS(s) can include but is not limited to batteries, capacitors, and kinetic energy devices (e.g., flywheels and compressed air). These systems can have ac or dc output for utilization and can include inverters and converters to change stored energy into electrical energy.

Energy Storage System, Self-Contained. Energy storage systems where the components such as cells, batteries, or modules and any necessary controls, ventilation, illumination, fire suppression, or alarm systems are assembled, installed, and packaged into a singular energy storage container or unit.

Informational Note: Self-contained systems will generally be manufactured by a single entity, tested and listed to safety standards relevant to the system, and readily connected on site to the electrical system and in the case of multiple systems to each other.

Energy Storage System, Pre-Engineered of Matched Components. Energy storage systems that are not self-contained systems but instead are pre-engineered and field-assembled using separate components supplied as a system by a singular entity that are matched and intended to be assembled as an energy storage system at the system installation site.

Informational Note: Pre-engineered systems of matched components for field assembly as a system will generally be designed by a single entity and comprised of components that are tested and listed separately or as an assembly.

Energy Storage System, Other. Energy storage systems that are not self-contained or pre-engineered systems of matched components but instead are composed of individual components assembled as a system.

Informational Note: Other systems will generally be comprised of different components combined on site to create an ESS. Those components would generally be tested and listed to safety standards relevant to the application.

Flow Battery. An energy storage component similar to a fuel cell that stores its active materials in the form of two electrolytes external to the reactor interface. When in use, the electrolytes are transferred between reactor and storage tanks.

Informational Note: Two commercially available flow battery technologies are zinc bromine and vanadium redox, sometimes referred to as pumped electrolyte ESS.

Intercell Connector. An electrically conductive bar or cable used to connect adjacent cells.

Intertier Connector. In a battery system, an electrical conductor used to connect two cells on different tiers of the same rack or different shelves of the same rack.

Inverter Input Circuit. Conductors between the inverter and the ESS in stand-alone and multimode inverter systems.

Inverter Output Circuit. Conductors between the inverter and another electric power production source, such as a utility for an electrical production and distribution network.

Inverter Utilization Output Circuit. Conductors between the multimode or standalone inverter and utilization equipment.

Nominal Voltage (Battery or Cell). The value assigned to a cell or battery of a given voltage class for the purpose of convenient designation. The operating voltage of the cell or battery may vary above or below this value.

Sealed Cell or Battery. A cell or battery that has no provision for the routine addition of water or electrolyte or for external measurement of electrolyte specific gravity.

Informational Note: Some cells that are considered to be sealed under conditions of normal use, such as valve-regulated lead-acid or some lithium cells, contain pressure relief valves.

Terminal. That part of a cell, container, or battery to which an external connection is made (commonly identified as a post, pillar, pole, or terminal post).

706.3 Other Articles. Wherever the requirements of other articles of this *Code* and Article 706 differ, the requirements of Article 706 shall apply. If the ESS is capable of being operated in parallel with a primary source(s) of electricity, the requirements in 705.6, 705.12, 705.14, 705.16, 705.32, 705.40, 705.100, 705.143, and Part IV of Article 705 shall apply.

706.4 System Classification. ESS shall be classified as one of the types described as follows:

(1) ESS, self-contained

Informational Note: Some self-contained systems may be listed.

(2) ESS, pre-engineered of matched components

(3) ESS, other

706.5 Equipment. Monitors, controls, switches, fuses, circuit breakers, power conversion systems, inverters and transformers, energy storage components, and other components of the energy storage system other than lead-acid batteries, shall be listed. Alternatively, self-contained ESS shall be listed as a complete energy storage system.

706.6 Multiple Systems. Multiple ESSs shall be permitted to be installed in or on a single building or structure.

706.7 Disconnecting Means.

(A) ESS Disconnecting Means. A disconnecting means shall be provided for all ungrounded conductors derived from an ESS. A disconnecting means shall be readily accessible and located within sight of the ESS.

Informational Note: See 240.21(H) for information on the location of the overcurrent device for conductors.

(B) Remote Actuation. Where controls to activate the disconnecting means of an ESS are not located within sight of the system, the disconnecting means shall be capable of being locked in the open position, in accordance with 110.25, and the location of the controls shall be field marked on the disconnecting means.

(C) Busway. Where a dc busway system is installed, the disconnecting means shall be permitted to be incorporated into the busway.

(D) Notification. The disconnecting means shall be legibly marked in the field. The marking shall meet the requirements of 110.21(B) and shall include the following:

(1) Nominal ESS voltage

(2) Maximum available short-circuit current derived from the ESS

(3) The associated clearing time or arc duration based on the available short-circuit current from the ESS and associated overcurrent protective devices if applicable

(4) Date the calculation was performed

Exception: The labeling in 706.7(D)(1) through (D)(4) shall not be required if an arc flash label is applied in accordance with acceptable industry practice.

Informational Note No. 1: Industry practices for equipment labeling are described in NFPA 70E-2015, *Standard for Electrical Safety in the Workplace.* This standard provides specific criteria for developing arc-flash labels for equipment that provides nominal system voltage, incident energy levels, arc-flash boundaries, minimum required levels of personal protective equipment, and so forth.

Informational Note No. 2: Battery equipment suppliers can provide information about short-circuit current on any particular battery model.

(E) Partitions and Distance. Where energy storage system input and output terminals are more than 1.5 m (5 ft) from connected equipment, or where the circuits from these terminals pass through a wall or partition, the installation shall comply with the following:

(1) A disconnecting means shall be provided at the energy storage system end of the circuit. Fused disconnecting means or circuit breakers shall be permitted to be used.

(2) A second disconnecting means located at the connected equipment shall be installed where the disconnecting means required by 706.7(E)(1) is not within sight of the connected equipment.

Informational Note No. 1: For remote disconnect controls in information technology equipment rooms, see 645.10.

Informational Note No. 2: For overcurrent protection of batteries, see 240.21(H).

(3) Where fused disconnecting means are used, the line terminals of the disconnecting means shall be connected toward the energy storage system terminals.

(4) Disconnecting means shall be permitted to be installed in energy storage system enclosures where explosive atmospheres can exist if listed for hazardous locations.

(5) Where the disconnecting means in (1) is not within sight of the disconnecting means in (2), placards or directories shall be installed at the locations of all disconnecting means indicating the location of all other disconnecting means.

706.8 Connection to Other Energy Sources. Connection to other energy sources shall comply with the requirements of 705.12.

(A) Load Disconnect. A load disconnect that has multiple sources of power shall disconnect all energy sources when in the off position.

(B) Identified Interactive Equipment. Only inverters and ac modules listed and identified as interactive shall be permitted on interactive systems.

(C) Loss of Interactive System Power. Upon loss of primary source, an ESS with a utility interactive inverter shall comply with the requirements of 705.40.

(D) Unbalanced Interconnections. Unbalanced connections between an energy storage system and electric power production sources shall be in accordance with 705.100.

(E) Point of Connection. The point of connection between an energy storage system and electric power production sources shall be in accordance with 705.12.

706.10 Energy Storage System Locations. Battery locations shall conform to 706.10(A), (B), and (C).

(A) Ventilation. Provisions appropriate to the energy storage technology shall be made for sufficient diffusion and ventilation of any possible gases from the storage device, if present, to prevent the accumulation of an explosive mixture. A pre-engineered or self-contained ESS shall be permitted to provide ventilation in accordance with the manufacturer's recommendations and listing for the system.

Informational Note No. 1: See NFPA 1-2015, *Fire Code*, Chapter 52, for ventilation considerations for specific battery chemistries.

Informational Note No. 2: Some storage technologies do not require ventilation.

Informational Note No. 3: A source for design of ventilation of battery systems is IEEE 1635-2012/ASHRAE Guideline 21-2012 *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*, and the UBC.

Informational Note No. 4: Fire protection considerations are addressed in NFPA 1-2015, *Fire Code*.

(B) Guarding of Live Parts. Guarding of live parts shall comply with 110.27.

(C) Spaces About ESS Components. Spaces about the ESS shall comply with 110.26. Working space shall be measured from the edge of the ESS modules, battery cabinets, racks, or trays. For battery racks, there shall be a minimum clearance of 25 mm (1 in.) between a cell container and any wall or structure on the side not requiring access for maintenance. ESS modules, battery cabinets, racks, or trays shall be permitted to contact adjacent walls or structures, provided that the battery shelf has a free air space for not less than 90 percent of its length. Pre-engineered and self-contained ESSs shall be permitted to have working space between components within the system in accordance with the manufacturer's recommendations and listing of the system.

Informational Note: Additional space is often needed to accommodate ESS equipment hoisting equipment, tray removal, or spill containment.

(D) Egress. A personnel door(s) intended for entrance to and egress from rooms designated as ESS rooms shall open in the direction of egress and shall be equipped with listed panic hardware.

(E) Illumination. Illumination shall be provided for working spaces associated with ESS and their equipment and components. Luminaires shall not be controlled by automatic means only. Additional luminaires shall not be required where the work space is illuminated by an adjacent light source. The location of luminaires shall not do either of the following:

(1) Expose personnel to energized system components while performing maintenance on the luminaires in the system space

(2) Create a hazard to the system or system components upon failure of the luminaire

706.11 Directory. ESS shall be indicated by 706.11(A) and (B). The markings or labels shall be in accordance with 110.21(B).

(A) Directory. A permanent plaque or directory denoting all electric power sources on or in the premises shall be installed at each service equipment location and at locations of all electric power production sources capable of being interconnected.

Exception: Installations with large numbers of power production sources shall be permitted to be designated by groups.

(B) Facilities with Stand-Alone Systems. Any structure or building with an ESS that is not connected to a utility service source and is a stand-alone system shall have a permanent plaque or directory installed on the exterior of the building or structure at a readily visible location acceptable to the authority having jurisdiction. The plaque or directory shall indicate the location of system disconnecting means and that the structure contains a stand-alone electrical power system.

Part II. Circuit Requirements

706.20 Circuit Sizing and Current.

(A) Maximum Rated Current for a Specific Circuit. The maximum current for the specific circuit shall be calculated in accordance with 706.20(A)(1) through (A)(5).

(1) Nameplate-Rated Circuit Current. The nameplate(s)-rated circuit current shall be the rated current indicated on the ESS nameplate(s) or system listing for pre-engineered or self-contained systems of matched components intended for field assembly as a system.

(2) Inverter Output Circuit Current. The maximum current shall be the inverter continuous output current rating.

(3) Inverter Input Circuit Current. The maximum current shall be the continuous inverter input current rating when the inverter is producing rated power at the lowest input voltage.

(4) Inverter Utilization Output Circuit Current. The maximum current shall be the continuous inverter output current rating when the inverter is producing rated power at the lowest input voltage.

(5) DC to DC Converter Output Current. The maximum current shall be the dc-to-dc converter continuous output current rating.

(B) Conductor Ampacity and Overcurrent Device Ratings. The ampacity of the feeder circuit conductors from the ESS(s) to the wiring system serving the loads to be serviced by the system shall not be less than the greater of the (1) nameplate(s) rated circuit current as determined in accordance with 706.20(A) or (2) the rating of the ESS(s) overcurrent protective device(s).

(C) Ampacity of Grounded or Neutral Conductor. If the output of a single-phase, 2-wire ESS output(s) is connected to the grounded or neutral conductor and a single ungrounded conductor of a 3-wire system or of a 3-phase, 4-wire, wye-connected system, the maximum unbalanced neutral load current plus the ESS(s) output rating shall not exceed the ampacity of the grounded or neutral conductor.

706.21 Overcurrent Protection.

(A) Circuits and Equipment. ESS circuit conductors shall be protected in accordance with the requirements of Article 240. Protection devices for ESS circuits shall be in accordance with the requirements of 706.21(B) through (F). Circuits shall be protected at the source from overcurrent.

(B) Overcurrent Device Ampere Ratings. Overcurrent protective devices, where required, shall be rated in accordance with Article 240 and the rating provided on systems serving the ESS and shall be not less than 125 percent of the maximum currents calculated in 706.20(A).

(C) Direct Current Rating. Overcurrent protective devices, either fuses or circuit breakers, used in any dc portion of an ESS shall be listed and for dc and shall have the appropriate voltage, current, and interrupting ratings for the application.

(D) Current Limiting. A listed and labeled current-limiting overcurrent protective device shall be installed adjacent to the ESS for each dc output circuit.

Exception: Where current-limiting overcurrent protection is provided for the dc output circuits of a listed ESS, additional current-limiting overcurrent devices shall not be required.

(E) Fuses. Means shall be provided to disconnect any fuses associated with ESS equipment and components when the fuse is energized from both directions and is accessible to other than qualified persons. Switches, pullouts, or similar devices that are rated for the application shall be permitted to serve as a means to disconnect fuses from all sources of supply.

(F) Location. Where ESS input and output terminals are more than 1.5 m (5 ft) from connected equipment, or where the circuits from these terminals pass through a wall or partition, overcurrent protection shall be provided at the ESS.

706.23 Charge Control.

(A) General. Provisions shall be provided to control the charging process of the ESS. All adjustable means for control of the charging process shall be accessible only to qualified persons.

Informational Note: Certain types of energy storage equipment such as valve-regulated lead acid or nickel cadmium can experience thermal failure when overcharged.

(B) Diversion Charge Controller.

(1) Sole Means of Regulating Charging. An ESS employing a diversion charge controller as the sole means of regulating charging shall be equipped with a second independent means to prevent overcharging of the storage device.

(2) Circuits with Diversion Charge Controller and Diversion Load. Circuits containing a diversion charge controller and a diversion load shall comply with the following:

(1) The current rating of the diversion load shall be less than or equal to the current rating of the diversion load charge controller. The voltage rating of the diversion load shall be greater than the maximum ESS voltage. The power rating of the diversion load shall be at least 150 percent of the power rating of the charging source.

(2) The conductor ampacity and the rating of the overcurrent device for this circuit shall be at least 150 percent of the maximum current rating of the diversion charge controller.

(3) Energy Storage Systems Using Utility-Interactive Inverters. Systems using utility-interactive inverters to control energy storage state-of-charge by diverting excess power into the utility system shall comply with 706.23(B)(3)(a) and (B)(3)(b).

a. These systems shall not be required to comply with 706.23(B)(2).

b. These systems shall have a second, independent means of controlling the ESS charging process for use when the utility is not present or when the primary charge controller fails or is disabled.

(C) Charge Controllers and DC-to-DC Converters. Where charge controllers and other DC-to-DC power converters that increase or decrease the output current or output voltage with respect to the input current or input voltage are installed, all of the following shall apply:

(1) The ampacity of the conductors in output circuits shall be based on the maximum rated continuous output current of the charge controller or converter for the selected output voltage range.

(2) The voltage rating of the output circuits shall be based on the maximum voltage output of the charge controller or converter for the selected output voltage range.

Part III Electrochemical Energy Storage Systems

Part III of this article applies to ESSs that are comprised of sealed and non-sealed cells or batteries or system modules that are comprised of multiple sealed cells or batteries that are not components within a listed product.

Informational Note: An energy storage component, such as batteries, that are integrated into a larger piece of listed equipment, such as an uninterruptible power supply (UPS), are examples of components within a listed product.

706.30 Installation of Batteries.

(A) Dwelling Units. An ESS for dwelling units shall not exceed 100 volts between conductors or to ground.

Exception: Where live parts are not accessible during routine ESS maintenance, an ESS voltage exceeding 100 volts shall be permitted.

(B) Disconnection of Series Battery Circuits. Battery circuits subject to field servicing, where exceeding 240 volts nominal between conductors or to ground, shall have provisions to disconnect the series-connected strings into segments not exceeding 240 volts nominal for maintenance by qualified persons. Non–load-break bolted or plug-in disconnects shall be permitted.

(C) Storage System Maintenance Disconnecting Means. ESS exceeding 100 volts between conductors or to ground shall have a disconnecting means, accessible only to qualified persons, that disconnects ungrounded and grounded circuit conductor(s) in the electrical storage system for maintenance. This disconnecting means shall not disconnect the grounded circuit conductor(s) for the remainder of any other electrical system. A non–load-break-rated switch shall be permitted to be used as a disconnecting means.

(D) Storage Systems of More Than 100 Volts. On ESS exceeding 100 volts between the conductors or to ground, the battery circuits shall be permitted to operate with ungrounded conductors, provided a ground-fault detector and indicator is installed to monitor for ground faults within the storage system.

706.31 Battery and Cell Terminations.

(A) Corrosion Prevention. Antioxidant material suitable for the battery connection shall be used when recommended by the battery or cell manufacturer.

> Informational Note: The battery manufacturer's installation and instruction manual can be used for guidance for acceptable materials.

(B) Intercell and Intertier Conductors and Connections. The ampacity of field-assembled intercell and intertier connectors and conductors shall be of such cross-sectional area that the temperature rise under maximum load conditions and at maximum ambient temperature shall not exceed the safe operating temperature of the conductor insulation or of the material of the conductor supports.

> Informational Note: Conductors sized to prevent a voltage drop exceeding 3 percent of maximum anticipated load, and where the maximum total voltage drop to the furthest point of connection does not exceed 5 percent, may not be appropriate for all battery applications. IEEE 1375-2003, *Guide for the Protection of Stationary Battery Systems*, provides guidance for overcurrent protection and associated cable sizing.

(C) Battery Terminals. Electrical connections to the battery and the cable(s) between cells on separate levels or racks shall not put mechanical strain on the battery terminals. Terminal plates shall be used where practicable.

706.32 Battery Interconnections. Flexible cables, as identified in Article 400, in sizes 2/0 AWG and larger shall be permitted within the battery enclosure from battery terminals to a nearby junction box where they shall be connected to an approved wiring method. Flexible battery cables shall also be permitted between batteries and cells within the battery enclosure. Such cables shall be listed and identified as moisture resistant. Flexible, fine-stranded cables shall only be used with terminals, lugs, devices, or connectors in accordance with 110.14.

706.33 Accessibility. The terminals of all cells or multicell units shall be readily accessible for readings, inspection, and cleaning where required by the equipment design. One side of transparent battery containers shall be readily accessible for inspection of the internal components.

706.34 Battery Locations. Battery locations shall conform to 706.34(A), (B), and (C).

(A) Live Parts. Guarding of live parts shall comply with 110.27.

(B) Top Terminal Batteries. Where top terminal batteries are installed on tiered racks or on shelves of battery cabinets, working space in accordance with the storage equipment manufacturer's instructions shall be provided between the highest point on a storage system component and the row, shelf, or ceiling above that point.

> Informational Note: IEEE 1187 provides guidance for top clearance of VRLA batteries, which are the most commonly used battery in cabinets.

(C) Gas Piping. Gas piping shall not be permitted in dedicated battery rooms.

Part IV. Flow Battery Energy Storage Systems

Part IV applies to ESSs composed of or containing flow batteries.

706.40 General. All electrical connections to and from the system and system components shall be in accordance with the applicable provisions of Article 692. The system and system components shall also meet the provisions of Parts I and II of this article. Unless otherwise directed by this article, flow battery ESS shall comply with the applicable provisions of Article 692.

706.41 Electrolyte Classification. The electrolyte(s) that are acceptable for use in the batteries associated with the ESS shall be identified by name and chemical composition. Such identification shall be provided by readily discernable signage adjacent to every location in the system where the electrolyte can be put into or taken out of the system.

706.42 Electrolyte Containment. Flow battery systems shall be provided with a means for electrolyte containment to prevent spills of electrolyte from the system. An alarm system shall be provided to signal an electrolyte leak from the system. Electrical wiring and connections shall be located and routed in a manner that mitigates the potential for exposure to electrolytes.

706.43 Flow Controls. Controls shall be provided to safely shut down the system in the event of electrolyte blockage.

706.44 Pumps and Other Fluid Handling Equipment. Pumps and other fluid handling equipment are to be rated/specified suitable for exposure to the electrolytes.

Part V. Other Energy Storage Technologies

The provisions of Part V apply to ESSs using other technologies intended to store energy and when there is a demand for electrical power to use the stored energy to generate the needed power.

706.50 General. All electrical connections to and from the system and system components shall be in accordance with the applicable provisions of this *Code*. Unless otherwise directed by this article, other energy storage technologies shall comply with the applicable provisions of Part III of Article 705.

Article 710
Stand-Alone Systems

710.1 Scope. This article covers electric power production sources operating in stand-alone mode.

710.6 Equipment Approval. All equipment shall be listed or field labeled for the intended use.

710.15 General. Premises wiring systems shall be adequate to meet the requirements of this *Code* for similar installations supplied by a feeder or service. The wiring on the supply side of the building or structure disconnecting means shall comply with the requirements of this *Code*, except as modified by 710.15(A) through (F).

(A) Supply Output. Power supply to premises wiring systems shall be permitted to have less capacity than the calculated load. The capacity of the stand-alone supply shall be equal to or greater than the load posed by the largest single utilization equipment connected to the system. Calculated general lighting loads shall not be considered as a single load.

(B) Sizing and Protection. The circuit conductors between a stand-alone source and a building or structure disconnecting means shall be sized based on the sum of the output ratings of the stand-alone sources.

(C) Single 120-Volt Supply. Stand-alone systems shall be permitted to supply 120 volts to single-phase, 3-wire, 120/240-volt service equipment or distribution panels where there are no 240-volt outlets and where there are no multiwire branch circuits. In all installations, the sum of the ratings of the power sources shall be less than the rating of the neutral bus in the service equipment. This equipment shall be marked with the following words or equivalent:

WARNING:
SINGLE 120-VOLT SUPPLY. DO NOT CONNECT
MULTIWIRE BRANCH CIRCUITS!

The warning sign(s) or label(s) shall comply with 110.21(B).

(D) Energy Storage or Backup Power System Requirements. Energy storage or backup power supplies are not required.

(E) Back-Fed Circuit Breakers. Plug-in type back-fed circuit breakers connected to an interconnected supply shall be secured in accordance with 408.36(D). Circuit breakers marked "line" and "load" shall not be back-fed.

(F) Voltage and Frequency Control. The stand-alone supply shall be controlled so that voltage and frequency remain within suitable limits for the connected loads.

Article 712
Direct Current Microgrids

Part I. General

712.1 Scope. This article applies to direct current microgrids.

712.2 Definitions.

Direct Current Microgrid (DC Microgrid). A direct current microgrid is a power distribution system consisting of more than one interconnected dc power source, supplying dc-dc converter(s), dc load(s), and/or ac load(s) powered by dc-ac inverter(s). A dc microgrid is typically not directly connected to an ac primary source of electricity, but some dc microgrids interconnect via one or more dc-ac bidirectional converters or dc–ac inverters.

> Informational Note: Direct current power sources include ac-dc converters (rectifiers), bidirectional dc-ac inverters/converters, photovoltaic systems, wind generators, energy storage systems (including batteries), and fuel cells.

Grounded Two-Wire DC System. A system that has a solid connection or reference-ground between one of the current carrying conductors and the equipment grounding system.

Grounded Three-Wire DC System. A system with a solid connection or reference-ground between the center point of a bipolar dc power source and the equipment grounding system.

Nominal Voltage. A value assigned to a circuit or system for the purpose of conveniently designating its dc voltage class.

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

Reference-Grounded DC System. A system that is not solidly grounded but has a low-resistance electrical reference that maintains voltage to ground in normal operation.

Resistively Grounded. A system with a high-resistance connection between the current carrying conductors and the equipment grounding system.

Primary DC Source. A source that supplies the majority of the dc load in a dc microgrid.

Ungrounded DC System. A system that has no direct or resistive connection between the current carrying conductors and the equipment grounding system.

712.3 Other Articles. Wherever the requirements of other articles of this *Code* and Article 712 differ, the requirements of Article 712 shall apply. DC microgrids interconnected

through an inverter or bi-directional converter with ac electric power production sources shall comply with Article 705.

712.4 Listing and Labeling. Any equipment used in the dc circuits of a direct-current micro grid shall be listed and labeled for dc use.

712.10 Directory. A permanent directory denoting all dc electric power sources operating to supply the dc microgrid shall be installed at each source location capable of acting as the primary dc source.

Part II. Circuit Requirements

712.25 Identification of Circuit Conductors

(A) Ungrounded circuit conductors in dc microgrids shall be identified according to the requirements of 210.5(C)(2) for branch circuits and 215.12(C)(2) for feeders.

(B) Ungrounded conductors of 6 AWG or smaller shall be permitted to be identified by polarity at all termination, connection, and splice points by marking tape, tagging, or other approved means.

712.30 System Voltage. The system voltage of a dc microgrid shall be determined by one of the following methods:

(1) The nominal voltage to ground for solidly grounded systems

(2) The nominal voltage to ground for reference-grounded systems

(3) The highest nominal voltage between conductors for resistively grounded dc systems and ungrounded dc systems.

Informational Note: Examples of nominal dc system voltages include but are not limited to 24, 48, 125, 190/380, or 380 volts.

Part III. Disconnecting Means

712.34 DC Source Disconnecting Means. The output of each dc source shall have a readily accessible, disconnecting means that is lockable in the open position and adjacent to the source.

712.35 Disconnection of Ungrounded Conductors. In solidly grounded two- and three-wire systems, the disconnecting means shall simultaneously open all ungrounded conductors. In ungrounded, resistively grounded and reference-grounded systems, such devices shall open all current-carrying conductors.

712.37 Directional Current Devices. Disconnecting means shall be listed, be marked for use in a single current direction, and only be used in the designated current direction.

Informational Note: Examples of directional current devices are magnetically quenched contactors and semiconductor switches in overcurrent devices.

Part IV. Wiring Methods

712.52 System Grounding.

(A) General. Direct-current microgrids shall be grounded in accordance with 250.162.

(B) Over 300 Volts. DC microgrids operating at voltages greater than 300 volts dc shall be reference-grounded dc systems or resistively grounded dc systems.

712.55 Ground Fault Detection Equipment. Ungrounded, reference grounded, or resistively grounded dc microgrids operating at greater than 60 volts dc shall have ground fault detection that indicates that a fault has occurred. The ground fault equipment shall be marked in accordance with 250.167(C).

712.57 Arc Fault Protection. Where required elsewhere in this *Code*, specific systems within the DC microgrid shall have arc fault protection. The arc fault protection equipment shall be listed.

Informational Note: Section 90.4 applies when suitable equipment for arc fault protection is not available.

Part V. Marking

712.62 Distribution Equipment and Conductors. Distribution equipment and conductors shall be marked as required elsewhere in this *Code*.

712.65 Available DC Short-Circuit Current.

(A) Field Marking. The maximum available dc short-circuit current on the dc microgrid shall be field marked at the dc source(s). The field marking(s) shall include the date the short-circuit current calculation was performed and be of sufficient durability to withstand the environment involved.

(B) Modifications. When modifications to the electrical installation occur that affect the maximum available short-circuit current at the dc source, the maximum available short-circuit current shall be verified or recalculated as necessary to ensure the equipment ratings are sufficient for the maximum available short-circuit current at the line terminals of the equipment. The required field marking(s) in 712.65(A) shall indicate the new maximum available short-circuit current and date.

Part VI. Protection

712.70 Overcurrent Protection. Equipment and conductors connected to more than one electrical source shall have overcurrent protective devices to provide protection from all sources.

712.72 Interrupting and Short-Circuit Current Ratings. Consideration shall be given to the contribution of short-circuit currents from all interconnected power sources for the interrupting ratings and short-circuit current ratings of equipment in the dc microgrid system(s). Overcurrent protective devices and equipment used within a dc microgrid shall have

an interrupting rating at nominal circuit voltage or a short-circuit current rating sufficient for the available short-circuit current at the line terminals of the equipment.

Part VII. Systems over 1000 Volts

712.80 General. Systems with a maximum voltage between conductors of over 1000 volts dc shall comply with Article 490 and other requirements in this *Code* applicable to installations rated over 1000 volts.

Article 750
Energy Management Systems

750.1 Scope. This article applies to the installation and operation of energy management systems.

Informational Note: Performance provisions in other codes establish prescriptive requirements that may further restrict the requirements contained in this article.

750.2 Definitions. For the purpose of this article, the following definitions shall apply.

Control. The predetermined process of connecting, disconnecting, increasing, or reducing electric power.

Energy Management System. A system consisting of any of the following: a monitor(s), communications equipment, a controller(s), a timer(s), or other device(s) that monitors and / or controls an electrical load or a power production or storage source.

Monitor. An electrical or electronic means to observe, record, or detect the operation or condition of the electric power system or apparatus.

750.20 Alternate Power Sources. An energy management system shall not override any control necessary to ensure continuity of an alternate power source for the following:

(1) Fire pumps

(2) Health care facilities

(3) Emergency systems

(4) Legally required standby systems

(5) Critical operations power systems

750.30 Load Management. Energy management systems shall be permitted to monitor and control electrical loads unless restricted in accordance with 750.30(A) through (C).

(A) Load Shedding Controls. An energy management system shall not override the load shedding controls put in place to ensure the minimum electrical capacity for the following:

(1) Fire pumps

(2) Emergency systems

(3) Legally required standby systems

(4) Critical operations power systems

(B) Disconnection of Power. An energy management system shall not be permitted to cause disconnection of power to the following:

(1) Elevators, escalators, moving walks, or stairway lift chairs

(2) Positive mechanical ventilation for hazardous (classified) locations

(3) Ventilation used to exhaust hazardous gas or reclassify an area

(4) Circuits supplying emergency lighting

(5) Essential electrical systems in health care facilities

(C) Capacity of Branch Circuit, Feeder, or Service. An energy management system shall not cause a branch circuit, feeder, or service to be overloaded at any time.

750.50 Field Markings. Where an energy management system is employed to control electrical power through the use of a remote means, a directory identifying the controlled device(s) and circuit(s) shall be posted on the enclosure of the controller, disconnect, or branch-circuit overcurrent device.

Informational Note: The use of the term remote is intended to convey that a controller can be operated via another means or location through communications without a direct operator interface with the controlled device.

INFORMATIVE ANNEX A

PRODUCT SAFETY STANDARDS

Informative Annex A is not part of the requirements of this NFPA document but is included for informational purposes only.

This informative annex provides a list of product safety standards used for product listing where that listing is required by this *Code*. It is recognized that this list is current at the time of publication but that new standards or modifications to existing standards can occur at any time while this edition of the *Code* is in effect.

This Informative Annex does not form a mandatory part of the requirements of this *Code* but is intended only to provide *Code* users with informational guidance about the product characteristics about which *Code* requirements have been based.

Product Standard Name	Product Standard Number
Concentrator Photovoltaic Modules and Assemblies	Subject 8703
Connectors for Use in Photovoltaic Systems	Subject 6703
Enclosed and Dead-Front Switches for Use in Photovoltaic Systems	Subject 98B
Flat-Plate Photovoltaic Modules and Panels	UL 1703
Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources	UL 1741
Low-Voltage Fuses—Fuses for Photovoltaic Systems	Subject 2579
Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures for Use with Photovoltaic (PV) Systems	Subject 489B
Multi-Pole Connectors for Use in Photovoltaic Systems	Subject 6703A
Photovoltaic DC Arc-Fault Circuit Protection	Subject 1699B
Photovoltaic Junction Boxes	Subject 3730
Photovoltaic Wire	UL 4703
Safety of Power Converters for Use in Photovoltaic Power Systems—Part 1: General Requirements	UL 62109-1
Safety of Power Converters for Use in Photovoltaic Power Systems—Part 2: Particular Requirements for Inverters	UL 62109-2
Solar Trackers	Subject 3703

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FOREWORD

Introduction

The first version of this standard was developed in 1989 by the Solar Rating and Certification Corporation (SRCC) as a result of efforts by a consortium including the U.S. Department of Energy, National Renewable Energy Laboratory (NREL), Interstate Renewable Energy Council (IREC), Florida Solar Energy Center (FSEC) and the Solar Energy Industry Association (SEIA). Since that time, the standard has been updated periodically by means of SRCC's standard development process. The consensus process used by SRCC was consistent with ANSI requirements for the development of voluntary consensus standards including balance of stakeholders, transparency and due process.

In 2013, SRCC and ICC agreed to collaborate to develop an updated version of the SRCC 300-2013 standard through ICC's ANSI-approved Standard Development process to seek designation as an American National Standard (ANS). With direction from ICC's Board of Directors and the SRCC Board of Directors, the ICC Standards Council appointed a consensus committee to develop an updated standard to establish minimum performance requirements and rating of solar thermal systems.

Development

This is the first edition of the International Code Council® (ICC®) 900/Solar Rating and Certification Corporation® (SRCC®) 300 *Solar Thermal System Standard*, but it is based substantially on the latest version of SRCC Standard 300, which originated in 1989. This standard was developed by the ICC/SRCC Solar Thermal Standard Consensus Committee (IS-STSC) that operates under ANSI-approved ICC Consensus Procedures for the development of ICC standards.

The meetings of the IS-STSC Consensus Committee were open to the public and interested individuals and organizations from across the country participated. Views and objections were solicited through several public comment periods. All views and objections were considered by the consensus committee and an effort was made toward their resolution. A vote by the consensus committee approved this standard.

The requirements in ICC 900/SRCC 300—2015 are based on the intent to both update the long-established SRCC 300 standard and improve consistency with the latest model plumbing and mechanical codes in use. A task group specifically reviewed the provisions within the standard to eliminate any conflicts with codes and establish common terms and rigor. The resulting document provides appropriate protections for health, safety and welfare while avoiding unnecessary restrictions on the use of new materials, technologies or designs.

Adoption

ICC 900/SRCC 300, *Solar Thermal System* is available for reference and use by jurisdictions in both codes and incentive programs internationally. It represents an update to SRCC Standard 300 and is appropriate for use as a successor to that document. Its use within a governmental jurisdiction is intended to be accomplished through adoption by reference in accordance with proceedings establishing the jurisdiction's law.

Interpretations

Requests for interpretations on the provisions of ICC 900/SRCC 300—2015 should be addressed to: ICC, Central Regional Office, 4051 Flossmoor Road, Country Club Hills, IL 60478.

Maintenance—Submittal of Proposals

All ICC standards are revised as required by ANSI. Proposals for revising this edition are welcome. Please visit the ICC website at www.iccsafe.org for the official "Call for Proposals" announcement. A proposal form and instructions can also be downloaded from www.iccsafe.org.

ICC, SRCC, its members and those participating in the development of ICC 900/SRCC 300—2015 do not accept any liability resulting from compliance or noncompliance with the provisions of ICC 900/SRCC 300—2015. Neither ICC nor SRCC have the power or authority to police or enforce compliance with the contents of this standard. Only the governmental body that enacts this standard into law has such authority.

International Code Council Solar Thermal Standard Consensus Committee (IS-STSC)

Consensus Committee SCOPE: The Solar Thermal Standard Consensus Committee (IS-STSC) shall have primary responsibility for minimum requirements to safeguard the public health, safety and general welfare along with minimum performance, and evaluation requirements for solar thermal systems. The requirements contained in the *International Codes* pertaining to these situations shall be coordinated with the standards developed by the IS-STSC Consensus Committee.

This standard was processed and approved for submittal to ANSI by the ICC Solar Thermal Standard Consensus Committee (IS-STSC). Committee approval of the standard does not necessarily imply that all committee members voted for its approval.

Representatives on the Consensus Committee are classified in one of three voting interest categories, General Interest (G), User Interest (U) and Producer Interest (P). The committee has been formed in order to achieve consensus as required by ANSI Essential Requirements. At the time it approved this standard, the IS-STSC Consensus Committee consisted of the following members:

Rolf Christ (P), R&R Solar Supply, Honolulu, Hawaii

Thomas Cleveland (U), North Carolina Clean Energy Technology Center at NC State University, Raleigh, North Carolina

John Del Mar, PE, MS (U), Florida Solar Energy Center (FSEC), Cocoa, Florida

William Funk, Jr. (G), Cecil County Permits and Inspections, Elkton, Maryland

Rex Gillespie (P), Caleffi North America, Inc., Milwaukee, Wisconsin

McKenzie W. James (G), City of Portland, Portland, Oregon

Robert J. Klein, CBO (G), Town of Hilton Head Island, Hilton Head Island, South Carolina

Nathan Lohse (P), FAFCO, Inc., Chico, California

Bill Miao (P), SunEnergyNet, San Diego, California

Larry Sherwood (U), Sherwood Associates, Boulder, Colorado

John Smirnow (P), Solar Energy Industries Association (SEIA), Washington, District of Columbia

Shawn Strausbaugh (G), Arlington County, Arlington, Virginia

Secretaries: **Shawn Martin,** Director of PMG Activities, Plumbing, Mechanical and Fuel Gas Group, International Code Council, Pittsburgh, Pennsylvania; **Jim Huggins,** Technical Director, Solar Rating and Certification Corporation, Cocoa, Florida.

Voting Membership in Each Category

Category	Number
General (G)	4
User (U)	3
Producer (P)	5
TOTAL	12

Interest Categories

General Interest: Individuals assigned to the General Interest category are those who represent the interests of an entity, including an association of such entities, representing the general public, or entities that promulgate or enforce the provisions within the committee scope. These entities include consumers and government regulatory agencies.

User Interest: Individuals assigned to the User Interest category are those who represent the interests of an entity, including an association of such entities, which is subject to the provisions or voluntarily utilizes provisions within the committee scope. These entities include academia, applied research laboratory, building owner, design professional, government nonregulatory agency, insurance company, private inspection agency and product certification/evaluation agency.

Producer Interest: Individuals assigned to the Producer Interest category are those who represent the interests of an entity, including an association of such entities, which produces, installs or maintains a product, assembly or system subject to the provisions within the committee scope. These entities include builder, contractor, distributor, laborer, manufacturer, material association, standards promulgator, testing laboratory and utility.

NOTE—Multiple Interests: Individuals representing entities in more than one of the above interest categories, one of which is a Producer Interest, are assigned to the Producer Interest. Individuals representing entities in the General Interest and User Interest categories are assigned to the User Interest.

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CHAPTER 1

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SECTION 101
GENERAL

101.1 Purpose. This standard sets forth the minimum criteria for the design and installation of *solar thermal system*s. Furthermore, this standard describes the requirements and methodology for standardized *solar thermal system* design evaluation, including the analytical evaluation of its components.

SECTION 102
SCOPE

102.1 Scope. This standard shall apply to solar energy systems used in applications for heating, cooling, dehumidification and co-generation—generally referred to as *solar thermal systems*. This standard shall not apply to utility-scale power generation or loads provided with fluid heated by *solar thermal system*s.

SECTION 103
REFERENCED DOCUMENTS

103.1 Referenced documents. The codes and standards referenced in this standard shall be considered to be part of the requirements of this standard to the prescribed extent of each such reference. Chapter 4 contains a complete list of all referenced documents.

CHAPTER 2
DEFINITIONS

SECTION 201
GENERAL

201.1 General. For the purpose of this standard, the terms listed in Section 202 have the indicated meaning.

201.2 Undefined terms. The meaning of terms not specifically defined in this document or in the referenced standards shall have ordinarily accepted meanings such as the context implies.

201.3 Interchangeability. Words, terms and phrases used in the singular include the plural and the plural include the singular.

SECTION 202
DEFINED TERMS

ACCESS (TO). That which enables a device, appliance or equipment to be reached by ready access or by a means that first requires the removal or movement of a panel, door or similar obstruction [see also "Ready access (to)"].

ACIDIC/CAUSTIC FLUIDS. A fluid is considered to be acidic if its pH is less than 6.7 and caustic if its pH is greater than 7.3.

ACTIVE SYSTEM. A *solar thermal system* using a pump to circulate fluid through any part of the system.

APPROVED. Acceptable to the code official or other authority having jurisdiction.

AUXILIARY HEATING EQUIPMENT. Equipment utilizing energy other than solar to supplement the output provided by the solar thermal system.

BACKFLOW. The flow of water or other fluids, mixtures or substances into the distribution pipes of a potable water supply from any source except the intended source.

CONTROLLER. Any device or part thereof that regulates the operation of the solar thermal system or component.

DAILY CLEARNESS INDEX (K_t). Ratio of the average radiation at the earth's surface to the average radiation available at the top of the atmosphere.

DESIGN LIFE. The intended useful operational life of a *solar thermal system* or component, as defined by the supplier.

DESIGN MAXIMUM NO-FLOW TEMPERATURE. The temperature below which a system component can return to normal operation following a *no-flow condition.*

DRAIN-BACK. *Solar thermal systems* in which the fluid in the solar collector loop is drained from the collector into a holding tank under prescribed circumstances.

DRAIN-DOWN. *Solar thermal systems* in which the fluid in the solar collector is drained from the system to an *approved* disposal area under prescribed circumstances.

DRAINAGE SLOPE. The designed continuous downward slope of installed piping or other components toward drain points.

FOOD GRADE FLUID. Potable water or a fluid containing additives listed in accordance with the Code of Federal Regulations, Title 21, Food and Drugs, Chapter 1, Food and Drug Administration, Parts 174–186.

FREEZE TOLERANCE LIMIT. Minimum outdoor temperature at which a given solar thermal system can be operated without permanently damaging system components or performance, as specified by the supplier.

HEAT EXCHANGER. A device that transfers heat from one medium to another.

DOUBLE-WALL HEAT EXCHANGER. A *heat exchanger* design in which a single failure of any fluid barrier will not cause a cross connection or permit backflow of heat transfer fluid between two separate fluid systems.

SINGLE-WALL HEAT EXCHANGER. A *heat exchanger* design in which a single failure of any fluid barrier will cause a cross connection or permit backflow of heat transfer fluid between two separate fluid systems.

HEAT TRANSFER FLUID. The operating or thermal storage fluid in a solar thermal system, including water or other base, and additives at the concentration present under operating conditions used to move heat from one location to another.

INDIRECT SYSTEM. *Solar thermal system* in which the fluid in the solar collector loop circulates between the solar collector(s) and a heat exchanger and during normal operation such fluid is not drained from the system and is not supplied to the load.

IN-SERVICE CONDITIONS. The conditions to which a *solar thermal system* and its components will be exposed during operation.

LABELED. Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation. These organizations conduct periodic inspection of the production of the above-labeled items. The labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

LISTED. Equipment, materials, products or services included in a list published by an organization acceptable to the code official. The organization evaluates products or services and conducts periodic inspection of production of listed equipment or materials or periodic evaluation of services. The listing states either that the equipment, material, product

or service meets identified standards or has been tested and found suitable for a specified purpose.

MANUAL. The total documentation package provided by the supplier to the purchaser that describes the general operation and maintenance procedures of the system.

NO-FLOW CONDITION. A condition where thermal energy is not transferred from the collector by means of flow of *heat transfer fluid*.

NON-FOOD GRADE. Any fluid that is not designated as a *food grade fluid.*

NONPOTABLE WATER. Water not safe for drinking, personal or culinary use.

POTABLE WATER. Water free from impurities present in amounts sufficient to cause disease or harmful physiological effects and conforming to the bacteriological and chemical quality requirements of the Public Health Service Drinking Water Standards or the regulations of the public health authority having jurisdiction.

PUMP STATION. A manufactured collection of components that moves fluid around and through a *solar thermal system.* It is permissible to include any of these components in a pump station: pump, piping and fittings, controller, valves, tank (expansion and/or storage), heat exchanger, and other components of the *solar thermal system.*

READY ACCESS (TO). That which enables a device, appliance or equipment to be directly reached without requiring the removal or movement of any panel, door or similar obstruction and without the use of a portable ladder, step stool, or similar device [see “Access (to)”].

SOLAR COLLECTOR LOOP. The portion of the *solar thermal system* that transports the *heat transfer fluid* in the form of gas or liquid through the *solar thermal collector*.

SOLAR THERMAL COLLECTOR. Components in a *solar thermal system* that collect and convert solar radiation to thermal energy.

SOLAR THERMAL SYSTEM. A system that converts solar radiation to thermal energy for use in heating or cooling.

STAGNATION. A condition where no heat is removed from a collector or system by a heat transfer fluid and the gain from solar radiation is balanced by the heat loss.

STORAGE TANK. Unfired vessel designed to store fluid.

SUBSYSTEM. A separable, functional assembly of components.

SUPPLEMENTAL HEATING EQUIPMENT. Equipment utilizing energy other than solar to supplement the output provided by the *solar thermal system*.

THIRD-PARTY TESTED. Procedure by which an *approved* testing laboratory provides documentation that a product, material or system conforms to specified requirements.

TOXIC FLUIDS. Fluids that are poisonous or irritating in nature or composition.

WATER HAMMER. A pressure surge that occurs when fluid or other incompressible fluid flow is suddenly stopped in a pressurized piping system.

CHAPTER 3

SYSTEM REQUIREMENTS

SECTION 301
OVERALL SYSTEM DESIGN CRITERIA

301.1 Overall system design. The overall system design criteria of the *solar thermal system* shall comply with Sections 301.1.1 through 301.1.11.

301.1.1 Operating limits. Means shall be provided to protect all *solar thermal system* components within the design limits of temperature and pressure as specified by the manufacturer.

301.1.2 Solar system isolation. Isolation valves shall be provided with access and installed to allow solar storage tanks to be bypassed in the case of a multi-tank system, or to shut off the cold water supply to the solar tank in a one-tank system. The normal operating position shall be marked on a label affixed to each isolation valve.

301.1.3 Thermal expansion. The system design, components and subassemblies shall include provisions for the thermal contraction and expansion of *heat transfer fluids* and system components that will occur over the manufacturer's specified design temperature range.

Exception: Thermal expansion control devices shall not be required in the drain-back section of drain-back systems.

301.1.4 Auxiliary heating equipment. A backup system shall be provided such that the combined solar and backup system will provide the same degree of reliability and performance as a conventional nonsolar system. The backup system shall be sized to meet the design load without any solar contribution. *Auxiliary heating equipment* shall be compatible with the solar thermal system heat output, temperatures, flow rates and *heat transfer fluid* types. *Auxiliary heating equipment* shall be *listed* and *labeled* by a recognized *third party listing agency*.

301.1.5 Thermosiphon prevention. Means shall be provided to control energy losses from thermal storage tanks and supplemental heating equipment caused by thermosiphonage.

301.1.6 Fluid system sizing. Pumps, piping, fans, ducts and other components shall be sized to carry the heat transfer fluid at design flow rates over the *design life* without operational impairment, erosion and corrosion.

301.1.7 Pressure drop and vibration. The maximum pressure drop and vibrations of *solar thermal system*s shall be limited to levels that will not exceed the manufacturer's design specifications or adversely impact system performance and longevity.

301.1.8 Vacuum-induced pressure protection. Components of the solar energy system shall be protected against the maximum vacuum that could occur within the system.

301.1.9 Thermal shock protection. The system shall be able to withstand sudden changes in temperature.

301.1.10 Protection from ultraviolet radiation. Ultraviolet radiation shall not alter beyond design specifications the performance of any component or subcomponent of the *solar thermal system* during their *design life.*

301.1.11 Airborne pollutants. *Solar thermal system* components and materials that are exposed to airborne pollutants such as ozone, salt spray, SO_2 or NO_x shall not be adversely affected by these pollutants to the extent that their function will be impaired beyond design specifications during their *design life*.

301.2 Collectors. The collectors shall be listed and labeled to relevant sections of ICC 901/SRCC 100.

301.3 Water heating equipment and storage tanks. Water heating equipment and *storage tanks* shall comply with Sections 301.3.1 through 301.3.3 and shall comply with the plumbing code and mechanical code adopted by the authority having jurisdiction, or, in the absence of such code, the *International Plumbing Code*® and *International Mechanical Code*®.

301.3.1 General. *Storage tanks* and water heating equipment shall comply with the requirements of this section. Tanks that are not separable from the collector shall comply with ICC 901/SRCC 100.

301.3.1.1 Protection from damage. *Storage tanks* and water heating equipment shall not be installed in a location where subject to mechanical damage unless protected by *approved* barriers.

301.3.1.2 Antisiphon devices. A cold water "dip" tube with a hole at the top or a vacuum relief valve installed in the cold water supply line above the top of the heater or tank or other *approved* means shall be provided to prevent siphoning of any storage water heater or tank.

301.3.1.3 Vacuum relief valve. Bottom-fed water heaters and bottom-fed storage tanks connected to water heaters shall be provided with a vacuum relief valve. Vacuum relief valves shall comply with ANSI Z21.22.

301.3.1.4 Outdoor installation. *Storage tanks* and heating equipment installed in outdoor locations shall be designed for outdoor installation.

301.3.2 Storage tanks. *Storage tanks* shall comply with Sections 301.3.2.1 through 301.3.2.3.

301.3.2.1 Pressurized hot water tanks. Pressurized hot water tanks shall comply with *ASME Boiler and Pressure Vessel Code, Section VIII, Division 1,* or *Section X* as applicable.

301.3.2.2 Insulation. *Storage tanks* shall be insulated to an R-value of not less than R-12.5 ($h \cdot ft^2 \cdot °F$)/Btu (R-2.2 $m^2 \cdot K/W$).

301.3.2.3 Separable tanks installed outside. Where *solar thermal systems* use collectors with separable tanks installed outdoors, the separable tanks shall be tested in accordance with Section 301.3.2.3.1. Upon completion of testing there shall not be degradation of any of the tank components or retention of water anywhere inside the tank jacket unintended by design.

301.3.2.3.1 Separable tank environmental test procedure. Solar collector(s) and tank(s) shall be installed in accordance with the system manufacturer's installation procedures. This assembly shall be subjected to the qualification tests in ICC 901/SRCC 100, Sections 401.3, 401.4, 401.7, 401.8, 401.9, and 401.19. Following these tests, the tank and the collectors shall be filled with the *heat transfer fluid(s)* specified in the installation manual and allowed to operate as they would in a typical installation while being exposed to one of these conditions:

1. Solar collectors and separable solar thermal tank shall be exposed to solar radiation outdoors for a period of 24 hours where the daily clearness index is equal to or greater than 0.7 for the duration of the test.
2. Solar collectors and separable solar thermal tank shall be exposed under a solar simulator with an irradiance equal to or greater than 800 W/m^2 at an ambient air temperature greater than or equal to 77°F (25°C).

301.3.2.4 Nonpressurized tank venting. Nonpressurized tanks shall be vented to atmospheric pressure with a total venting cross-sectional area of no less than 12 square inches. The reservoir vent shall not be connected to, or combined with, any other vents. Vents shall extend vertically not less than 6 inches above the reservoir fluid level. Vents shall be protected from contamination by means of an approved cap or U-bend installed with the opening directed downward. Vent openings shall be protected against the entrance of vermin and insects. Screen materials shall be compatible with contacting system components and shall not accelerate corrosion of system components.

301.3.2.5 Waterproofing. Unsheltered *storage tanks* shall be waterproofed to prevent water intrusion and damage.

301.3.3 Water heating equipment. Water heaters shall be listed and labeled to one of the standards listed in Table 301.3.3.

301.3.3.1 Shutdown. A means for disconnecting an electric hot water supply system from its energy supply shall be provided in accordance with NFPA 70. A separate valve shall comply with the mechanical code adopted by the authority having jurisdiction, or in the absence of such code, the *International Mechanical Code* or the *International Fuel Gas Code* and shall be provided to shut off the fuel supply to all other types of hot water supply systems.

301.4 Expansion tanks design criteria. Where expansion tanks are used to provide thermal expansion control in accordance with Section 301.1.3, expansion tanks used in a collector loop shall be sized to allow for compensation of pressure and volume increase caused by accumulation of thermal energy during operating, stagnation, and no-flow conditions, in accordance with Section 301.4.1. Thermal expansion tank components shall be compatible with the heat transfer fluid and rated for the fluid temperature and pressure at design conditions.

301.4.1 Expansion tank sizing. The required expansion tank volume shall demonstrate consideration of all of the following:

1. Total system volume shall be calculated for as-built conditions.
2. Calculation of total volume that can evaporate and turn to steam, including collectors and associated piping experiencing similar conditions for the heat transfer fluid contained therein.
3. Static pressure height calculated from the highest point in the collector loop to the location of the pressure relief device.
4. An additional 10 percent safety factor shall be used.
5. If the calculated size is greater than a readily available expansion tank, the next greater size shall be specified.
6. Expansion tanks used in single-phase systems shall be sized in accordance with the mechanical code adopted by the authority having jurisdiction, or, in the absence of such code, the *International Mechanical Code.*

301.5 Heat exchanger design criteria. *Heat exchangers* shall comply with Sections 301.5.1 through 301.5.2.

301.5.1 Double-wall heat exchangers. *Double-wall heat exchangers* shall be required. *Double-wall heat exchanger* design shall be such that any failure of a barrier will allow the discharge of *heat transfer fluid* or potable water to the

TABLE 301.3.3
WATER HEATING EQUIPMENT

WATER HEATING EQUIPMENT	STANDARD
Electric water heaters	UL 174; UL 1453; UL 499
Oil-fired water heaters	UL 732
Solid-fuel-fired water heaters	UL 2523
Gas-fired water heaters	ANSI Z21.10.1/CSA 4.1; Z21.10.3/CSA 4.3

atmosphere. The discharge shall be readily observable and in accordance with Section 305.1.7.2.

Exception: *Single-wall heat exchangers* shall be permitted when in compliance with both of the following:

1. Fluids containing only components that are food grade are used in the system.
2. The maximum operating pressure of the nonpotable *heat transfer fluid* within the *heat exchanger* is less than the normal operating pressure of the *potable water* system.

301.5.2 Shutoff valves. Shutoff valves shall be installed on the supply and return side of each heat exchanger.

Exception: Shutoff valves shall not be required where *heat exchangers* are integral with *water heating equipment*, or are a component of a manufacturer's *water heating equipment* and *heat exchanger* packaged units that are capable of being isolated from the *solar thermal system* by the supply and return valves required by this section.

301.6 Controller subsystem design criteria. Controller subsystems for *solar thermal systems* shall comply with Sections 301.6.1 through 301.6.4.

301.6.1 General. *Controller subsystems* shall facilitate installation, startup, operation, shutdown and maintenance of the solar thermal system. The *controller subsystem* shall include provisions for bypass, adjustment and override as established in a design evaluation in accordance with the requirements of this standard. Safety controls shall not have provision for bypass or override. Operational controls and means of disconnect and their function shall be labeled and readily accessible in accordance with the NFPA 70. Wires and connections, sensors, pneumatic lines, hydraulic lines or other means for transmitting sensor outputs to control devices shall be sufficiently protected from degradation or from introducing false signals as a result of environmental or system operating conditions.

301.6.2 Sensors. Sensors shall be installed in accordance with the *controller subsystem* design.

301.6.3 Wiring identification. Control circuit wiring and terminals shall be identified in accordance with NFPA 70.

301.6.4 Temperature rating for sensor wiring. Sensor wiring shall be rated in accordance with NFPA 70.

301.7 Thermostatic mixing valve. Where hot water is supplied to a potable hot water distribution system for domestic use, a master thermostatic mixing valve complying with ASSE 1017 shall be provided to reduce water temperature to defined limits.

301.7.1 Thermostatic mixing valve location. The thermostatic mixing valve shall be placed upstream of *auxiliary heating equipment* not rated for solar storage temperatures.

301.8 Plumbing and piping design criteria. Plumbing and piping shall comply with Sections 301.8.1 through 301.8.13. Piping shall be installed in accordance with the plumbing code and mechanical code adopted by the authority having jurisdiction, or, in the absence of such code, the *International Plumbing Code* and *International Mechanical Code*.

301.8.1 Protection of piping. Exterior piping insulation shall be protected from ultraviolet radiation and moisture damage and shall be for outdoor use. The exterior of piping shall be protected from corrosion and degradation.

301.8.2 Potable piping materials and standards. Water distribution pipe shall comply with Section 303.1.5 and at least one of the standards listed in Table 301.8.2. Hot water distribution pipe and tubing shall have a pressure rating of not less than 100 psi (690 kPa) at 180°F (82°C).

301.8.3 Nonpotable piping materials standards. Piping for nonpotable fluids shall conform to the standards listed in Table 301.8.3.

301.8.4 Potable pipe fittings. Pipe fittings shall conform to the respective pipe standards or to the standards listed in Table 301.8.4 and Section 303.1.5.

301.8.5 Nonpotable pipe fittings. Pipe fittings shall conform to the respective pipe standards or to the standards listed in Table 301.8.5.

301.8.6 Joints and connections. Joints and connections shall be of an *approved* type. Joints and connections shall be listed for the pressure of the hydronic system. Joints between different piping materials shall be made with *approved* adapter fittings.

301.8.7 Protection from foreign substances. The system shall be protected to prevent contamination by foreign substances that could impair the flow, quality, and safety of the system.

301.8.8 Insulation. Insulation shall be used on all solar system fluid piping and ducts and the final 1.5 meters (5.0 feet) of metallic cold water supply pipe leading into the system, or the length of piping that is exposed if less than 1.5 meters. Insulation shall have a value of R-0.46 °K • m^2/W (R-2.6 °F-ft^2-hr /Btu) or greater.

Exception: Nonmetallic pipe and fittings approved for outdoor use that are exposed to solar radiation commensurate with the solar collector and contribute to the collection of energy.

301.8.9 Water shutoff. The *solar thermal system* shall have valves to provide for shutoff from the service water supply without interrupting cold water service to the remaining portion of the water distribution system.

301.8.10 Service connections. Connections shall be provided with access for filling, draining and flushing liquid systems.

301.8.11 Filters. Where filters are used in solar thermal systems, they shall be provided with *access* so that they can be cleaned or replaced without cutting or altering the solar thermal piping system or requiring the removal of adjacent equipment or other piping. The maintenance instructions shall be provided in the applicable installation, operation or maintenance section of the system manual provided by the manufacturer.

TABLE 301.8.2
POTABLE WATER PIPE

MATERIAL	STANDARD
Brass pipe	ASTM B43
Chlorinated polyvinyl chloride (CPVC) plastic pipe and tubing	ASTM D2846; ASTM F441; ASTM F442; CSA B137.6
Copper or copper-alloy pipe	ASTM B42; ASTM B302
Copper or copper-alloy tubing (Type K, WK, L, WL, M or WM)	ASTM B75; ASTM B88; ASTM B251; ASTM B447
Cross-linked polyethylene (PEX) plastic tubing	ASTM F876; ASTM F 877; CSA B137.5
Cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX) pipe	ASTM F1281; ASTM F2262; CSA B137.10M
Cross-linked polyethylene/aluminum/high-density polyethylene (PEX-AL-HDPE)	ASTM F986
Ductile iron pipe	AWWA C151/A21.51; AWWA C115/A21.15
Galvanized steel pipe	ASTM A53
Polyethylene/aluminum/polyethylene (PE-AL-PE) composite pipe	ASTM F1282
Polyethylene of raised temperature (PE-RT) plastic tubing	ASTM F2769
Polypropylene (PP) plastic pipe or tubing	ASTM F2389; CSA B137.11
Stainless steel pipe (Type 304/304L)	ASTM A312; ASTM A778
Stainless steel pipe (Type 316/316L)	ASTM A312; ASTM A778

TABLE 301.8.3
NONPOTABLE WATER PIPE

MATERIAL	STANDARD
Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D1527; ASTM D2282
Brass pipe	ASTM B43
Brass tubing	ASTM B135
Copper or copper-alloy pipe	ASTM B42; ASTM B302
Copper or copper-alloy tube (Type K, L or M)	ASTM B75; ASTM B88; ASTM B251
Chlorinated polyvinyl chloride (CPVC) plastic pipe	ASTM D2846; ASTM F441; ASTM F442
Cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX) pressure pipe	ASTM F1281; CSA CAN/CSA-B-137.10
Cross-linked polyethylene (PEX) tubing	ASTM F876; ASTM F877
Ductile iron pipe	AWWA C151/A21.51; AWWA C115/A21.15
Flexible stainless steel pipe	ASME A112.18.6; ISO 10380
Hoses containing rubber	ASTM D750; ASTM D471; ASTM D1149
Lead pipe	FS WW-P-325B
Polybutylene (PB) plastic pipe and tubing	ASTM D3309
Polyethylene/aluminum/polyethylene (PE-AL-PE) pressure pipe	ASTM F1282; CSA B137.9
Polyethylene (PE) pipe, tubing and fittings (for ground source heat pump loop systems)	ASTM D2513; ASTM D3035; ASTM D2683; ASTM F1055; ASTM D2837; ASTM D3350; ASTM D1693
Polypropylene (PP) plastic pipe	ASTM F2389
Polyvinyl chloride (PVC) plastic pipe	ASTM D1785; ASTM D2241
Raised temperature polyethylene (PE-RT)	ASTM F2623; ASTM F2769
Steel pipe	ASTM A53; ASTM A106
Steel tubing	ASTM A254
Stainless steel pipe (Type 304/304L)	ASTM A312; ASTM A778
Stainless steel pipe (Type 316/316L)	ASTM A312; ASTM A778

TABLE 301.8.4
POTABLE PIPE FITTINGS

MATERIAL	STANDARD
Acrylonitrile butadiene styrene (ABS) plastic	ASTM D2468
Cast-iron	ASME B16.4; ASME B16.12
Chlorinated polyvinyl chloride (CPVC) plastic	ASSE 1061; ASTM D2846; ASTM F37; ASTM F438; ASTM F439; CSA B137.6
Copper or copper alloy	ASSE 1061; ASME B16.15; ASME B16.18; ASME B16.22; ASME B16.23; ASME B16.26; ASME B16.29
Cross-linked polyethylene/aluminum/high-density polyethylene (PEX-AL-HDPE)	ASTM F1986
Fittings for cross-linked polyethylene (PEX) plastic tubing	ASSE 1061; ASTM F877; ASTM F1807; ASTM F1960; ASTM F2080; ASTM F2098; ASTM F2159; ASTM F2434; ASTM F2735; CSA B137.5
Fittings for polyethylene of raised temperature (PE-RT) plastic tubing	ASTM F1807; ASTM F2098; ASTM F2159; ASTM F2735
Gray iron and ductile iron	AWWA C110/A21.10; AWWA C153/A21.53
Insert fittings for polyethylene/aluminum/polyethylene (PE-AL-PE) and cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX)	ASTM F1974; ASTM F1281; ASTM F1282; CSA B137.9; CSA B137.10M
Malleable iron	ASME B16.3
Metal (brass) insert fittings for polyethylene/aluminum/polyethylene (PE-AL-PE) and cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX)	ASTM F1974
Polyethylene (PE) plastic pipe	ASTM D2609; ASTM D2683; ASTM D3261; ASTM F1055; CSA B137.1
Polypropylene (PP) plastic pipe or tubing	ASTM F389; CSA B137.11
Polyvinyl chloride (PVC) plastic	ASTM D2464; ASTM D2466; ASTM D2467; CSA B137.2; CSA B137.3
Stainless steel (Type 304/304L)	ASTM A312; ASTM A778
Stainless steel (Type 316/316L)	ASTM A312; ASTM A778
Steel	ASME B16.9; ASME B16.11; ASME B16.28

TABLE 301.8.5
NONPOTABLE PIPE FITTINGS

MATERIAL	STANDARD
Brass	ASTM F1974
Bronze	ASME B16.24
Copper and copper alloys	ASME B16.15; ASME B16.18; ASME B16.22; ASME B16.23; ASME B16.26; ASME B16.29
Ductile iron and gray iron	ANSI/AWWA C110/A21.10
Ductile iron	ANSI/AWWA C153/A21.53
Gray iron	ASTM A126
Malleable iron	ASME B16.3
PEX fittings	ASTM F877; ASTM F1807; ASTM F2159
Plastic	ASTM D2466; ASTM D2467; ASTM D2468; ASTM F438; ASTM F439; ASTM F877; ASTM F2389; ASTM F2735
Steel	ASME B16.5; ASME B16.9; ASME B16.11; ASME B16.28; ASTM A420

301.8.12 Piping systems. The piping system shall be provided with isolation valves that can be closed for the purpose of bypassing the *solar thermal system* thereby permitting operation of the *auxiliary heating equipment* when the *solar thermal system* is inoperative or being serviced.

301.8.13 Entrapped air. Means shall be provided for air and gas removal from the piping system. Open loop circulating systems using potable water as the *heat transfer fluid* shall use an automatic means of air removal. Closed loop systems shall use manual or automatic means of air removal.

Exception: Where allowed by system design, including but not limited to integral collector storage, direct thermosiphon, or drain-back systems.

SECTION 302
RELIABILITY AND DURABILITY

302.1 General. *Solar thermal system*s shall comply with Sections 302.1.1 through 302.1.13.

302.1.1 Stagnation. The system shall be able to withstand *stagnation* without degradation of performance and with no maintenance. This requirement includes conditions that occur during loss of electric power to the system.

302.1.2 Solar degradation. Components or materials exposed to sunlight shall not be affected by exposure to sunlight to an extent that will deteriorate their function beyond design specifications during their design life.

302.1.3 Operation conditions. Solar thermal system components shall be capable of operating within manufacturer's specified pressure and temperature ranges and shall be capable of withstanding environmental extremes anticipated in actual service without reducing the *design life* of the system.

302.1.4 Incompatible materials. Incompatible materials shall be isolated or treated to prevent degradation to the extent that their function could be impaired under in-service conditions.

302.1.5 Freeze protection. Protection from freezing temperatures shall be provided for all system components subject to damage. The supplier shall specify a *freeze tolerance limit* for each system. Solar thermal systems shall comply with Section 302.1.5.1 through 302.1.5.3.

Exception: Systems installed in a location that has no record of an ambient temperature below 5°C (41°F) shall be exempted from the requirements of this paragraph, except the specification of a freeze tolerance limit.

302.1.5.1 Water exposed to freezing temperatures. For solar thermal systems where water is exposed to freezing temperatures, a minimum of two freeze protection mechanisms shall be provided on each system. Manual intervention in accordance with Section 302.5.2 shall be considered as one mechanism. Other acceptable mechanisms include but are not limited to thermal mass (protection, but protection is limited to the thermal capacitance of the system), automatic draining, and closed-loop recirculation (with uninterruptible power supply).

302.1.5.2 Manual intervention freeze protection. For solar thermal systems that rely on manual intervention for freeze protection, not less than one freeze protection mechanism shall be provided to protect components from freeze damage under all conditions, including in the event of power failure. Acceptable manual intervention actions include but are not limited to:

1. Draining: A system in which components and/or piping are subject to damage by freezing shall have the proper fittings, pipe slope and collector design to allow for manual gravity draining and air filling of the affected components and piping. Pipe slope for gravity draining shall have a minimum 2 cm vertical drop for each meter of horizontal length ($^1/_4$ inch per foot). This also applies to any header pipes or absorber plate riser tubes internal to the collector.
2. Valve position adjustments: Valves must be labeled in accordance with Section 302.1.5.3.

302.1.5.3 Labeling. A conspicuously placed label shall be attached to the system explaining how the system is protected from freezing and what actions are required to prevent freeze damage and further leakage if rupture occurs. For systems that rely on manual intervention for freeze protection, this label shall indicate the *freeze tolerance limit* below which manual intervention is required and the procedure to be followed.

302.1.6 Protection from leaks. Piping in a solar water heating system shall pass a leak test in accordance with the plumbing code adopted by the authority having jurisdiction, or in the absence of such code, the *International Plumbing Code*, for direct systems; or the mechanical code adopted by the authority having jurisdiction, or in the absence of such code, the *International Mechanical Code*, for indirect systems.

302.1.7 Fluid compatibility. Fluids in contact with *solar thermal system* materials shall not corrode or otherwise adversely affect system materials to the extent that their function will be impaired beyond design specifications during the system *design life*.

302.1.8 Deterioration of fluids. Fluids shall not freeze, give rise to precipitation or otherwise lose their homogeneity, boil or develop vapor pressure, change absorptivity, or change pH, viscosity or thermal properties beyond design ranges when exposed to their maximum and minimum service temperatures and pressures during the *heat transfer fluid design life*.

Exception: When the system design allows for these conditions.

302.1.9 Thermal storage system. Materials comprising a thermal storage system shall not cause corrosive wear that would result in premature failure or degradation in performance greater than that specified within the system.

302.1.10 Buried components. Solar thermal system components and materials that are intended to be buried in soils shall be protected from degradation under in-service condi-

tions to ensure that their function is not impaired during the system *design life.*

302.1.11 Deterioration protection. Gaskets, sealants, and coupling hoses shall not be adversely affected by contact with fluids or the environment to an extent that will impair beyond design specifications their ability to function during the system *design life*.

302.1.12 Water hammer. Where an incompressible liquid is used as the *heat transfer fluid* and quick-closing valves are employed in the design, the piping system shall be able to control or withstand the effects of water hammer.

302.1.13 Sound and vibration control. Piping and associated fittings shall be designed to carry the *heat transfer fluid* at design flow rates without degradation during the system *design life*. Components involving moving parts shall be balanced or mounted in such a manner that they do not induce vibration that could cause damage during the system *design life.*

SECTION 303
SAFETY CRITERIA

303.1 General. *Solar thermal system*s shall comply with Sections 303.1.1 through 303.1.9.

303.1.1 Protection of electrical components. Overload and overcurrent protection of electrically operated components shall be consistent with the maximum current rating of the device and NFPA 70.

303.1.2 System failure prevention. The system shall be designed so that, in the event of a power failure or a failure of any of the system components, the temperatures, pressures, or other conditions developed in the *solar thermal system* will not damage the system, or the building, or endanger its occupants.

303.1.3 High temperature control. Means shall be provided to limit the temperatures of the components to values not to exceed high temperature limits specified by the supplier. Pressure/temperature relief valves shall not be used for this purpose.

303.1.4 Protection against auto-ignition of combustibles. Combustible materials used in solar equipment shall not be exposed to temperatures that could cause ignition.

303.1.5 Protection of potable water from contamination. Materials that come in direct contact with *potable water* shall not adversely affect the taste, odor or physical quality and appearance of the water and shall comply with NSF 61 and NSF 372, and shall have a weighted average lead content of 0.25 percent or less.

303.1.6 Fluid safety. Heat transfer fluids used within *solar thermal systems* shall comply with Section 303.1.6.1 through 303.1.6.6.

303.1.6.1 Food grade fluid additives. Any *food grade fluid* used as a heat transfer fluid containing additives shall be third-party tested by an approved agency to the appropriate section of the *Code of Federal Regulations, Title 21, Food and Drugs, Chapter 1, Food and Drug Administration, Parts 174–186.*

303.1.6.2 Combustible and flammable fluids. The storage, piping and handling of combustible and flammable fluids shall conform to the requirements of the *International Fire Code.*

303.1.6.3 Flash point. The flash point of a heat transfer fluid shall exceed by 28ºC (50ºF), or more, the design maximum no-flow temperature to be reached by the fluid in the collector. The flash point shall be determined in accordance with the *International Fire Code*. In systems using a gaseous heat transfer fluid, a flammable gas shall not be used.

303.1.6.4 Toxicity. The use of *toxic fluids* shall comply with the *Title 15 of the Federal Hazardous Substances Act,* Chapter 60 of the *International Fire Code*, and the requirements of the local jurisdiction.

303.1.6.5 Fluid safety labeling. *Solar thermal systems* shall be provided with labels indicating heat transfer fluid classes used as defined in Section 202. Labels shall identify the drain and fill valves in the *solar thermal system.* Each label shall identify the fluid in that loop. The location of fluid handling instructions shall be referenced. Labeling shall categorize the heat transfer fluid with one of the following: "Potable Water," "Food Grade," "Non-Food Grade," or "Toxic." Labeling shall also be provided that reads as follows: "Fluid could be discharged at high temperature or pressure, or both. Fluids shall not be used that would change the original classification of this system. Unauthorized alterations to this system could result in a health hazard or hazardous condition."

303.1.6.6 Heat exchanger labeling. Heat exchangers shall be labeled to indicate the heat exchanger type as follows:

1. "Single-wall without leak protection"
2. "Double-wall with no leak protection"
3. "Double-wall with leak protection"

303.1.7 Backflow. Means shall be provided to prevent the backflow of nonpotable fluids, solids or gases into the potable water system through cross-connections or any other piping connections to the system.

303.1.8 Pressure relief. Each portion of the system where excessive pressures can develop shall be protected by a pressure relief device. Means of rendering a pressure relief device ineffective shall not be allowed under this standard. A section shall not be isolated from a pressure relief device. Automatic pressure relief devices shall be designed to open at or below the maximum design pressure of the system device that has the lowest pressure rating.

303.1.9 Occupant protection. System subassemblies and components that are exposed to the public and are maintained at elevated temperatures shall be insulated to maintain exposed surface temperatures below 49ºC (120ºF) during operation, or they shall be isolated.

SECTION 304
OPERATION AND SERVICING CRITERIA

304.1 General. *Solar thermal system*s shall comply with Sections 304.1.1 through 304.1.6.

304.1.1 Operating indicators. *Solar thermal system*s shall include means for an observer to readily determine that the system is operating properly.

304.1.2 Tanks. Tanks shall be labeled to indicate the maximum operating pressure and temperature.

304.1.3 Waste disposal. Where fluid is automatically discharged in systems using a *toxic heat transfer fluid*, a means shall be provided for the catchment and removal of these fluids in accordance with *Title 15 of the Federal Hazardous Substances Act*, Chapter 60 of the *International Fire Code*, and the requirements of the local jurisdiction.

304.1.4 Dirt retention and staining. Solar thermal systems and collectors shall be accessible for periodic cleaning if conditions are such that self-cleaning by rain will not keep the collectors operating efficiently.

304.1.5 Maintenance and servicing. Access to individual components of the system that require periodic examination, adjustment, service or maintenance shall be provided in accordance with the plumbing code and mechanical code adopted by the authority having jurisdiction, or in the absence of such code, the *International Plumbing Code* and *International Mechanical Code*.

304.1.6 Permanent maintenance accessories. Permanent maintenance accessories shall be provided, including but not limited to hose bibbs and drains necessary for maintenance of the system. Where accessories are in contact with potable water, they shall be protected against backflow in accordance with Section 303.1.8.

SECTION 305
INSTALLATION CRITERIA

305.1 General. *Solar thermal system*s shall comply with Sections 305.1.1 through 305.1.18.

305.1.1 Penetrations of floor/ceiling assemblies and fire-resistance-rated assemblies. Penetrations of floor/ceiling assemblies and assemblies required to have a fire-resistance rating shall be protected in accordance with the International Building Code.

305.1.2 Auxiliary heating equipment. Interconnection of the *auxiliary heating equipment* to the solar energy system shall be made in a manner that will not result in temperatures or pressures beyond design specifications in the auxiliary heating equipment or bypassing of safety devices in the auxiliary heating equipment.

305.1.3 Component placement. Components of a solar water heating system that, during operating conditions, will increase or decrease humidity, temperature or thermal radiation, beyond acceptable levels for building materials, shall be identified in the installation, operation and maintenance manuals with properly stated clearance requirements to maintain acceptable levels.

305.1.4 Access. The location of solar components shall not impair access needed to maintain and protect the building or site.

305.1.5 Building penetrations. Penetrations of the building through which piping or wiring is passed shall not reduce or impair the function of the enclosure. Penetrations through walls or other surfaces shall not allow intrusion by insects and vermin. Required roof penetrations shall be made in accordance with the *International Building Code*.

305.1.6 Water damage. Collectors and supports shall be installed in such a manner that water flowing off the collector surface will not damage the building or cause erosion of the roof beyond design specifications.

305.1.6.1 Required pan. Where a storage tank-type water heater or a hot water storage tank is installed in a location where water leakage from the tank will cause damage, the tank shall be installed in a galvanized steel pan having a material thickness of not less than 0.0236 inch (0.6010 mm) (No. 24 gage), or other pans approved for such use.

305.1.6.2 Pan size and drain. The pan shall be not less than $1^1/_2$ inches (38 mm) in depth and shall be of sufficient size and shape to receive all dripping or condensate from the tank or water heater. The pan shall be drained by an indirect waste pipe having a diameter of not less than $^3/_4$ inch (19 mm). Piping for safety pan drains shall be of those materials listed in Table 301.8.3 or Table 301.8.4.

305.1.6.3 Pan drain termination. The pan drain shall extend full-size and terminate over a suitably located indirect waste receptor or floor drain or extend to the exterior of the building and terminate not less than 6 inches (152 mm) and not more than 24 inches (610 mm) above the adjacent ground surface.

305.1.7 Relief valve discharge. Solar energy system components containing pressurized fluids shall be protected against pressures and temperatures exceeding design limitations with a pressure and temperature relief valve. Each section of the system in which excessive pressures are capable of developing shall have a relief device located so that a section cannot be isolated from a relief device. Relief valves shall comply with the requirements of Section 305.1.7.1 and discharge in accordance with Section 305.1.7.2.

Exception: Solar energy system collector loops containing pressurized fluids, and separated from a domestic water source by an approved heat exchanger, shall be protected against pressures exceeding design limitations with a pressure relief valve.

305.1.7.1 Safety and safety relief valves. Safety and safety relief valves shall be listed and labeled, and shall have a minimum rated capacity for the equipment or appliances served.

305.1.7.2 Discharge pipes. Safety and relief valve discharge pipes shall be of rigid pipe that is approved for the temperature of the system. The discharge pipe shall be the same diameter as the safety or relief valve outlet.

Safety and relief valves shall not discharge so as to be a hazard, a potential cause of damage or otherwise a nuisance. Relief valves in partially filled collector loops capable of producing steam shall be discharged to the outside of the structure. Where a relief valve discharges inside a structure or to the drainage system, the installation shall conform to the plumbing code adopted by the authority having jurisdiction or, in the absence of such code, the *International Plumbing Code*. Where a solar thermal system component requiring a relief valve is located outside the structure, the termination shall be not more than 6 inches (152 mm) above a splash block, a secured surface material or catchment method to prevent damage.

305.1.8 Structural supports. Neither wind loading, including uplift, nor the additional weight of filled collectors and tanks shall exceed the live or dead load ratings of the building, roof, roof anchorage, foundation or soil. Collector supports shall not impose stresses on the collectors beyond design specifications. The design load shall be as specified by the codes in force at the installation site and shall include an additional load for snow accumulation for applicable locations.

305.1.8.1 Expansion and contraction of supports. Structural supports shall be selected and installed in such a manner that thermal expansion of the collector and piping will not cause damage to the collector structural frame or the building.

305.1.9 Penetration of structural members. Where penetrations are required in structural members to accommodate passage of solar components, such modified structural members shall comply with the plumbing code and mechanical code adopted by the authority having jurisdiction or, in the absence of such code, the *International Plumbing Code* and *International Mechanical Code*, as applicable.

305.1.10 Protection from thermal deterioration. Building materials adjacent to solar equipment shall not be exposed to elevated temperatures that could accelerate their deterioration.

305.1.11 Tilt and azimuth. Collectors shall be installed on a mount capable of maintaining tilt and azimuth to design conditions.

305.1.12 Shading of collector. The location and orientation of collectors shall be such that they are not shaded by external obstructions or each other more than the specified period allowed in the design.

305.1.13 Pipe and component supports. Piping shall be installed and supported in accordance with the plumbing code and mechanical code adopted by the authority having jurisdiction or, in the absence of such code, the *International Plumbing Code* and *International Mechanical Code*. Hangers shall provide support and maintain slope of pipes. Hangers or supports for insulated pipes and components shall be designed to not compress or damage the insulation material. Hangers shall not cause galvanic corrosion of the hanger or the pipe.

305.1.14 Underground piping. Underground piping material shall conform to Section 301.8.2 or 301.8.3. Underground piping subject to vehicular traffic shall be installed to withstand the additional loading applied by such traffic. The trenches and backfill shall be free of sharp objects in contact with the pipe.

305.1.15 Control sensor installation. Control sensors and the means for transmitting sensor outputs to control devices shall be protected from environmental influence such as wind, moisture, temperature, ultraviolet radiation, and other factors that have the potential to adversely affect accuracy.

305.1.16 Emergency egress and access. The design and installation of systems shall not impair egress of the building occupants.

305.1.17 Rain and snow on collector. The location, orientation, and position of collectors relative to nearby objects and surfaces shall be such that water run-off from the collector surface is not impeded and excessive build-up of snow on lower portions of the collector glazing is not permitted to occur.

305.1.18 Lightning protection. Lightning protection shall be provided for collectors in accordance with NFPA 780.

SECTION 306
MANUAL CRITERIA

306.1 General. *Solar thermal system*s shall comply with Sections 306.1.1 through 306.1.5.

306.1.1 Provision for manuals. A manual or manuals shall be provided with each *solar thermal system*. The manual shall contain the name and address of the system supplier, the system model name or number and shall describe the operation of the system and its components and the procedures for installation, operation and maintenance in accordance with Sections 306.1.1.1 through 306.1.1.3.

306.1.1.1 Installation instructions. The manuals shall include an explanation of the physical and functional requirements of the system and its components and the general procedures for their proper installation. The instructions shall describe the interconnection requirements of the various subsystems and components and their interface requirements with the building and the site. Installation instructions shall prescribe installation complying with the building code, plumbing code, mechanical code, and fire code adopted by the authority having jurisdiction or, in the absence of such codes, with the *International Building Code*, *International Plumbing Code*, *International Mechanical Code*, and *International Fire Code.*

306.1.1.2 Operation instructions. The manual shall:

1. Clearly describe the operation of the *solar thermal system*, explaining the function of each subsystem and component. The manual shall also include a system diagram showing the components and their relationships in the typical installed system and list the system manufacturer's design flow range in each collector bank.

2. Describe major components in a separate section or by enclosing descriptive material furnished by the supplier of the components.
3. Describe procedures for system start-up, routine maintenance and special conditional operations such as drain-down.
4. Specify fill weights, pressure ratings and temperature ratings for servicing and routine maintenance of the system.
5. Specify temperature, pressure and flow conditions expected at various access points to allow simple operational checks and troubleshooting.
6. Include instructions for isolating different sections of the system in emergency situations and include instructions for leaving the system unattended and unused for long periods of time.
7. Indicate the *freeze tolerance limit* and freezing control measures and include the statement: "Freeze tolerance limits are based upon an assumed set of environmental conditions." Where the freezing point of the fluid in an exposed part of the system is above the freeze tolerance limit specified for the system, the following statement shall be provided: "Extended periods of cold weather, including ambient air temperatures above the specified limit, might cause freezing in exposed parts of the system. It is the owner's responsibility to protect the system in accordance with the supplier's instructions if the air temperature is anticipated to approach the specified freeze tolerance limit."
8. Be provided at the installation site.

306.1.1.3 Maintenance plan. The manual shall include a comprehensive plan for maintaining the specified performance of the *solar thermal system* over the *design life* of the system. The plan shall include a schedule and description of procedures for ordinary and preventive maintenance including cleaning of collector exterior surfaces. The manual shall describe minor repairs and provide projections for component replacement.

306.1.2 Fluid quality. The manual shall identify *heat transfer fluid(s)* used in the *solar thermal system* and state whether or not the fluid(s) are toxic or hazardous. Proper procedures for handling, safe disposal, and first aid shall be provided for each non-water fluid. A technical data sheet shall be provided for each non-water fluid or additives for water used in the system. Procedures shall be described for maintaining the heat transfer fluid's chemical composition at levels that prevent deposits on the heat transfer surfaces that are beyond design specifications, corrosion of the heat transfer surfaces and loss of freeze resistance. Recommended inspection and test intervals for the heat transfer fluid shall be provided.

306.1.3 Service and replacement parts. The manual shall include a parts list with a sufficient description of each part for ordering a replacement. Parts, components and equipment required for service, repair or replacement shall be commercially available or available from the system or subsystem supplier. The manual shall list on the same page of both the installation and operation manuals the make and model of all options for the following components: solar collector, solar storage tank, pump, piping material, controller, heat exchanger, and heat transfer fluid. This page shall also include temperature, pressure, and flow conditions expected at system monitoring points to allow simple operational checks. The number and piping connection arrangement of the solar collectors shall be included. The manual shall include contact information for not less than one company in close geographic proximity to the purchaser that offers service for the system.

306.1.4 Hazards. The manual shall provide warning against health and safety hazards that could arise in the operation and maintenance of the system and shall fully describe the precautions that must be taken to avoid these hazards.

306.1.5 Warranty coverage. The manual shall provide a full description of the warranty coverage on the system. The manual shall describe what actions the purchaser must undertake to obtain warranty coverage.

SECTION 307
PUMP STATIONS

307.1 General. The performance of a *pump station* that is comprised of multiple components can be evaluated separately from a complete solar thermal system if the performance of the individual pump station components working together as one is known. Pump stations shall comply with Sections 307.2 through 307.21.2.

307.2 Controller. The pump station controller shall comply with Section 301.6.

307.3 Wiring identification. Pump station wiring shall comply with Section 301.6.3.

307.4 Protection of electrical components. Electrical components in a pump station shall comply with Section 303.1.1.

307.5 Pump station failure. The pump station shall comply with Section 303.1.2. The pump station shall remain in a secure state and keep the freezing and overheating protection mechanisms operable when tested in accordance with Sections 307.5.1 through 307.5.3.

307.5.1 Operating conditions. Pumps shall be tested under operating conditions for the duration of the test.

307.5.2 Failure mode. Failure of the temperature sensors shall be simulated by short circuiting all sensors and opening the circuit one sensor at a time and then simultaneously together.

307.5.3 Operation verification. Operation state or mode of the station shall be verified.

307.6 Piping and fittings. Piping shall comply with Sections 301.8.2 and 301.8.3. Fittings shall comply with Sections 301.8.4 and 301.8.5.

307.7 Service connections. Pump station service connections shall comply with Section 301.8.10.

307.8 Solar thermal system isolation. Isolation valves that can be closed for the purpose of isolating the solar thermal system shall be listed and labeled by a recognized third-party listing agency.

307.9 Fluid system sizing. Pumps, piping, fans, ducts and other components shall comply with Section 301.1.6.

307.10 Pressure drop and vibration. Pump stations shall comply with Section 301.1.7. Except for the higher startup flow rate needed in a *drain-back* system to establish a siphon, the instantaneous flow rate within the pump station shall not exceed 10 percent of average flow to maintain the proper design flow rate of the heat transfer fluid through the *solar thermal system*.

307.11 Contamination of potable water. Pump stations shall comply with Section 303.1.5.

307.12 Fluid compatibility. Pump stations shall comply with Section 302.1.7.

307.13 Pressure integrity test. The pressure integrity test shall be conducted in accordance with the following procedure. The piping components pass the test where observable pressure change has not occurred.

1. The pressure gauge shall be attached to the exit port of the pump station and the outlet shall be sealed.
2. The supply side shall be filled with unheated water.
3. The test pressure shall be 1110 kPa gauge (160 psig).
4. Hydraulic pressure shall be applied to the inlet port until the gauge indicates the test pressure has been reached.
5. The inlet pressure port shall be closed and the pressure monitored for 15 minutes.
6. The final pressure shall be recorded.

307.14 Thermostatic mixing valve. Thermostatic mixing valves in pump stations shall comply with Section 301.7.

307.14.1 Thermostatic mixing valve location. The location of all thermostatic mixing valves in a pump station shall comply with Section 301.7.1.

307.15 Components. Temperature and pressure control valves and devices used in pump stations shall be listed and labeled by recognized third-party listing agencies.

307.16 High temperature control. High temperature control in pump stations shall comply with Section 303.1.3.

307.16.1 Temperature-limiting system test. Temperature-limiting system testing shall comply with the following procedure. The system passes the test when the pump station disables any heat input device when the maximum temperature limit is exceeded.

1. Pumps shall be tested under operating conditions for the duration of the test.
2. The pump station shall be connected to a suitable heating source that can supply the target temperature.
3. The heating source output temperature shall be set not less than 5°C (10°F) above the maximum temperature limit specified by manufacturer.
4. The pump station shall be observed during testing.

307.17 Expansion tanks. Expansion tanks in pump stations shall comply with Section 301.4.

307.18 Heat exchangers. Heat exchangers in pump stations shall comply with Section 301.5.

307.19 Reliability and durability. Pump stations shall comply with Section 302 of this standard, as applicable.

307.20 Combustible materials. Combustible materials used in pump stations shall comply with Section 303.1.4.

307.21 Labeling and manuals. Pump stations shall be labeled with the manufacturer's contact information or trademark, a model name or number, the recommended working fluids, the maximum working temperature and pressure and the recommended flow rates.

307.21.1 Labels. Warning lights, switches and controls in pump stations shall be clearly identified. Where the pump station includes electrical components, the station shall be labeled with the electrical rating in volts, amperes and motor phase.

307.21.2 Manuals and instructions. Pump stations' operation, maintenance, and installation instruction manuals from the manufacturer shall be supplied or made available. Manufacturer's contact information shall be included within these documents.

CHAPTER 4

REFERENCED STANDARDS

This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title and the section or sections of this document that reference the standard. The application of the referenced standards shall be as specified in Section 103.1.

ANSI

American National Standards Institute
25 West 43rd Street, Fourth Floor
New York, NY 10036

Standard reference number	Title	Referenced in code section number
Z21.10.1/CSA 4.1—13	Gas Water Heaters, Volume 1, Storage Water Heaters with Input Ratings of 75,000 Btu per Hour or Less	Table 301.3.3
Z21.10.3/CSA 4.3—13	Gas Water Heaters, Volume III, Storage Water Heaters with Input Ratings above 75,000 Btu per Hour, Circulating and Instantaneous	Table 301.3.3
ANSI Z21.22-1999 (R2014)	Relief Valves for Hot Water Supply Systems	301.3.1.3

ASME

American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990

Standard reference number	Title	Referenced in code section number
ASME Boiler and Pressure	Vessel Code 2013, Division 1, Section VIII, Rules for Construction of Pressure Vessels	301.3.2.1
ASME Boiler and Pressure	Vessel Code 2013, Section X, Fiber-Reinforced Plastic Pressure Vessels	301.3.2.1
ASME A112.18.6/ CSA B125.6—09	Flexible Water Connectors	Table 301.8.3
B16.3—11	Malleable Iron Threaded Fittings, Classes 150 & 300	Table 301.8.4
B16.4—11	Gray Iron Threaded Fittings Classes 125 and 250	Table 301.8.4
B16.5—13	Pipe Flanges and Flanged Fittings NPS 1/2 through NPS 24	Table 301.8.4
B16.9—12	Factory Made Wrought Steel Buttwelding Fittings	Table 301.8.4
B16.11—11	Forged Fittings, Socket-welding and Threaded	Table 301.8.4
B16.12—09	Cast Iron Threaded Drainage Fittings	Table 301.8.4
B16.15—11	Cast Bronze Threaded Fittings	Table 301.8.4
B16.18—12	Cast Copper Alloy Solder Joint Pressure Fittings	Table 301.8.4
B16.22—13	Wrought Copper and Copper Alloy Solder Joint Pressure Fittings	Table 301.8.4
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ASSE

American Society of Safety Engineers
1800 East Oakton Street
Des Plaines, IL 60018

Standard reference number	Title	Referenced in code section number
1017—10	Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems	301.7
1061—10	Performance Requirements for Removable and Non-Removable Push-Fit Fittings	Table 301.8.4

ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

Standard reference number	Title	Referenced in code section number
A53—12	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless	Table 301.8.2, Table 301.8.3
A106—13	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service	Table 301.8.3
A126—04 (R2014)	Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings	Table 301.8.4
A254—12	Standard Specification for Copper-Brazed Steel Tubing	Table 301.8.3
A312—14	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes	Table 301.8.2, Table 301.8.3, Table 301.8.4
A420—14	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service	Table 301.8.4
A778—09	Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products	Table 301.8.2, Table 301.8.3, Table 301.8.4
B42—10	Standard Specification for Seamless Copper Pipe, Standard Sizes	Table 301.8.2, Table 301.8.3
B43—10	Standard Specification for Seamless Red Brass Pipe, Standard Sizes	Table 301.8.2, Table 301.8.3
B75—11	Standard Specification for Seamless Copper Tube	Table 301.8.2, Table 301.8.3
B88—09	Standard Specification for Seamless Copper Water Tube	Table 301.8.2, Table 301.8.3
B135—10	Standard Specification for Seamless Brass Tube	Table 301.8.3
B251—10	Standard Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube	Table 301.8.2, Table 301.8.3
B302—12	Standard Specification for Threadless Copper Pipe, Standard Sizes	Table 301.8.2, Table 301.8.3
B447—12	Standard Specification for Welded Copper Tube	Table 301.8.2
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D750—12	Standard Practice for Rubber Deterioration Using Artificial Weathering Apparatus	Table 301.8.3
D1149—12	Standard Test Methods for Rubber Deterioration—Cracking in an Ozone Controlled Environment	Table 301.8.3
D1527—99 (2005)	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80	Table 301.8.3
D1693—13	Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics	Table 301.8.3
D1785—12	Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120	Table 301.8.3
D2282—99(2005)	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR)	Table 301.8.3
D2241—09	Standard Specification for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)	Table 301.8.3
D2464—15	Specification for Threaded Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80	Table 301.8.4
D2466—15	Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40	Table 301.8.4
D2467—15	Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80	Table 301.8.4
D2468—96a	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 40	Table 301.8.4
D2513—14	Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings	Table 301.8.3
D2609—15	Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe	Table 301.8.4
D2846—09	Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems	Table 301.8.2, Table 301.8.3, Table 301.8.4
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D3035—14	Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter	Table 301.8.3

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D3261—12	Specification for Butt Heat Fusion Polyethylene (PE) Plastic fittings for Polyethylene (PE) Plastic Pipe and Tubing . . . . . Table 301.8.4
D3309—02	Specification for Polybutylene (PB) Hot and Cold Water Distribution Systems . . . . . Table 301.8.3
D3350—12e1	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials . . . . . Table 301.8.3
F437—15	Specification for Threaded Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80 . . . . . Table 301.8.4
F438—15	Specification for Socket-type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40 . . . . . Table 301.8.4
F439—13	Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80 . . . . . Table 301.8.4
F441—13	Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80. . . . . Table 301.8.2 and Table 301.8.3
F442—13	Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe (SDR–PR). . . . . Table 301.8.2 and Table 301.8.3
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F1960—15	Specification for Cold Expansion Fittings with PEX Reinforcing Rings for use with Cross-linked Polyethylene (PEX) Tubing
F1986—11	Standard Specification for Multilayer Pipe Type 2, Compression Fittings, and Compression Joints for Hot and Cold Drinking-Water Systems . . . . . Table 301.8.2, Table 301.8.4
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F2389—10	Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems. . . . . Table 301.8.2, Table 301.8.3, Table 301.8.4, Table 301.8.5
F2434—09	Standard Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Cross-linked Polyethylene/Aluminum/ Cross-linked Polyethylene (PEX AL-PEX) Tubing . . . . Table 301.8.4
F2467—06 (R2013)	Standard Practice for Measuring Static Sealing Pressure Using Pressure-Indicating Film (PIF) in Transportation Applications. . . . . Table 301.8.4
F2468—05 (R2011)	Standard Classification for Specifying Silicone Adhesives and Sealants for Transportation Applications
F2623—08	Standard Specification for Polyethylene of Raised Temperature (PE-RT) SDR 9 Tubing. . . . . Table 301.8.3
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F2769—10	Standard Specification for Polyethylene of Raised Temperature (PE-RT) Plastic Hot and Cold-Water Tubing and Distribution Systems. . . . . Table 301.8.2, Table 301.8.3

AWWA

American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235

Standard reference number	Title	Referenced in code section number
C110/A21.10-2012	Standard for Ductile Iron & Gray Iron Fittings	Table 301.8.4
C115/A21.15—11	Flanged Ductile-Iron Pipe With Ductile-Iron or Gray-Iron Threaded Flanges	Table 301.8.2, Table 301.8.3
C151/A21.51—09	Ductile-Iron Pipe, Centrifugally Cast.	Table 301.8.2, Table 301.8.3
C153/A21.53-2011	Standard for Ductile-Iron Compact Fittings for Water Service	Table 301.8.4

CSA

Canadian Standards Association
8501 East Pleasant Valley
Cleveland, OH 44131-5516

Standard reference number	Title	Referenced in code section number
B137.1—13	Polyethylene (PE) Pipe, Tubing and Fittings for Cold Water Pressure Services.	Table 301.8.4
B137.2—13	Polyvinylchloride (PVC) Injection-moulded Gasketed Fittings for Pressure Applications.	Table 301.8.4
B137.3—13	Rigid Poly (Vinyl Chloride) (PVC) Pipe for Pressure Applications	Table 301.8.4
B137.9—09	Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure-Pipe Systems	Table 301.8.3, Table 301.8.4
B137.10—09	Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) composite Pressure-Pipe Systems	Table 301.8.2, Table 301.8.3, Table 301.8.4
B137.5—09	Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications	Table 301.8.2, Table 301.8.4
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CSA B137.11-09	Polypropylene (PP-R) Pipe and Fittings for Pressure Applications.	Table 301.8.2, Table 301.8.4

FS

Federal Specifications General Services Administration
7th & D Streets
Specification Section, Room 6039
Washington, DC 20407

Standard reference number	Title	Referenced in code section number
WW-P-325B—76	Pipe Bends, Traps, Caps and Plugs; Lead (for Industrial Pressure and Soil and Waste Applications)	Table 301.8.3

ICC

International Code Council, Inc.
500 New Jersey Ave, NW
6th Floor
Washington, DC 20001

Standard reference number	Title	Referenced in code section number
ICC 901/ SRCC Standard 100—15	Test Methods and Minimum Standards for Certifying Solar Collectors	301.2, 301.3.2, 301.3.2.3.1
IBC—12	International Building Code	305.1.1, 305.1.5, 306.1.1.1
IFC—12	International Fire Code.	303.1.6.3, 303.1.6.4, 304.1.3, 306.1.1.1
IFGC—12	International Fuel Gas Code.	301.3.3.1
IMC—12	International Mechanical Code	301.3, 301.3.3.1, 301.4.1, 301.8, 302.1.6, 304.1.5, 305.1.9, 305.1.13, 306.1.1.1
IPC—12	International Plumbing Code	301.3, 301.8, 302.1.6, 304.1.5, 305.1.7.2, 305.1.9, 305.1.13, 306.1.1.1

ISO

International Organization for Standardization
ISO Central Secretariat
1 ch, de la Voie-Creuse, Case Postale 56
CH-1211 Geneva 20, Switzerland

Standard reference number	Title	Referenced in code section number
10380—12	Pipework—Corrugated Metal Hoses and Hose Assemblies	
	Code of Federal Regulations, Title 21, Food and Drugs, Chapter 1, Food and Drug Administration, Parts 174-186. Federal Hazardous Substances Act, Title 15	Table 301.8.3

NFPA

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02169-7471

Standard reference number	Title	Referenced in code section number
70—14	National Electrical Code	301.3.3.1, 301.6.1, 301.6.3, 301.6.4, 303.1.1
780—14	Standard for the Installation of Lightning Protection Systems	305.1.19

NSF

NSF International
789 N. Dixboro
Ann Arbor, MI 48105

Standard reference number	Title	Referenced in code section number
NSF 61—13	Drinking Water System Components—Health Effects	303.1.5
NSF 372—11	Drinking Water System Components—Lead Content	303.1.5

UL

UL LLC
333 Pfingsten Road
Northbrook, IL 60062-2096

Standard reference number	Title	Referenced in code section number
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1453—11	Electric Booster and Commercial Storage Tank Water Heaters	Table 301.3.3
499—13	Electric Heating Appliances	Table 301.3.3
732—13	Oil-Fired Storage Tank Water Heaters	Table 301.3.3
2523—13	Oil-Fired Storage Tank Water Heaters	Table 301.3.3

ICC 901/ SRCC 100-2015

Solar Thermal Collector Standard

American National Standard

International Code Council
500 New Jersey Avenue, NW, 6th Floor
Washington, D.C. 20001

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American National Standard

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Consensus is established when, in the judgement of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

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FOREWORD

Introduction

The first version of SRCC Standard 100 was developed in 1981 by the Solar Rating and Certification Corporation (SRCC) as a result of efforts by a consortium including the U.S. Department of Energy, National Renewable Energy Laboratory (NREL), Interstate Renewable Energy Council (IREC), Florida Solar Energy Center (FSEC) and the Solar Energy Industry Association (SEIA). Since that time, the standard has been updated periodically by means of SRCC's standard development process. The consensus process used by SRCC was consistent with ANSI requirements for the development of voluntary consensus standards including balance of stakeholders, transparency and due process.

In 2013, SRCC and ICC agreed to collaborate to develop an updated version of the SRCC 100—2013 *Minimum Standards for Solar Thermal Collectors* and SRCC 600-2013 *Minimum Standard for Solar Thermal Concentrating Collectors* standards through ICC's ANSI-approved Standard Development process to seek designation as an American National Standard (ANS). With direction from ICC's Board of Directors and the SRCC Board of Directors, the ICC Standards Council appointed a consensus committee to develop a single updated standard to establish minimum requirements for safety, performance and testing of solar thermal collectors.

Development

This is the first edition of the International Code Council® (ICC®) 901/Solar Rating and Certification Corporation® (SRCC®) 100 *Solar Thermal Collector Standard*, but it is based substantially on the SRCC Standard 100—2013, SRCC 600-2013, and SRCC TM-1 *Solar Thermal Component Test and Analysis Protocol*. By incorporating the provisions for concentrating collectors from Standard 600, and the provisions for integrated collector storage (ICS) types from TM-1, this new version of Standard 100 addresses the widest possible range of collector types in a single document. This standard was developed by the ICC/SRCC Solar Thermal Standard Consensus Committee (IS-STSC) that operates under ANSI-approved ICC Consensus Procedures for the development of ICC standards.

The meetings of the IS-STSC Consensus Committee were open to the public and interested individuals and organizations from across the country participated. Views and objections were solicited through several public comment periods. All views and objections were considered by the consensus committee and an effort was made toward their resolution. A vote by the consensus committee approved this standard.

The requirements in ICC 901/SRCC 100—2015 are based on the intent to both update the long-established SRCC 100 standard and improve consistency with the latest model plumbing and mechanical codes in use. A task group specifically reviewed the provisions within the standard to eliminate any conflicts with codes and establish common terms and rigor. The resulting document provides appropriate protections for health, safety and welfare while avoiding unnecessary restrictions on the use of new materials, technologies or designs.

Adoption

ICC 901/SRCC 100, *Solar Thermal Collector Standard* is available for reference and use by jurisdictions in both codes and incentive programs internationally. It represents an update to SRCC Standard 100 and SRCC Standard 600 and is appropriate for use as a successor to those documents. Its use within a governmental jurisdiction is intended to be accomplished through adoption by reference in accordance with proceedings establishing the jurisdiction's law.

Interpretations

Requests for interpretations on the provisions of ICC 901/SRCC 100—2015 should be addressed to: ICC, Central Regional Office, 4051 Flossmoor Road, Country Club Hills, IL 60478.

Maintenance—Submittal of Proposals

All ICC standards are revised as required by ANSI. Proposals for revising this edition are welcome. Please visit the ICC website at www.iccsafe.org for the official "Call for Proposals" announcement. A proposal form and instructions can also be downloaded from www.iccsafe.org.

ICC, SRCC, its members and those participating in the development of ICC 901/SRCC 100—2015 do not accept any liability resulting from compliance or noncompliance with the provisions of ICC 901/SRCC 100—2015. Neither ICC nor SRCC have the power or authority to police or enforce compliance with the contents of this standard. Only the governmental body that enacts this standard into law has such authority.

International Code Council Solar Thermal Standard Consensus Committee (IS-STSC)

Consensus Committee SCOPE: The Solar Thermal Standard Consensus Committee (IS-STSC) shall have primary responsibility for minimum requirements to safeguard the public health, safety and general welfare along with minimum performance, and evaluation requirements for solar thermal systems. The requirements contained in the *International Codes* pertaining to these situations shall be coordinated with the standards developed by the IS-STSC Consensus Committee.

This standard was processed and approved for submittal to ANSI by the ICC Solar Thermal Standard Consensus Committee (IS-STSC). Committee approval of the standard does not necessarily imply that all committee members voted for its approval.

Representatives on the Consensus Committee are classified in one of three voting interest categories, General Interest (G), User Interest (U) and Producer Interest (P). The committee has been formed in order to achieve consensus as required by ANSI Essential Requirements. At the time it approved this standard, the IS-STSC Consensus Committee consisted of the following members:

Rolf Christ (P), R&R Solar Supply, Honolulu, Hawaii

Thomas Cleveland (U), North Carolina Clean Energy Technology Center at NC State University, Raleigh, North Carolina

John Del Mar, PE, MS (U), Florida Solar Energy Center (FSEC), Cocoa, Florida

William Funk, Jr. (G), Cecil County Permits and Inspections, Elkton, Maryland

Rex Gillespie (P), Caleffi North America, Inc., Milwaukee, Wisconsin

McKenzie W. James (G), City of Portland, Portland, Oregon

Robert J. Klein, CBO (G), Town of Hilton Head Island, Hilton Head Island, South Carolina

Nathan Lohse (P), FAFCO, Inc., Chico, California

Bill Miao (P), SunEnergyNet, San Diego, California

Larry Sherwood (U), Sherwood Associates, Boulder, Colorado

John Smirnow (P), Solar Energy Industries Association (SEIA), Washington, District of Columbia

Shawn Strausbaugh (G), Arlington County, Arlington, Virginia

Secretaries: **Shawn Martin,** Director of PMG Activities, Plumbing, Mechanical and Fuel Gas Group, International Code Council, Pittsburgh, Pennsylvania; **Jim Huggins,** Technical Director, Solar Rating and Certification Corporation, Cocoa, Florida.

Voting Membership in Each Category

Category	Number
General (G)	4
User (U)	3
Producer (P)	5
TOTAL	12

Interest Categories

General Interest: Individuals assigned to the General Interest category are those who represent the interests of an entity, including an association of such entities, representing the general public, or entities that promulgate or enforce the provisions within the committee scope. These entities include consumers and government regulatory agencies.

User Interest: Individuals assigned to the User Interest category are those who represent the interests of an entity, including an association of such entities, which is subject to the provisions or voluntarily utilizes provisions within the committee scope.

These entities include academia, applied research laboratory, building owner, design professional, government nonregulatory agency, insurance company, private inspection agency and product certification/evaluation agency.

Producer Interest: Individuals assigned to the Producer Interest category are those who represent the interests of an entity, including an association of such entities, which produces, installs or maintains a product, assembly or system subject to the pro-

visions within the committee scope. These entities include builder, contractor, distributor, laborer, manufacturer, material association, standards promulgator, testing laboratory and utility.

NOTE—Multiple Interests: Individuals representing entities in more than one of the above interest categories, one of which is a Producer Interest, are assigned to the Producer Interest. Individuals representing entities in the General Interest and User Interest categories are assigned to the User Interest.

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SECTION 102
SCOPE

102.1 Scope. This standard applies to solar thermal collectors using a fluid for the heat transfer. The standard sets forth minimum requirements for durability, construction and performance testing and provides the methodology and means for evaluating the durability and performance of tested solar thermal collectors.

SECTION 103
REFERENCED DOCUMENTS

103.1 Referenced documents. The codes and standards referenced in this standard shall be considered to be part of the requirements of this standard to the prescribed extent of each such reference. Chapter 5 contains a complete list of all referenced standards.

CHAPTER 2
DEFINITIONS

SECTION 201
GENERAL

201.1 General. For the purpose of this standard, the terms listed in Section 202 have the indicated meaning.

201.2 Undefined terms. The meaning of terms not specifically defined in this document or in referenced standards shall have ordinarily accepted meanings as the context implies. Where a definition does not appear herein, informative reference is made to ISO 9488.

201.3 Interchangeability. Words, terms and phrases used in the singular include the plural and the plural the singular.

SECTION 202
DEFINED TERMS

ABSORBER. That part of the solar collector that receives the incident solar radiation and transforms it into thermal energy. It usually is a solar surface through which energy is transmitted to the transfer fluid; however, the transfer fluid itself could be the absorber in certain configurations.

ABSORBER AREA. The maximum area in which concentrated or unconcentrated solar radiation is admitted and converted to heat or power. Absorber area does not include portions of the absorber/receiver where light is permanently screened and thermal barriers are in place.

ACTIVE CONTROLS. Control and actuator systems where external power and a computational device are used for operation and safety control purposes.

AMBIENT AIR. The air in the vicinity of the solar collector.

APERTURE AREA. The maximum area projected on a plane perpendicular to the optical normal through which the unconcentrated solar radiant energy is captured. In a concentrating collector, the following areas are excluded: 1) any area of the reflector or refractor permanently shaded by collector elements that are opaque, such as a secondary reflector or receiver; 2) structural elements such as supports; 3) gaps between reflector segments within the collector module.

AVAILABLE ENERGY. The time-integrated solar irradiance.

COLLECTED ENERGY. The product of the fluid mass, specific heat and integrated temperature gain across the collector.

COLLECTOR ENCLOSURE. The structural frame that supports the components of the collector and protects internal components from the environment.

COMBINED ASSEMBLY. A solar collector with one or more subcomponents that are not physically attached within a common structure or assembly at the point of manufacture, but are assembled in the field. Once assembled, collector modules shall not vary in geometry and performance from design specifications. A combined assembly would generally be comprised of subcomponents, each with individual nameplates and serial numbers, and might be shipped from separate facilities and manufacturers to a common location for final assembly. A building-integrated collector that requires specific shared external components for normal operation is an example of a combined assembly.

COMPLETE ASSEMBLY. A solar collector designed and constructed as a permanent, single unit. Complete assemblies cannot be physically separated for normal operation and would generally carry a single nameplate and serial number. A single parabolic trough with mounted receiver and tracking frame is an example of a complete assembly.

CONCENTRATING PHOTOVOLTAIC. A solar collector that uses optical elements, such as lenses or mirrors, to concentrate sunlight onto solar photovoltaic cells to generate electrical energy.

CONCENTRATING THERMAL COLLECTOR. A solar collector that uses optical elements to concentrate solar energy onto an absorber. Concentrating collectors include flat plate and tubular collectors with mirrors.

CONCENTRATION. The direction of a quantity of solar insolation greater than normal incident insolation onto a solar collector absorber surface.

CONCENTRATOR. The concentrator is that part of the concentrating collector that directs the incident solar radiation onto the absorber.

CORROSION. The deterioration of a substance or its properties caused by a chemical or electrochemical reaction with its environment.

COVER PLATE. The material or materials covering the absorber. These materials generally are used to reduce the heat loss from the absorber to the surroundings and to protect the absorber. In some collector designs, materials in the shape of a tube serve as a cover plate by enclosing the absorber (see "Transparent Cover").

CRAZING. Formation of minute surface cracks.

DEGRADATION. Leading to significant permanent loss of collector performance or leading to elevated risk of danger to life, limb or product. "Repeated exposure" is defined as a minimum total of 1000 hours/year at stagnation conditions during the design life.

Modes of degradation include, but are not limited to:

Outgassing from coatings or insulation that result in harmful deposits or significant structural failure or significant reduction in insulation value.

Structural weakening with permanent failure, melting, charring, ignition of wooden or polymer components exposed to temperatures greater than documented limits.

Release of undesirable compounds from the wall of the fluid passageway into the heat transfer fluid.

DELAMINATION. Separation into constituent layers, as in one layer of material separating from another.

DESIGN LIFE. Period for which a collector is expected to function at its designated capacity without major repairs.

DISTORTION. A change witnessed or measured during testing that suggests a change to the functional dimensional integrity of a product raising safety, reliability or performance concerns.

DISTRIBUTED ASSEMBLY. A solar collector using subcomponents that are not physically attached to each other or a common structure. When fully assembled, the geometry of the assembly can vary from module to module due to customization of design or installation. Distributed assemblies have the potential to be scaled by subcomponent count and collector geometry without changes to actual subcomponent specifications. An example of a distributed assembly would be a central receiver design where layout or count of heliostats can vary while the central receiver and individual heliostat module designs and specifications remain fixed.

DRY COLLECTORS. Collectors where heat transfer fluid is not shared with other external components as part of a heat transfer loop.

FAIL-SAFE. An operating condition of a collector where collector protection functions will continue under all collector and system failure modes.

FLAT-PLATE COLLECTOR. A solar collector, either liquid or air, in which the surface absorbing the incident radiation is essentially flat and employs no concentration. In this standard the term refers to all collectors designed to perform satisfactorily with all parts of the collector in fixed positions.

FLUID. A substance that can flow and does not maintain a fixed shape. Gases and liquids are considered to be fluids.

GLAZED. A typed of solar collector with a cover over the absorber plate.

GROSS AREA. The maximum projected area of the complete module, including integral mounting means.

HAIL. Precipitation in the form of small balls or lumps, usually consisting of concentric layers of clear ice and compact snow.

HEAT TRANSFER FLUID. Air, water, or other fluid that is used to transfer thermal energy between collectors and other components in a system.

ICS. Acronym for solar collectors in which the solar energy collection function is integrated with storage of the heated fluid, thus: Integral Collector Storage collector. In this type of collector the collection and storage functions cannot be separated for testing or operation.

INCIDENT ANGLE MODIFIER (IAM). The measurement of changes in collector efficiency as a function of the angle at which light enters the aperture.

INSTANTANEOUS EFFICIENCY. The amount of energy removed by the heat transfer fluid over a given measuring period divided by the total incident solar radiation onto the gross collector area during the measuring period.

INTEGRITY OF CONSTRUCTION. Those physical and mechanical properties of the solar collector that collectively are responsible for the overall thermal performance and physical structure of the solar collector.

IRRADIANCE. The rate of solar radiation received by a unit surface area in unit time. Irradiance is expressed in Btu per hour square feet. (Btu/hr-ft.^{2}) (W/m^2).

IRRADIANCE, BEAM. Irradiance, on a defined plane, originating from a narrow solid angle centered on a solar disk.

IRRADIANCE, DIFFUSE. Scattered irradiance, on a defined plane, originating from outside the solar disk.

IRRADIANCE, GLOBAL. Hemispherical irradiance on a horizontal surface.

IRRADIANCE, HEMISPHERICAL. The sum of direct and diffuse irradiance.

MODEL. A unit of solar equipment that is identifiable by a specified size, set of materials, and performance. A change in any of these basic characteristics constitutes a new model.

NO-FLOW CONDITION. A condition where thermal energy is not transferred from the collector by means of heat transfer fluid flow.

NONCONCENTRATING SOLAR THERMAL COLLECTOR. A solar collector without optical elements that redirect incident solar radiation onto an integral flat absorber.

NORMAL SOLAR ANGLE, GEOMETRIC. An imaginary line perpendicular to the surface of an optical medium. The word normal is used in the mathematical sense, meaning perpendicular.

OPTICAL NORMAL SOLAR ANGLE. The angle at which the sun is perpendicular to each axis of the solar collector optical plane, as determined by the manufacturer. The aperture optical plane can be characterized as an invisible datum plane that can be orthogonal to or have any symmetrical relationship to the aperture, reflecting elements, heat collecting apparatus, or the solar collector frame. An optical-based definition of the normal solar angle is necessary when the collector is geometrically asymmetrical or has a tailored and nonsymmetrical solar response.

OUTGASSING. The generation of vapors by solar collector components or construction materials usually occurring during periods of solar collector exposure to elevated temperatures or reduced pressure.

PASSIVE. An operating condition of a solar concentrating collector where human or mechanical intervention is not required for operation as intended.

PASSIVE CONTROLS. Control and actuation systems where external energy source is not required and computational device is not used.

PITTING. The process by which localized material loss is caused in materials or components by erosion, corrosion, or chemical decomposition.

POWER. The amount of energy produced over time, expressed as watts or Btu per hour.

PYRANOMETER. A radiometer used to measure the total hemispherical irradiance incident on a surface.

RECEIVER. The part of the solar collector to which the solar irradiance is finally directed or redirected, including the absorber and any associated glazing through which the redirected energy must pass.

REFLECTOR OR REFLECTIVE SURFACE. A surface intended for the primary function of reflecting radiant energy.

SITE DEPENDENT COLLECTOR. A collector intended to be assembled only at the site of its application because the fully assembled size of the collector or other construction characteristics make delivery in operational form impractical.

SOLAR ENERGY. Energy originating from the sun's radiation primarily encountered in the wavelength region from 0.3 to 3.0 micrometers.

SOLAR THERMAL COLLECTOR. A device designed to absorb solar radiation and to transfer the thermal energy so produced to a fluid passing through it.

STAGNATION. The solar collector temperature at which the energy gain is balanced by the heat loss.

STANDARD. A document that specifies the performance, durability, or safety requirements of a product.

THERMAL EFFICIENCY. The ratio of thermal energy removed from a collector to the available solar energy falling upon the collector area.

TIME CONSTANT. The time required for the fluid leaving a solar collector to attain 63.2% of its steady state value following a step change in solar radiation or inlet fluid temperature.

TRACKING SOLAR COLLECTOR. A solar collector that moves so as to follow the apparent motion of the sun. Tracking can be accomplished by rotation around a single axis in the transverse direction for tracking the sun through the day or by longitudinal adjustment. Two-axis tracking can be employed to precisely track the sun in both the longitudinal and transverse axes.

TRANSFER FLUID. A medium such as air, water, or other fluid that passes through or comes in contact with a system component, such as the solar collector, and carries thermal energy to another component.

TRANSPARENT COVER. Radiation-transmitting material covering the absorber.

TRANSPIRED. A type of solar collector in which fluid is drawn through holes in the absorber plate rather than flowing through tubes or across the absorber plate.

UNGLAZED. A type of solar collector without a cover over the absorber plate.

WET COLLECTOR. A concentrating collector where thermal subcomponents share a common heat transfer fluid with and are part of a fluid circuit with external components.

CHAPTER 3
GENERAL REQUIREMENTS

SECTION 301
GENERAL

301.1 Collector standards. This chapter establishes minimum requirements for durability in collector design and construction.

SECTION 302
COVER

302.1 General. Collector covers shall comply with Sections 302.1.1 through 302.1.2.

302.1.1 Tempered glass. Where the outer cover is flat, and constructed of glass, the glass shall be tempered in accordance with ASTM C1048 or equivalent. Testing in accordance with this section shall not be required when tempered glass is used.

302.1.2 Nonglass and nontempered glass. The outer cover of the test specimen shall be tested in accordance with ISO 9806, Section 17, Method 2 using steel balls. Where the outer cover is not flat, the impact shall be perpendicular to the curvature. The optical elements of the collector shall withstand impacts without adverse effect on operation or performance.

SECTION 303
CONDENSATION

303.1 General. The collector shall be designed to prevent condensate build-up. The use of desiccants to control condensation shall be permitted. Test reports shall note any unusual condensate built up during any point in the testing.

SECTION 304
PRESSURE TEST REQUIREMENTS

304.1 General. Pressure test results shall comply with Sections 304.1.1 through 304.1.2.

304.1.1 Liquid. A collector, after testing, shall be considered to be passable if: 1) a loss of pressure greater than that specified in ISO 9806, Section 6.4 does not occur; 2) there is no evidence of fluid leakage; 3) there is no evidence of fluid path deterioration, including but not limited to swelling and stretching.

304.1.2 Air. A collector, after testing, shall be considered to be passable if there is no evidence of permanent fluid path deterioration, including but not limited to swelling and stretching.

SECTION 305
THERMAL SHOCK RESULTS

305.1 General. A collector shall be considered to have failed the test where the test specimen experiences permanent distortion, damage or degradation of performance.

305.2 Thermal shock/Water spray. The collector structure and performance shall not be degraded by moisture penetration. There shall not be cracking, crazing, warping or buckling of the *cover plate*.

305.3 Thermal shock/Cold fill. The collector's fluid pathway shall not leak. The absorber shall not be permanently distorted such that performance is degraded.

SECTION 306
DISASSEMBLY AND FINAL INSPECTION

306.1 General. After completing the test sequence outlined in Section 401, the collector shall be disassembled, its subassemblies visually inspected, and their condition noted as specified in ISO 9806, Section 18, to determine final collector condition and actual or potential points of failure that can lead to impairment of function or abnormally short collector life. The format specified in ISO 9806, Annex A.15, "Final inspection results," shall be used to report conditions observed. Components and inspection criteria shall be in accordance with Table 306.1.1.

Test specimens and their components shall not exhibit conditions capable of producing premature failure, including but not limited to the items listed in Table 306.1.2.

TABLE 306.1.1
COMPONENT INSPECTION CRITERIA

COLLECTOR COMPONENT	INSPECTION CRITERIA
Collector box/fasteners	Cracking, warping, corrosion, rain, and penetration
Mountings/structure	Strength and safety
Seals/gaskets	Cracking, adhesion, and elasticity
Cover/reflector	Cracking, crazing, buckling, delamination, warping, and outgassing
Absorber coating	Cracking, crazing, and blistering
Absorber tubes and headers	Deformation, corrosion, leakage, and loss of bonding
Absorber mountings	Deformation and corrosion
Insulation	Water retention, outgassing, and degradation

TABLE 306.1.2
PREMATURE FAILURE CONDITIONS

Severe deformation[1] of the absorber
Severe deformation[1] of the fluid flow passages
Loss of bonding between fluid flow passages and absorber plate
Leakage from fluid flow passages or connections
Loss of mounting integrity
Severe corrosion[1] or other deterioration caused by chemical action
Crazing, cracking, blistering or flaking of the absorber coating or concentrating optical element surfaces
Excessive retention of water anywhere in the collector
Swelling, severe outgassing or other detrimental changes in the collector insulation that could adversely affect collector performance
Cracking, loss of elasticity, or loss of adhesion of gaskets and sealants
Leakage or damage to hoses used inside the collector enclosure, or leakage from mechanical connections
Cracking, crazing, permanent warping or buckling of the cover plate
Cracking or warping of the collector enclosure materials

Note:
1. Deformation or corrosion shall be considered severe if it impairs the function of the collector or there is evidence that it will progress.

SECTION 307
PROTECTION OF MATERIALS

307.1 Nonconcentrating solar collectors. Materials used in the construction of nonconcentrating solar collectors shall withstand not less than 1000 hours per year at stagnation temperature without significant degradation over the design life. Stagnation temperature shall be determined in accordance with ISO 9806, Section 10.

307.2 Concentrating solar collectors. Materials used in the construction of concentrating solar collectors shall withstand the maximum temperature to which the solar collector is tested in accordance with Sections 307.2.1 and 307.2.2.

307.2.1 No controls employed. If controls are not employed, collector stagnation temperature shall be determined in accordance with ISO 9806, Section 10.

307.2.2 Controls employed. If controls are employed, collector stagnation temperature shall be determined in accordance with manufacturer's stated maximum operating temperature.

307.3 Photovoltaic collectors. When a photovoltaic module is incorporated into the collector design, the photovoltaic module shall be listed and labeled to UL 1703.

Exception: The photovoltaic module portion of a photovoltaic-thermal collector shall comply with UL 1703.

CHAPTER 4

TEST METHODS

SECTION 401
REQUIREMENTS

401.1 General. Minimum testing requirements for solar collectors shall be in accordance with Sections 401.2 through 401.19.

401.2 Testing requirements. Table 401.2 specifies the tests that shall be conducted on each type of solar collector. An "X" in the table indicates the test shall be conducted. An "O" indicates the test shall be conducted but can be conducted on either collector if two collectors are used to complete testing requirements. The testing sequence is determined by identifying the type of collector, identifying the method of testing to be used, and then following the requirements in Table 401.2 and Sections 401.2.1 and 401.2.2.

401.2.1 Methods for conducting tests. There are two methods for conducting the test. Table 401.2 demonstrates the appropriate requirements for each type of collector and each method as follows:

1. When all of the tests are conducted on a single collector, the testing requirements for each type of collector are designated with the column heading "1."
2. When two collectors are tested, one shall be subjected to the qualification tests, designated in column heading of "2Q," and the other shall be subjected to the performance tests, designated in column heading of "2P."

401.2.2 Testing sequence. The test sequence shall follow the order as listed in Table 401.2.

Exceptions:

1. The following tests can be conducted in any sequence relative to each other: thermal capacity and time constant, thermal performance, incident angle modifier and pressure drop.
2. The following tests can be conducted in any sequence relative to each other: high-temperature resistance, exposure, external thermal shock, and internal thermal shock.
3. All solar collectors containing heat pipes shall be subjected to the exposure test in accordance with Section 401.7 before the thermal performance test is conducted. The same serial-numbered collector shall be subjected to the exposure test and then to the thermal performance test.

401.3 Test specimen selection. Collectors to be tested shall be selected at random in accordance with Sections 401.3.1 through 401.3.2.

401.3.1 Selection method. Random selection of test collectors shall be accomplished through a personal visit by the laboratory, certification body, or authority having jurisdiction or selection from photographs of the collectors in stock. The selected collectors, or collector components, shall be affixed with nonremovable serial-numbered labels.

401.3.2 Selection process. Collectors shall be randomly selected from a group of at least five collectors. Where final assembly of the collector components occurs only at the installation site, each of the components shall be randomly selected from a group of at least five components. The collector's final assembly geometry shall not change from its design specification.

Exceptions:

1. Large collectors greater than 4.6 m^2 (50 ft^2) shall be randomly selected from a group of at least two collectors where either:
   1.1. Transport in a fully constructed condition is impractical; or
   1.2. Collectors are not inventoried in a fully constructed condition.
2. If the collector design to be tested is always built for a specific installation, the collector is to be tested in-situ without random selection.
3. For distributed assembly solar concentrating collectors where the subcomponents are not physically connected to each other, the manufacturer shall specify the geometric parameters and configuration of all subcomponents and the total collector.
   3.1. Parameters shall include orientation, distance, height, and angle of all solar collector subcomponents in relation to each other and the installation site, including the quantity of each.
   3.2. The manufacturer's specifications shall include minimum and maximum values for each geometric parameter defining the configuration's final assembly with minimum- and maximum-operating specifications.
   3.3. The configuration(s) to be tested shall fall within these specified ranges, representing operating conditions closest to the minimum and maximum allowed. The most rigorous test conditions applicable shall be used.

401.4 Baseline inspection. The collectors shall be tested as received from the manufacturer when assembled per manufacturer's documentation. Test specimens shall be inspected prior to testing and any visible damage or assembly flaws shall be recorded. Documentation shall include photographs of the collector or its constituent parts, as received, showing

TABLE 401.2
SOLAR COLLECTOR TEST REQUIREMENTS

TEST	SECTION	LIQUID HEATING COLLECTORS												AIR HEATING COLLECTORS					
		UNGLAZED			GLAZED (FLAT PLATE, TUBULAR)			PROTECTED BY CONTROLS (UNABLE TO WITHSTAND DRY STAGNATION)			NONSEPARABLE STORAGE (ICS)			CLOSED LOOP			TRANSPIRED		
		1	2 Q	2 P	1	2 Q	2 P	1	2 Q	2 P	1	2 Q	2 P	1	2 Q	2 P	1	2 Q	2 P
Test Specimen Selection	401.3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Baseline Inspection	401.4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
High-Temperature Resistance	401.5	X	X		X	X		X	X		X	X		X	X		X	X	
Stagnation Temperature	401.6	X	X		X	X					X	X		X	X		X	X	
Exposure	401.7	X	X		X	X		X	X		X	X		X	X		X	X	
External Thermal Shock	401.8.1	X	X		X	X		X	X		X	X		X	X		X	X	
Internal Thermal Shock	401.8.2	X	X		X	X					X	X		X	X		X	X	
Internal Pressure	401.9	X	X		X	X		X	X		X	X							
Leakage	401.10													X	X				
Rupture and Collapse	401.11													X	X		X	X	
Freeze Resistance (only when freeze tolerance claimed)	401.12	X	X		X	X		X	X		X	X							
Thermal Capacity/Time Constant	401.13	X		X	X		X	X		X	X		X	X		X	X		X
Thermal Performance	401.14.1	X		X	X		X	X		X				X		X	X		X
Thermal Performance	401.14.2										X		X						
Incident Angle Modifier	401.15	X		X	X		X	X		X				X		X	X		X
Pressure Drop	401.16	X	O	O	X	O	O	X	O	O				X	O	O			
Rain Penetration (glazed only)	401.17				X	X		X	X		X	X		X	X				
Mechanical Load	401.18	X	X		X	X		X	X		X	X		X	X		X	X	
Impact Resistance	302.1	X	X		X	X		X	X		X	X		X	X		X	X	
Final Inspection	401.19	X	X		X	X		X	X		X	X		X	X		X	X	

all visible surfaces. Any abnormalities shall be noted and photographed in detail.

401.4.1 Pre-exposure pressure test. It is permissible to conduct the internal pressure test according to Section 401.9 to confirm the flow passages are in a condition suitable for testing.

401.5 High temperature resistance test. A high temperature resistance test shall be performed as specified in Section 9 of ISO 9806.

401.6 Stagnation temperature. The collector stagnation temperature shall be determined as specified in Section 10 of ISO 9806.

401.7 Exposure test. Exposure testing shall be in accordance with Section 11 of ISO 9806, using a minimum of Class B climate conditions, for no less than 30 days of exposure to adverse conditions.

401.8 Thermal shock tests. All collectors shall comply with Sections 401.8.1 through 401.8.7.

401.8.1 Outdoor testing option. When testing is conducted outdoors, each shock shall be performed on a different day.

401.8.2 Indoor testing option. When testing is conducted indoors under a solar simulator, it is permissible to conduct multiple shock tests on the same day provided the collector is allowed to cool to ambient air temperature between shock tests.

401.8.3 Factory-sealed containers. When the solar collector design incorporates one or more factory-sealed containers charged with a refrigerant, other fluid, or phase-change material, these containers shall not be removed for these tests.

401.8.4 Active mechanisms. If the collector assembly has active mechanisms that are intended to be functional during operation, those mechanisms shall be operational during testing.

401.8.5 Test failure. Any test specimen having integrity that is permanently compromised by this test, such that it

obviously will not be able to perform, shall be considered to have failed the test.

401.8.6 External thermal shock/water spray test. Two external thermal shock tests shall be performed as specified in ISO 9806, Section 12, using a minimum of Class B conditions.

401.8.7 Internal thermal shock/cold fill test. Two internal thermal shock tests shall be performed as specified in ISO 9806, Section 13, using a minimum of Class B conditions. All parts of the solar collector assembly that are not factory sealed shall be subjected to this test.

Exception: This test is not applicable to collectors in which heat transfer fluid is continuously flowing for protection purposes. In such cases, control(s) used to manage a no-flow condition shall be validated to be functional in such a way that any failure can be detected. Control functions that have been verified shall be described and reported with the test results.

401.9 Internal pressure test. An internal pressure test shall be performed as specified in ISO 9806, Section 6.

401.10 Leakage test. A leakage test shall be performed on closed loop air heating collectors as specified in ISO 9806, Section 7.

401.11 Rupture and collapse test. A rupture and collapse test shall be performed on air heating collectors as specified in ISO 9806, Section 8.

401.12 Freeze resistance test. A freeze resistance test shall be performed on collectors claimed to be resistant to freezing as specified in ISO 9806, Section 15.

401.12.1 Freeze resistance test for heat pipes used in solar collectors. All heat pipes used in solar collectors shall meet the requirements of Sections 401.12.1.1 through 401.12.1.9**.**

401.12.1.1 Purpose. This test evaluates the impact of freeze-thaw cycles on heat pipes. The test shall be performed in a controllable climate chamber for the duration of a set number of freeze and thaw cycles (see Table 401.12.1.6). This test shall be performed on heat pipes that are part of the solar collector submitted for testing, regardless of the collector loop design heat transfer fluid.

401.12.1.2 Selection. During the disassembly phase (Section 401.19) of the testing protocol, a minimum of six heat pipes shall be selected to undergo a freeze resistance test. In addition, at least one heat pipe shall be retained as a control sample for comparison with the tested samples. It is permissible to destroy part of the collector (evacuated tubes, collector housing, etc.) to extract the heat pipes. However, when the heat pipes cannot be separated from the evacuated tube without damage to the heat pipe, it is permissible to conduct the test with the evacuated tube in place.

401.12.1.3 Storage. After the heat pipes are extracted from the collector, they shall be kept at a minimum tilt angle of 15 degrees with respect to horizontal, with the condenser at the upper end so that all components of the fluid (inhibitors, particles, etc.) remain in the bottom part of the heat pipe. If the solar collector was stored at less than a 15-degree tilt between the qualification tests and disassembly, the heat pipes must be tilted to at least 15 degrees then raised to and held for 1 hour at what their normal operating temperature would be when exposed to 800 W/m^2.

401.12.1.4 Inspection and measurement. A detailed initial inspection of all of the heat pipes shall document the following:

1. The shape (round, oval, cylindrical, conical, etc.) of all parts of the heat pipe;
2. The outside dimension of all parts of the heat pipe; and
3. A photographic record of all test samples.

401.12.1.5 Temperature sensors. Two heat pipes shall have a temperature sensor attached to ensure an accurate and average temperature is measured. Each temperature sensor shall have a maximum standard uncertainty of +/- 1 K and shall be mechanically and thermally attached to the outside of the lower end of a heat pipe near the fluid level when all of the fluid inside the heat pipe is condensed and the heat pipe is held at the tilt specified in Section 401.12.1.3. The temperature indicated by these sensors shall be assumed to represent the temperature of the fluid inside the heat pipe.

Exception: When the heat pipe cannot be separated from the evacuated tube without damage to the heat pipe, it is permissible to conduct the test with the evacuated tube in place if a temperature sensor is placed inside one of the heat pipes. On one sample, the condenser shall be opened by drilling a hole so that a temperature sensor can be inserted and run to the location where the heat pipe heat transfer fluid rests. The temperature sensor shall have a maximum standard uncertainty of +/-1 K. Every effort shall be made to minimize disruption to the basic structure of the heat pipe, while maximizing the accuracy of temperature measurement at this location.

401.12.1.6 Test conditions. All conditions in Table 401.12.1.6 shall be met.

TABLE 401.12.1.6
REQUIRED TEST CONDITIONS

TEST PARAMETER	REQUIRED VALUE
Tilt angle	The highest of 60 degrees or the manufacturer's highest recommended tilt angle
Freezing temperature	Negative 20 +/- 2ºC
Freezing time	The temperature sensor shall indicate the freezing temperature for at least 30 minutes per cycle
Thawing temperature	Positive 10 +/- 2ºC
Thawing time	The temperature sensor shall indicate the thawing temperature for at least 30 minutes per cycle
Number of cycles	20

401.12.1.7 Intermediate inspection. A visual inspection of all heat pipes shall be conducted after the initial five freeze-thaw cycles. If there is a failure, (e.g., fluid leaking or burst pipe) as a result of the freeze-thaw cycling in any of the test samples, the test shall be terminated.

401.12.1.8 Final inspection. A detailed final inspection of all samples shall document the following for each sample tested:

1. Any permanent change in shape or dimension of all parts of the heat pipe;
2. Any evidence of fluid leaking from the heat pipe; and
3. A photographic record of all test samples.

401.12.1.9 Results. The following shall be reported:

1. The tilt angle of the heat pipes during the test;
2. All changes to the physical condition of the heat pipes and that of any collector components adjacent to the heat pipe;
3. The number of temperature cycles that were performed;
4. The temperature indicated by the temperature sensor(s) during the required dwell periods;
5. The time the heat pipes were exposed to each dwell period;
6. Before and after photographs of the tested heat pipes; and
7. Any deviations from the procedure as defined in Sections 401.12.1.1 through 401.12.1.8.

401.13 Thermal capacity and time constant test. The thermal capacity shall be determined as specified in ISO 9806, Section 26. If the time constant is measured, the test shall be performed as specified in ISO 9806, Section 26.4.

401.14 Thermal performance test. Thermal performance testing of solar thermal collectors shall be performed as specified in Section 401.14.1 or 401.14.2.

401.14.1 Collectors containing no internal storage. The thermal performance test on collectors that do not contain internal storage shall be performed as specified in ISO 9806, Section 20.

401.14.2 Collectors containing storage. Additional testing shall be required for collectors containing storage because the mass of the storage precludes measurement of instantaneous efficiency. Such collectors include both integral collector storage designs and thermosiphon designs where the collection function cannot be separated from the storage function for testing. Such collectors shall be subjected to the applicable tests described in Sections 401.14.2.1 through 401.14.2.2.

401.14.2.1 General testing procedures. Test objects shall be mounted in a manner that is similar to the intended usage. This requirement includes the use of such devices as reflectors and roof support structures. The hydraulic, thermal and optical characteristics shall be reproduced during the test.

401.14.2.1.1 Testing with fluid other than water. Where testing with a fluid other than water, fluid composition tests shall be performed to ensure that the specified fluid composition exists. At a minimum, a hygrometer test or its equivalent shall be performed and checked with the fluid specification before proceeding with the test.

401.14.2.1.2 Pre-heating heat exchanger. In any collector with a heat exchanger containing more than 2.5 percent by volume of the storage vessel volume, the heat exchanger shall be preheated to the same temperature as the rest of the collector for all tests. This heat exchanger shall not be directly purged at the end of the test. The energy within it shall be purged in the normal operating fashion.

401.14.2.1.3 Manufacturer's recommended operating conditions. Performance testing shall not be performed in excess of manufacturer's recommended operating conditions. Adjustment of test-operating conditions is permissible to conform to the intent of the test

401.14.2.1.4 Required instrumentation accuracy and resolution. Table 401.14.2.1.4 indicates the required assurances for the instrumentation used in the tests required in Section 401.14.2. The radiation measurements shall be performed with devices that meet the standards of the World Meteorological Organization for a first-class pyranometer or pyrheliometer. The data resolution shall be not lower than the stated accuracy. The test lab shall ensure that data is checked for any offsets immediately prior to and at the conclusion of the test. Offsets shall be applied to the processed data and noted in the test report.

TABLE 401.14.2.1.4
INSTRUMENTATION ACCURACIES

VALUE TO BE MEASURED	ACCURACY SI UNITS (±)	ACCURACY IP UNITS (±)
Temperature	0.1°C (precision 0.1°C)	0.2°F (precision 0.2°F)
Temperature Difference	0.1 K (precision 0.1 K)	0.2 R (precision 0.2 R)
Mass	1%	1%
Fossil Fuel Usage	1%	1%
Air Flow	1%	1%
Liquid Flow	1% measured mass value	1% measured mass value

401.14.2.1.5 Minimum data time step. Data shall be sampled at a maximum interval of 15 seconds. This data shall be averaged and reported at a maximum rate of 5 minutes for long-term tests having a duration longer than 1 day, or 0.5 minute for short-term tests. Because of the interaction with the transient system simulation software, which uses a fixed time step, data for all collected channels shall be reported in fixed time steps. Note that any test using an energy purge shall be measured with the highest data resolution available at the laboratory.

401.14.2.1.6 Instrument calibration. Calibration of instrumentation used in the testing setup shall be traceable to a national standard and be performed at least annually.

401.14.2.1.7 Required experimental data. The data specified in Sections 401.14.2.1.7.1 through 401.14.2.1.7.3 are required.

401.14.2.1.7.1 Required numerical data. The minimum real time data to be collected for the tests shall consist of the following in metric units. Data channels shall be reported on a regular time interval. Channels not used in a particular test shall be populated with a value not found elsewhere in the data for that channel. The test lab shall review for and address any missing or erroneous data. This data reduction shall occur prior to submission for modeling.

401.14.2.1.7.1.1 Data gaps or corrections. Gaps or corrections for critical data shall not last longer than 10 minutes during non-purge periods. During purge periods, critical data shall not be missing or erroneous. The missing or adjusted data shall be filled in using proxy measurements or interpolation to existing data and highlighted in the data set and noted in the test report.

401.14.2.1.7.1.2 Log requirements. A log indicating the timing of the draw, purge, and irradiation start and stop times shall be included. Other data including site elevation, longitude, latitude, and test sample orientation shall be supplied. Any data sets that do not meet these minimum requirements shall be excluded from the analysis. Required data includes:

1. Data collection time, both local and solar, and date and day of year (*dd-mm-yyyy*)
2. Inlet temperature(s) (°C)
3. Outlet temperature(s) (°C)
4. Ambient temperature (i.e., “Outside,” if applicable) (°C)
5. Environmental temperature (i.e., “Inside,” if applicable) (°C)
6. Flow rate(s) (kg/hr)
7. Fluid heat capacities(s) (kJ/kg-°C)
8. Wind velocity (m/s)
9. Auxiliary energy usage, if applicable (kJ)
10. Radiation measurements (kJ/m^2)
    a. Total surface
    b. Total horizontal
    c. Horizontal diffuse
    d. Horizontal infrared, integral collector storage and unglazed collectors only

401.14.2.1.7.2 Required physical data. Easily accessible significant characteristics of the component or collector shall be measured and reported in consistent sets of units, including:

1. Diameters, lengths and widths, internal and external.
2. Lengths, internal and external, and spacing of tubes and fins.
3. Heights, internal and external, minimum and maximum water levels shall be denoted.
4. Thickness, such as insulation, tank shell, tank vessel, and fins.
5. Volumes at ambient air temperature of the tank and any integral heat exchangers.
6. A diagram indicating geometry including vessel, shell, and any protrusions such as heat exchangers and plumbing connections.
7. Materials used for vessel, including insulation, shell, tank liner, and heat exchangers.
8. Piping lengths and orientations.
9. Slope of components.

401.14.2.1.7.3 Additional required documentation. The following documentation shall be provided:

1. Equipment model number(s);
2. Description of the test method(s) and any deviations from the standard method; and
3. Photographs of any applicable equipment.

401.14.2.1.8 Laboratory process. The testing and analytical work shall consist of these steps:

1. The test lab shall determine physical parameters from the tests.
2. The test lab shall collect extended test data from warm up tests.
3. The test lab shall prepare the data in the format requested by the certification body.
4. The certification body shall create a model using transient system simulation software.

401.14.2.1.9 Data processing methods. These tests shall provide data for computer modeling of collectors or collector components, or both. The method of modeling shall depend upon the test and available transient system simulation software models. The certification body will provide direction for new and innovative collector tests that are not explicitly covered in this test method.

401.14.2.1.9.1 Use of real-time data. The calculation of temperature-dependent densities and heat capacities shall be performed using real-time data by the test lab. Data reduction shall include the filtering out of any erroneous data. The delivered energy value shall be used where matching net delivered energy with the transient system simulation software. It is permissible to not adjust this value if the simulation software accounts for energy changes caused by different starting and ending temperatures and losses from the collector during the purge period.

401.14.2.1.9.2 Data consistency. All data shall be consistent with the test conditions. When the pyranometer and pyrheliometer are not covered by the collector cover, the visual radiation shall be set to zero and the sky infrared radiation shall be adjusted to an equivalent sky radiation to account for the covering of the collector during the purge period. Any adjustments shall be noted in the test report.

401.14.2.1.9.3 Processing for component model calibration using transient system simulation software. Upon receipt of the processed data, the certification body shall create a series of computer models using transient system simulation software. One model shall be created for each test. This model is called the "audit" model. Each of the audit models is then fit to the test data as indicated in Items 1 through 4:

1. Collector heat loss shall be determined as follows:
   1.1. When both capacitance and heat loss tests are performed, the results from the heat loss test and capacitance tests shall be iterated upon until a final value of collector loss rate is determined. The loss value shall be used directly in the model. No other explicit fit is required at this point.
   1.2. When only the heat loss test is performed, the results are used to calibrate a transient system simulation software computer model. The loss value shall be used directly in the model. No other explicit fit is required at this point.
2. Parameters for heat exchangers integral to a collector shall be used directly in the model. No other explicit calibration is required at this point. The calibration is done by minimizing the chi-squared value for all data sets.
3. The data from each of the individual data points in the warm-up tests shall be used to calibrate a transient system simulation software computer model using the $F_R\tau\alpha$ and F_RU_L isothermal initial conditions. A calibration routine shall be used to compare the observed net, solar or auxiliary energy deliveries to the observed data points (one per test). The calibration is done by minimizing the chi-squared (x^2) value for all data sets.

   For integral collector storage collectors, the F_RU_L adjustment is actually a UA_{loss} adjustment since there is no measured value for F_RU_L. (Note that the ICS nighttime loss test shall be calibrated as part of the data set.) The net result of this process is two points ($F_R\tau\alpha$ and F_RU_L) that are used in the transient system simulation software model.
4. When the collector is initially stratified due to the presence of an auxiliary heater, a separate set of tests and calibrations shall be completed. This is required when a heater is located within the storage vessel of a thermosiphon collector.

401.14.2.2 Specific testing procedures. Collectors containing internal storage shall be tested using the procedures described in ISO 9459-4, Annex C, with the following clarifications:

1. During the collector purge described in ISO 9459-4, Section B.2, a bypass loop shall be used to precondition the inlet water to the specified temperature before introducing water to the test article. Unless otherwise specified, the purge temperature shall be the same temperature as the charge temperature in order to minimize internal energy change in the collector.
2. During the heat loss test described in ISO 9459-4, Section B.4.1, any source of heating, including resistance heaters and/or solar radiation, shall be shut off or blocked. All pumps shall be shut off for the duration of the test.
3. During the heat loss test described in ISO 9459-4, Section B.4.1, when internal temperature probes are used, the test shall continue until both of the following are satisfied:
   3.1. The collector temperature drops at least 3°C.
   3.2. The differential between the average collector temperature and the average environmental temperature changes by at least 3°C.
4. During the warm-up tests described in ISO 9459-4, Section C.3, the temperature in the collector at

the beginning of a low-temperature test shall be close to ambient temperature.

5. During the warm-up tests described in ISO 9459-4, Section C.3, wind at a speed between 1 and 3 m/s shall be required when testing collectors with integral storage tanks or unglazed collectors, or both.

401.15 Collector incident angle modifier. The incident angle modifiers of the collector shall be determined for each test specimen in accordance with ISO 9806, Section 27. Biaxial incident angle modifiers are required on collectors that are nonsymmetrical in their response to irradiance as solar altitude and azimuth change. Data shall be taken in each of the two perpendicular planes that characterize the collector geometry.

401.15.1 Concentrating collectors. Concentrating solar collector testing shall include all operational conditions in which the collector is designed to operate. Incident angle modifiers shall be found for the maximum acceptance angle and all intermediate angles as needed to properly characterize the optical behavior of the collector. Unless the manufacturer stipulates otherwise, the maximum acceptance angle to be tested shall be at least 60 degrees.

401.15.1.1 Biaxial incident and single angle modifiers testing. Biaxial incident angle modifiers testing and reporting shall be conducted on all nontracking concentrating collectors as covered by this standard and any single axis tracking collector where reflectors and/or receivers move independently of each other.

401.15.1.2 Drawings. The manufacturer shall submit a drawing showing the optical normal, transverse plane and longitudinal plane.

401.16 Pressure drop test. The pressure drop across the collector shall be measured as specified in ISO 9806, Section 28.

401.17 Rain penetration test. A rain penetration test shall be performed on glazed collectors as specified in ISO 9806, Section 14.

401.18 Mechanical load test. The ability of the collector to withstand loading by wind or snow shall be determined as specified in ISO 9806, Section 16.

401.19 Disassembly and final inspection. After the completion of testing, test specimens shall be disassembled and inspected in accordance with Section 306. Any visible damage, deformation, discoloration or flaw shall be recorded.

CHAPTER 5

REFERENCED STANDARDS

This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title. The application of the referenced standards shall be as specified in Section 103.1.

ASTM

ASTM International
100 Bar Harbor Drive
West Conshohocken, PA 19428-2959

Standard reference number	Title	Referenced in code section number
C1048—12e1	Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass	302.1.1

ISO

International Organization for Standardization
ISO Central Secretariat
1 ch, de la Voie-Creuse, Case Postale 56
CH-1211 Geneva 20, Switzerland

Standard reference number	Title	Referenced in code section number
9459-4—13	Solar Heating—Domestic water heating systems—Part 4: System performance characterization by means of component tests and computer simulation.	401.14.2.2
9488—99	Solar Energy—Vocabulary	202
9806—13	Solar Energy—Solar thermal collectors—Test methods	302.1.2, 306.1, 307.1, 401.5, 401.6, 401.7, 401.8.6, 401.8.7, 401.9, 401.10, 401.11, 401.12, 401.13, 401.14, 401.14.1, 401.16, 401.17, 401.18

UL

UL LLC
333 Pfingsten Road
Northbrook, IL 60062-2096

Standard reference number	Title	Referenced in code section number
1703—02	Flat-Plate Photovoltaic Modules and Panels—with revisions through November 2014	307.3

APPENDIX A

TEST GUIDELINES FOR CONCENTRATING COLLECTORS

The information contained in this portion of the document is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. As such, this Appendix A may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the standard.

Concentrating collectors can be categorized based on the type of assembly and the control strategy. The test procedure must be configured to be compatible with both of these parameters.

Assembly Type:

1. *Complete Assembly* – All components of the collector are defined and the geometry (spatial relationship between components) does not change. Since the reflector(s) and absorber(s) are contained in a single housing, the test unit can be randomly selected from a group of at least five collectors and shipped to the test laboratory (see Section 401.3.2). Examples include compound parabolic concentrating collectors and collectors where the entire reflector/absorber assembly is mounted inside a box.
2. *Combined Assembly* – All components of the collector are defined and the geometry (spatial relationship between components) does not change upon installation, but the components must be field assembled. When the collector is large, the reflector(s) and/or the absorber(s) may be shipped to the installation site separately and the collector is assembled in the field. Selection of the test unit is accomplished by randomly selecting each component of the collector from a group of at least two of each component (see Section 401.3.2, Exception 1). Examples include large linear concentrating collectors (parabolic or Fresnel) and large single point (2-axis tracking) concentrating collectors.
3. *Distributed Assembly* - Receiver(s) and reflector(s) are defined, but quantities and spacing can vary at the time of installation. The power tower is an example of a distributed assembly.

Control Strategy:

1. *No Control* – The collector is fixed in place on installation and no action is taken to protect it from overheating, loss of heat transfer fluid flow, high winds, power failure, etc.
2. *Passive Control* – The collector is capable of protecting itself without electrical power. This is frequently done with thermally activated actuators to control admission of solar radiation into the collector.
3. *Active Control* – Electrical power is required to protect the collector. Electronic actuators (motors, solenoids, etc.) are used to control admission of solar radiation into the collector.

TABLE A.1
EXAMPLE IMPLEMENTATIONS OF TABLE 401.2

Configuration:	1	2	3	4	5
Assembly Type	Complete	Complete	Combined	Combined	Distributed
Control Strategy	None	Active	Passive or Active	Active	Active
Tracking	None	1-Axis	1-Axis	2-Axis	2-Axis
Tracking Type	None	Time of Day	Time of Day or Time of Year	Time of Day	Time of Day
Thermal Shock/Overheat Protection	None	Heat Transfer Fluid & Defocus	Heat Transfer Fluid & Defocus	Heat Transfer Fluid & Defocus	Heat Transfer Fluid & Defocus
Mechanical (wind, snow, etc.) Stress Protection	None	None	Stow	Stow	Stow
Specific tests:					
Test Specimen Selection	Yes	Yes	Yes	Yes	Yes
Baseline Inspection	Yes	Yes	Yes	Yes	Yes
High-Temperature Resistance	Yes	No	No	No	No
Stagnation Temperature	Yes	No	No	No	No
Exposure	Yes	Wet, with continuous fluid flow	Wet, with continuous fluid flow	Wet, with continuous fluid flow	Wet, with continuous fluid flow
External Thermal Shock	Yes	Yes	Yes	Yes	Yes
Internal Thermal Shock	Yes	No	No	No	No
Internal Pressure	Yes	Yes	Yes	Yes	Yes
Leakage	Only if gaseous heat transfer fluid	Only if gaseous heat transfer fluid	Only if gaseous heat transfer fluid	Only if gaseous heat transfer fluid	Only if gaseous heat transfer fluid
Rupture & Collapse	Only if gaseous heat transfer fluid	Only if gaseous heat transfer fluid	Only if gaseous heat transfer fluid	Only if gaseous heat transfer fluid	Only if gaseous heat transfer fluid
Freeze Resistance (only when freeze tolerance claimed)	Yes	Yes	Yes	Yes	Yes
Thermal Capacity/Time Constant	Yes	Yes	Yes	Yes	Yes
Thermal Performance	Yes	Yes	Yes	Yes	Yes
Incident Angle Modifier	Yes	Yes	Yes	No	No
Pressure Drop	Yes	Yes	Yes	Yes	Yes
Rain Penetration	Yes	Yes	Yes	Yes	Yes
Mechanical Load	Yes	Yes	Yes	Yes	Yes
Impact Resistance	Yes	Yes	Yes	Yes	Yes
Final Inspection	Yes	Yes	Yes	Yes	Yes
Control systems tests (Section 401.8.7, exception): -Flow loss -Power loss -High wind -Over temperature	No	Yes	Yes	Yes	Yes

TABLE A.2
EXAMPLE TIME SEQUENCING OF TESTS

Configuration (From Table A.1)						
1	Selection & Inspection (Sections 401.2, 401.4)	Qualification Testing (Sections 302.1, 401.5, 401.6, 401.7, 401.8.1, 401.9, 401.16, 401.17, 401.18)	Thermal Performance Testing (Sections 401.13, 401.14.2, 401.15)			Final Inspection (Section 401.19)
2, 3, 4	Selection & Inspection	Qualification Testing	Thermal Performance Testing		Active Control Testing (Section 401.8.7, Exception)	Final Inspection
2, 3, 4	Selection & Inspection	Qualification Testing			Active Control Testing	Final Inspection
		Thermal Performance Testing				
2, 3, 4	Selection & Inspection	Qualification Testing				Final Inspection
		Thermal Performance Testing				
		Active Control Testing				
5	Selection & Inspection	Qualification Testing	Range Thermal Performance Testing (Sections 401.3.2 Exception 3.3, 401.15.1)	Range Thermal Performance Testing (Sections 401.3.2 Exception 3.3, 401.15.1)	Active Control Testing	Final Inspection

RESOURCE A

Forms, checklist and plans in this Resource A may be used by applicants for expedited permitting only if allowed by the jurisdiction.

Checklist and Submittal Requirements for Expedited Permitting of Solar Photovoltaic Systems in accordance with the solar energy provisions of the International Codes®

Instructions: Complete the following, with all of the information requested.

1. **Eligibility Checklist for the expedited permitting process**

2. **Application**

3. **_____Set(s) of plans that include:**

   - Site Plan showing location of major components of solar system and other equipment on roof or legal accessory structure. This plan should represent relative location of components at site, including, but not limited to, location of array, existing electrical service location, utility meter, inverter location, system orientation and tilt angle. This plan should show access and pathways that are compliant with local codes, if applicable.
   - A One-Line or 3-Line Electrical Diagram as required by the local jurisdiction.
   - Specification Sheets for all manufactured components. If these sheets are available electronically, a web address will be accepted in place of an attachment, at the discretion of the municipality.
   - All diagrams and plans include the following:
     - Project address, section, block and lot number of the property;
     - Owner's name, address and phone number;
     - Name, address and phone number of the person preparing the plans; and
     - System capacity in kW-DC.

4. **Permit Fee Amount**

Jurisdictions wishing to adopt the Checklist and Submittal Requirements for Expedited Permitting of Solar Photovoltaic Systems as a permitting process for solar systems should ensure that the language in this example is compliant with the laws and regulations in force at the time adoption is being considered by the appropriate governmental body.

ELIGIBILITY CHECKLIST

To determine if you are eligible for the expedited permitting process, answer the questions below.

__ Yes __ No 1. Solar installation has a rated capacity of 12 kW or less.

__ Yes __ No 2. Solar installation is not subject to review by an Architectural or Historical Review Board.

__ Yes __ No 3. Solar installation does not need a zoning variance or special use permit/conditional use permit.

__ Yes __ No 4. Solar installation is to be mounted on a permitted roof structure of a building, or on a legal accessory structure. If on a legal accessory structure, a diagram showing existing electrical connection to structure is attached.

__ Yes __ No 5. Solar installation is compliant with all applicable electrical and building codes.

__ Yes __ No 6. Solar installation is compliant with local fire codes.

__ Yes __ No 7. The Solar Installation Contractor complies with all licensing and other requirements of the jurisdiction and the State.

__ Yes __ No 8. The proposed equipment is permitted by code and equipment meets all relevant certification standards.

__ Yes __ No 9. The solar electric system and all components will be installed per the manufacturer's specifications.

__ Yes __ No 10. The project will comply with adopted *National Electrical Code*® requirements.

__ Yes __ No 11. The roof has no more than a single layer of roof covering (in addition to the solar equipment).

__ Yes __ No 12. The system is to be mounted parallel to the roof surface or tilted, with no more than an 18-inch gap between the module frame and the roof surface.

__ Yes __ No 13. The system will have a distributed weight of less than 5 pounds per square foot and less than 45 pounds per attachment point to roof.

If you answered "No" to any of Questions 1-10, you are not eligible to participate in the expedited permitting process and must go through the standard permitting process dictated by the municipality. If you answered "No" to any of Questions 11-13, in order to use this form, in addition to other requirements, you must provide a letter from a registered design professional certifying that the existing structure can support the additional weight and wind loads of the solar electric system. If you answered "Yes" to all of the above questions, please sign below to affirm that all answers are correct, and you have met all of the conditions and requirements to participate in this expedited process.

Property Owner's Signature Date

Solar Installation Contractor's Signature Date

APPLICATION

1. Property Owner:

Property Owner's Name | Phone | Email

Property Address

Section | Block | Lot Number

2. Existing Use:

__ One- or Two-family __ Townhouse __ Commercial __ Other _____

3. Provide the total system capacity rating (sum of all panels):

Solar Electric System:_____kW-DC

4. Solar Installation Contractor and Electrician:

Installer's Business Name

Installer's Business Address

Installer's Contact Name | Installer's Phone Number

Installer's License Number(s) | Installer's Email

Electrician's Business Name | Electrician's License Number

5. What is the existing roofing material?

6. Provide method and type of weatherproofing for roof penetrations (i.e., flashing, caulk).

7. Is the mounting structure an engineered product designed to mount solar electric modules? __Yes__No
If no, provide details of structural attachment in a letter certified by a registered design professional.

continued >

APPLICATION

8. For manufactured mounting systems, provide the following information about the mounting system:

a. Mounting System Manufacturer _____

b. Product Name and Model Number _____

c. Total Weight of Solar Electric Modules and Rails_____lbs.

d. Total Number of Attachment Points _____

e. Weight per Attachment Point (c ÷ d)_____lbs.

f. Maximum Spacing Between Attachment Points on a Rail_____inches
(See product manual for maximum spacing allowed based on maximum design wind speed)

g. Total Surface Area of Solar Electric Modules (square feet)_____ft^2

h. Distributed Weight of Solar Electric Module on Roof (c ÷ g)_____lbs./ft^2

9. Indicate quantity, brand, make and model of the:

Inverter(s):

Quantity	Make	Model

Modules:

Quantity	Make	Model

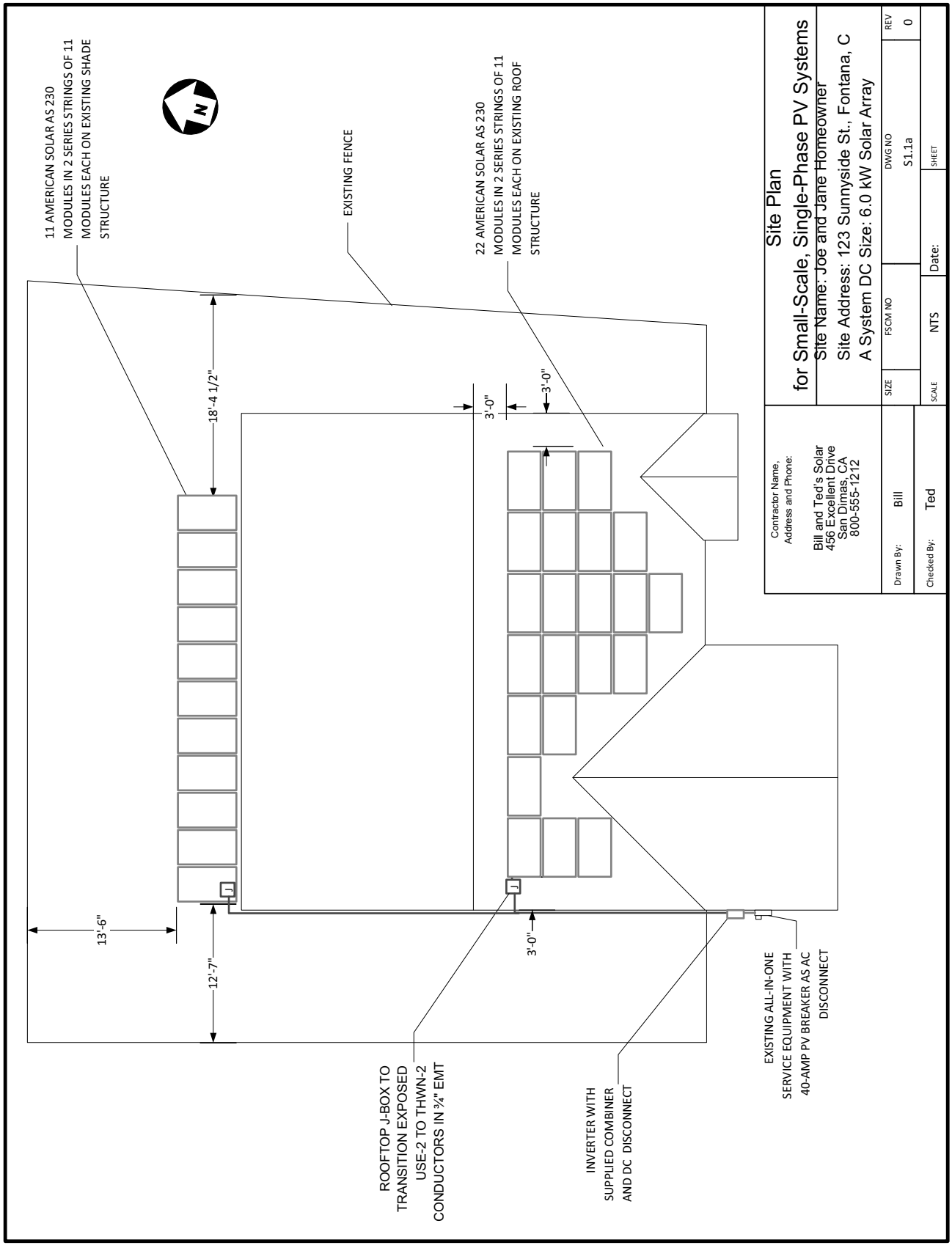
Please sign below to affirm that all answers are correct and that you have met all of the conditions and requirements to participate in this expedited process.

Property Owner's Signature _____ Date _____

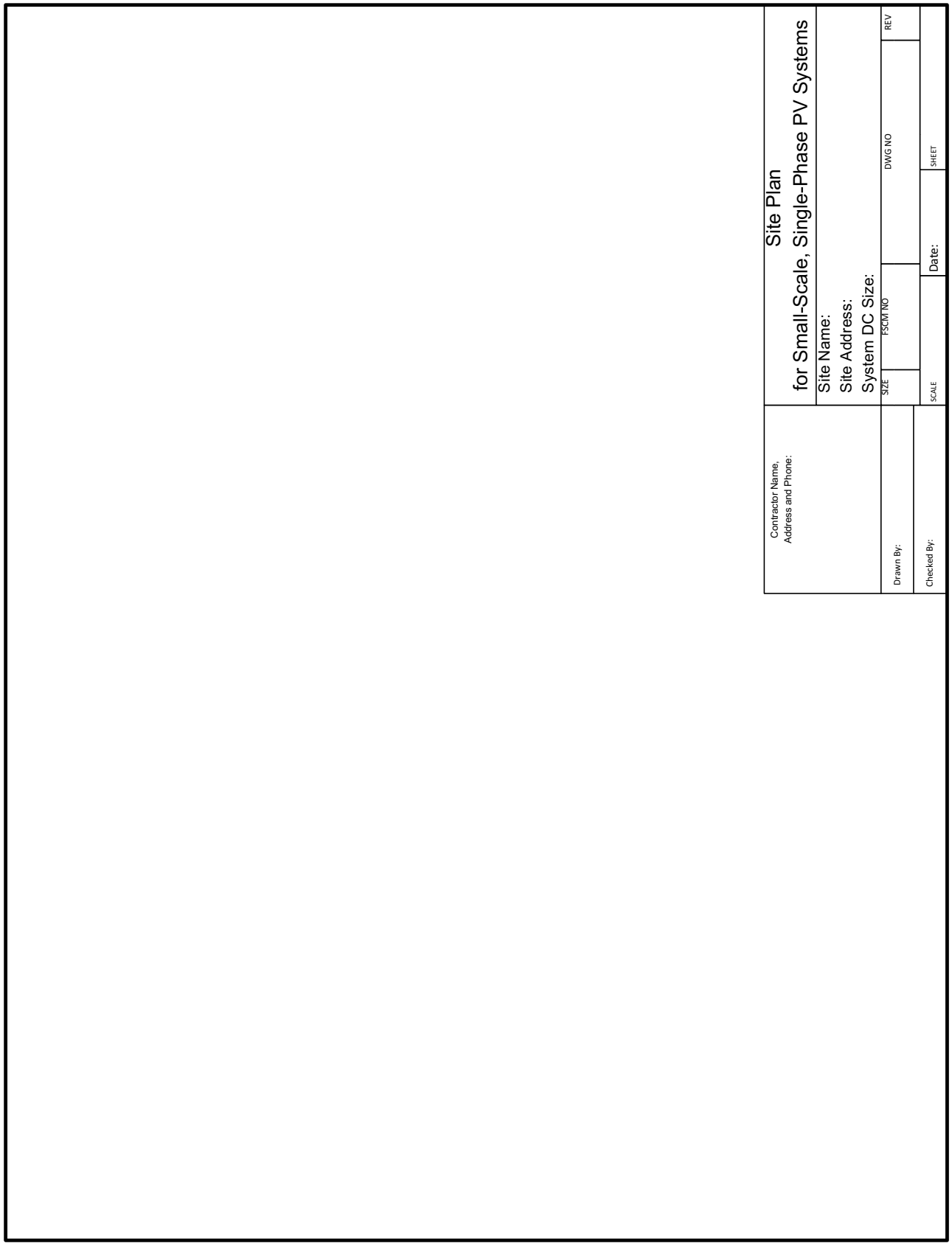
Solar Installation Contractor's Signature _____ Date _____

SUBMITTAL DIAGRAM TEMPLATES

EXAMPLE SITE PLAN

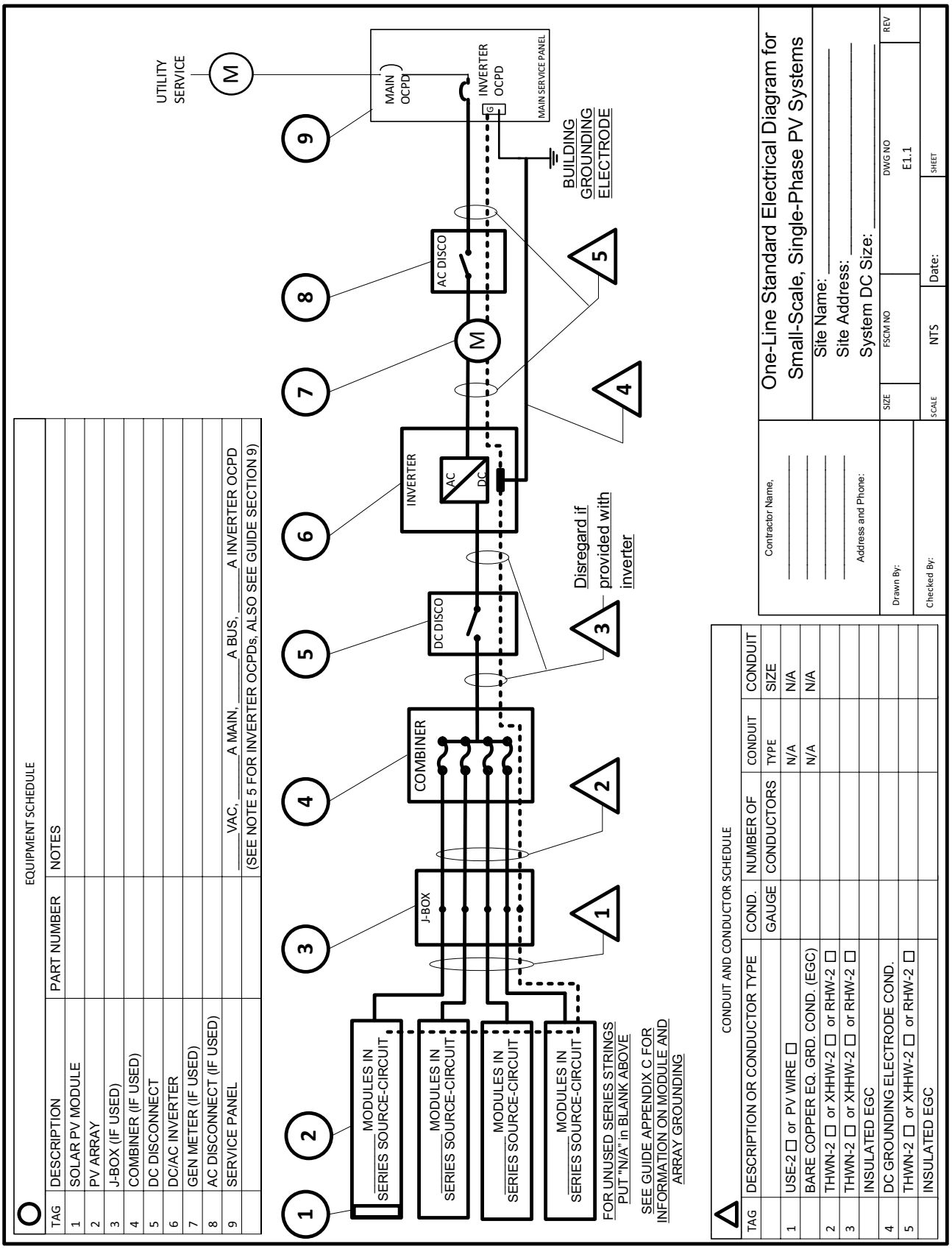


SUBMITTAL DIAGRAM TEMPLATES

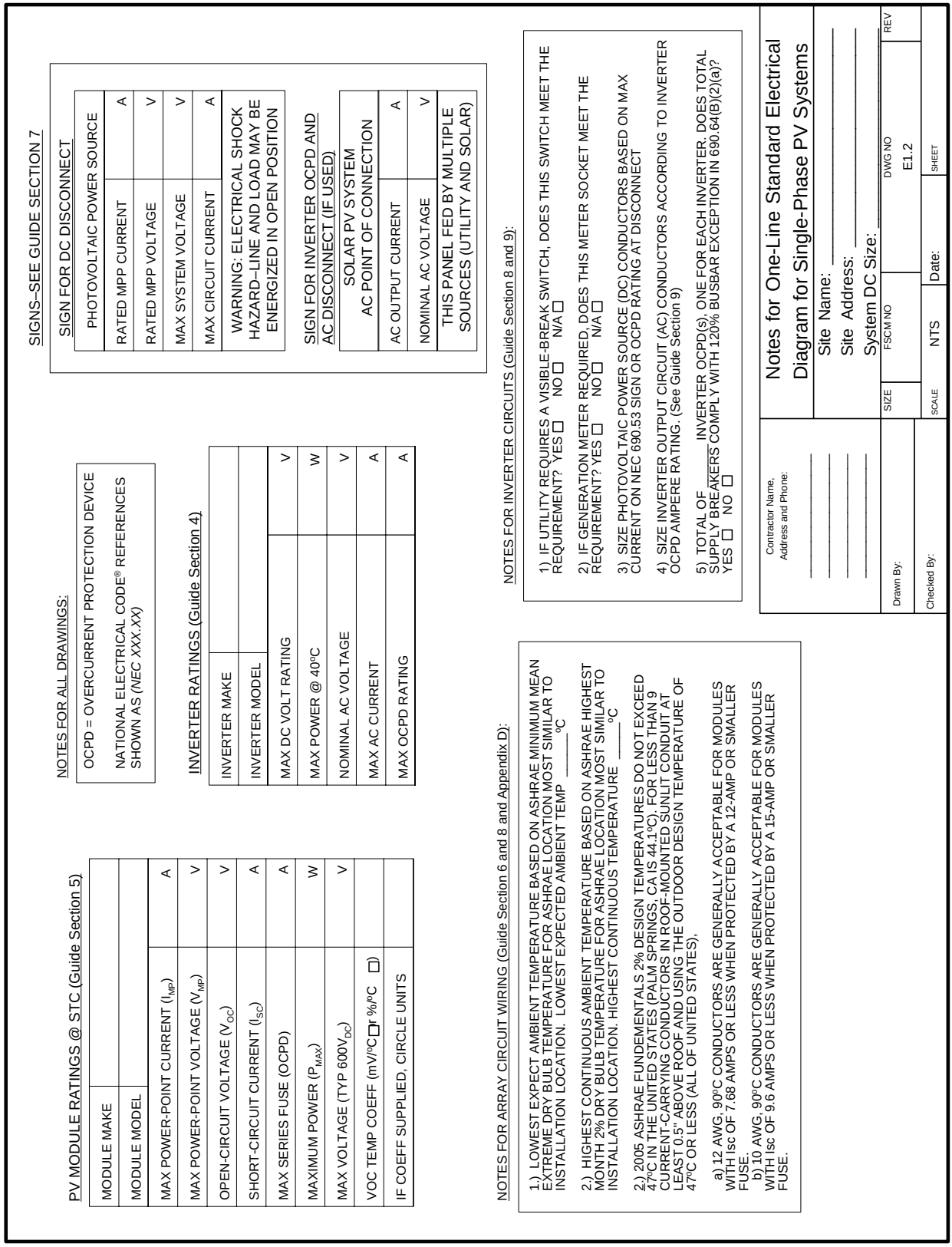


SUBMITTAL DIAGRAM TEMPLATES

STANDARD ELECTRICAL DIAGRAM

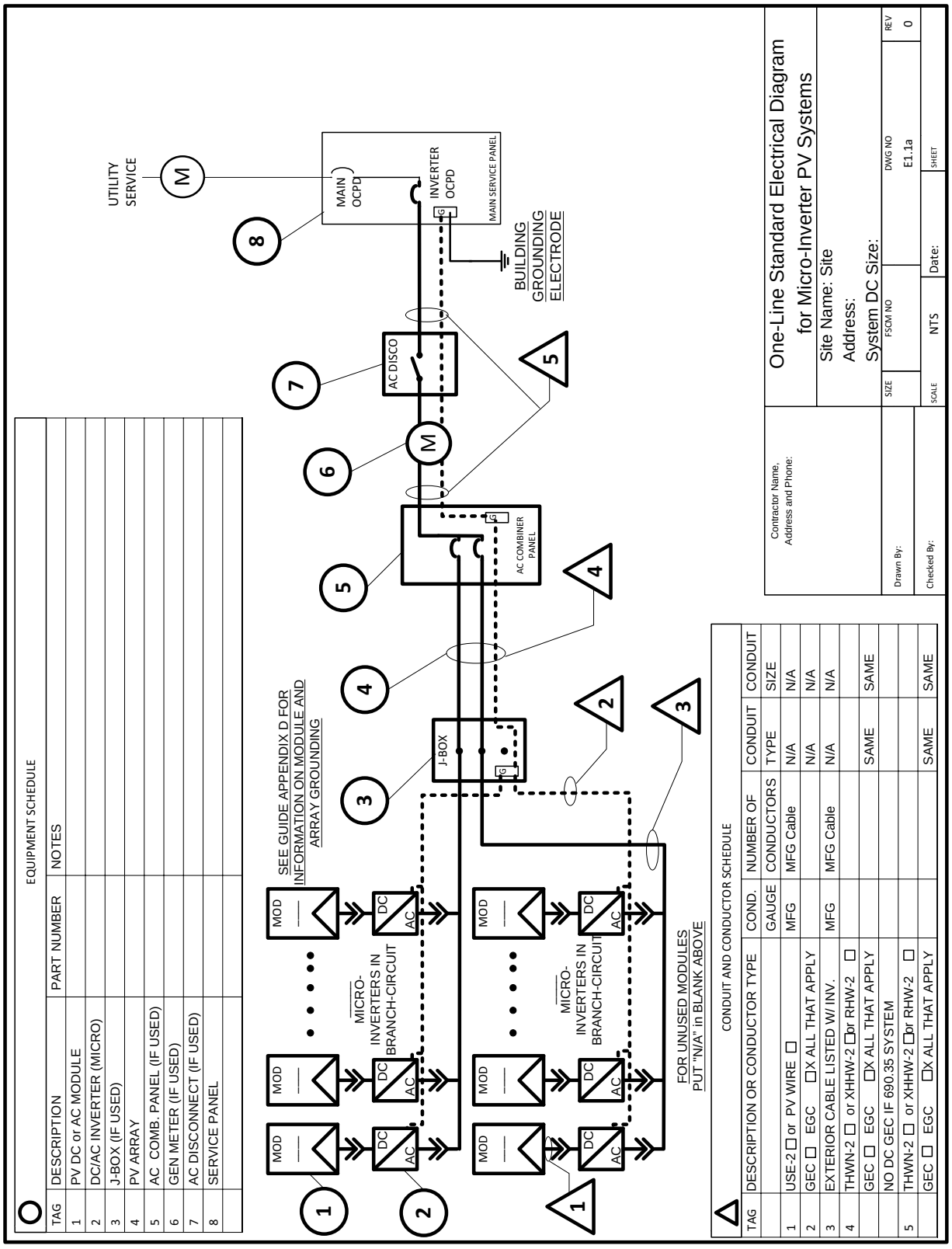


SUBMITTAL DIAGRAM TEMPLATES



SUBMITTAL DIAGRAM TEMPLATES

MICRO-INVERTER ELECTRICAL DIAGRAM



RESOURCE A

SUBMITTAL DIAGRAM TEMPLATES

NOTES FOR MICRO-INVERTER ELECTRICAL DIAGRAM

PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	
MODULE MODEL	
MAX POWER-POINT CURRENT (I_{MP})	
MAX POWER-POINT VOLTAGE (V_{MP})	
OPEN-CIRCUIT VOLTAGE (V_{OC})	
SHORT-CIRCUIT CURRENT (I_{SC})	
MAX SERIES FUSE (OCPD)	
MAXIMUM POWER (P_{MAX})	
MAX VOLTAGE (TYP 600V_{DC})	
VOC TEMP COEFF (mV/°C☐ or %/°C ☐	
IF COEFF SUPPLIED, CIRCLE UNITS	

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE

NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS *(NEC XXX.XX)*

INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	
INVERTER MODEL	
MAX DC VOLT RATING	
MAX POWER @ 40°C	
NOMINAL AC VOLTAGE	
MAX AC CURRENT	
MAX OCPD RATING	

SIGNS–SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

No sign necessary since 690.51 marking on PV module covers needed information

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM
AC POINT OF CONNECTION

AC OUTPUT CURRENT	
NOMINAL AC VOLTAGE	

THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)

NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix E):

1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP ____°C

2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE ____°C

2.) 2009 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),

a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.

b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT

4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)

5) TOTAL OF _____ INVERTER OUTPUT CIRCUIT OCPD(s), ONE FOR EACH MICRO-INVERTER CIRCUIT. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES☐ NO☐

Contractor Name, Address and Phone:

Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems

Site Name: Site

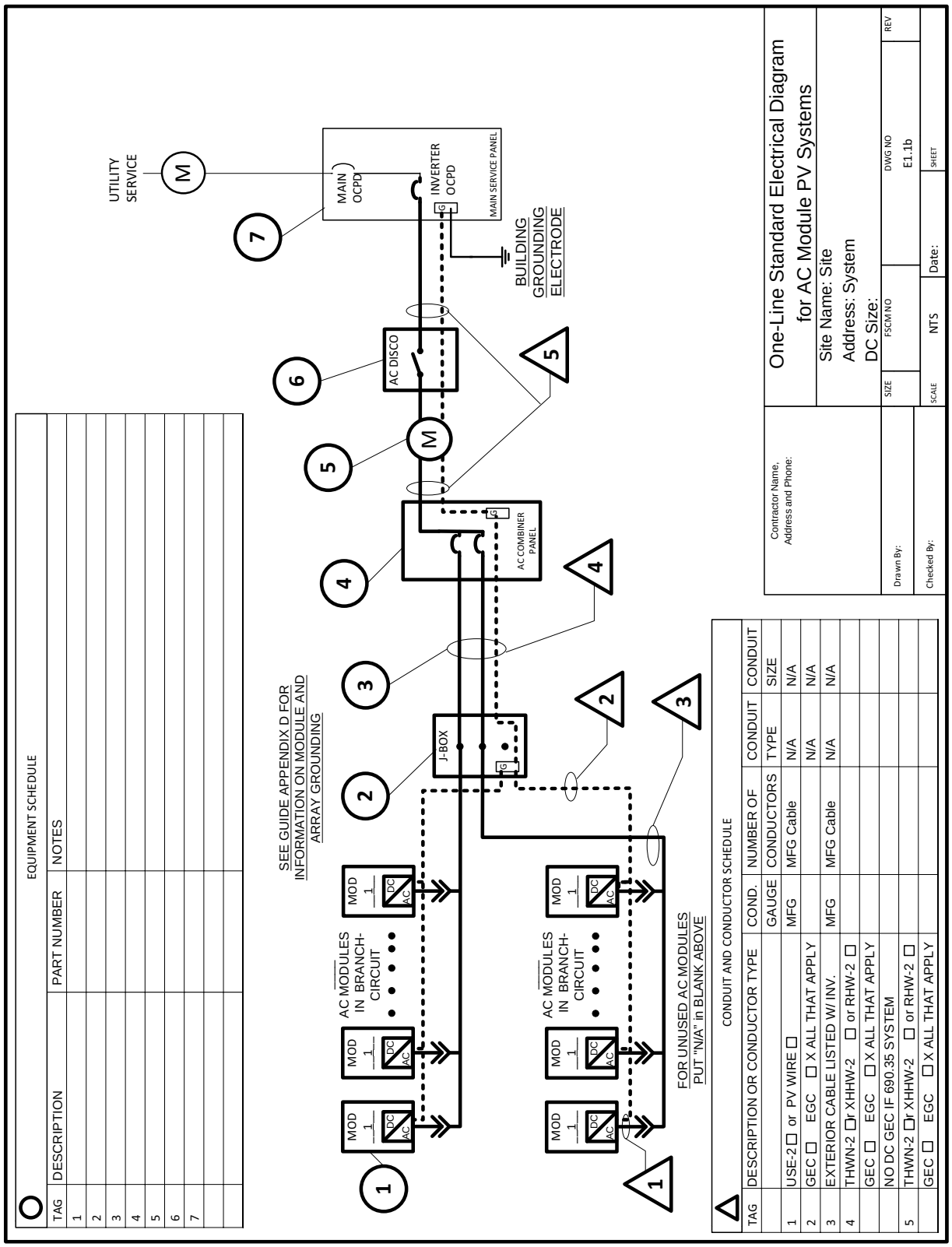
Address:

System DC Size:

Drawn By:	SIZE	FSCM NO	DWG NO	REV
			E1.2a	
Checked By:	SCALE	NTS	Date:	SHEET

SUBMITTAL DIAGRAM TEMPLATES

AC Module Electrical Diagram



Notes for AC Module Electrical Diagram

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE

NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS *(NEC XXX.XX)*

AC MODULE RATINGS (Guide Appendix C)

AC MODULE MAKE	
AC MODULE MODEL	
NOMINAL OPERATING AC VOLTAGE	
NOMINAL OPERATING AC FREQUENCY	
MAXIMUM AC POWER	
MAXIMUM AC CURRENT	
MAXIMUM OCPD RATING	

SIGNS–SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

N/A since no dc wiring

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM AC POINT OF CONNECTION	
AC OUTPUT CURRENT	
NOMINAL AC VOLTAGE	

THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)

NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix F):

1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP ____°C

2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE ___°C

2.) 2009 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR 6 OR LESS CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),

a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR AC MODULES INVERTER OUTPUT CIRCUITS WITH 12 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER OCPD.

b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR AC MODULES INVERTER OUTPUT CIRCUITS WITH 16 AMPS OR LESS WHEN PROTECTED BY A 20-AMP OR SMALLER OCPD.

NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

EXCEPTION IN 690.64(B)(2)(a)? YES NO
MODULE CIRCUIT. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR
1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES NO N/A

2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES NO N/A

3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT (N/A)

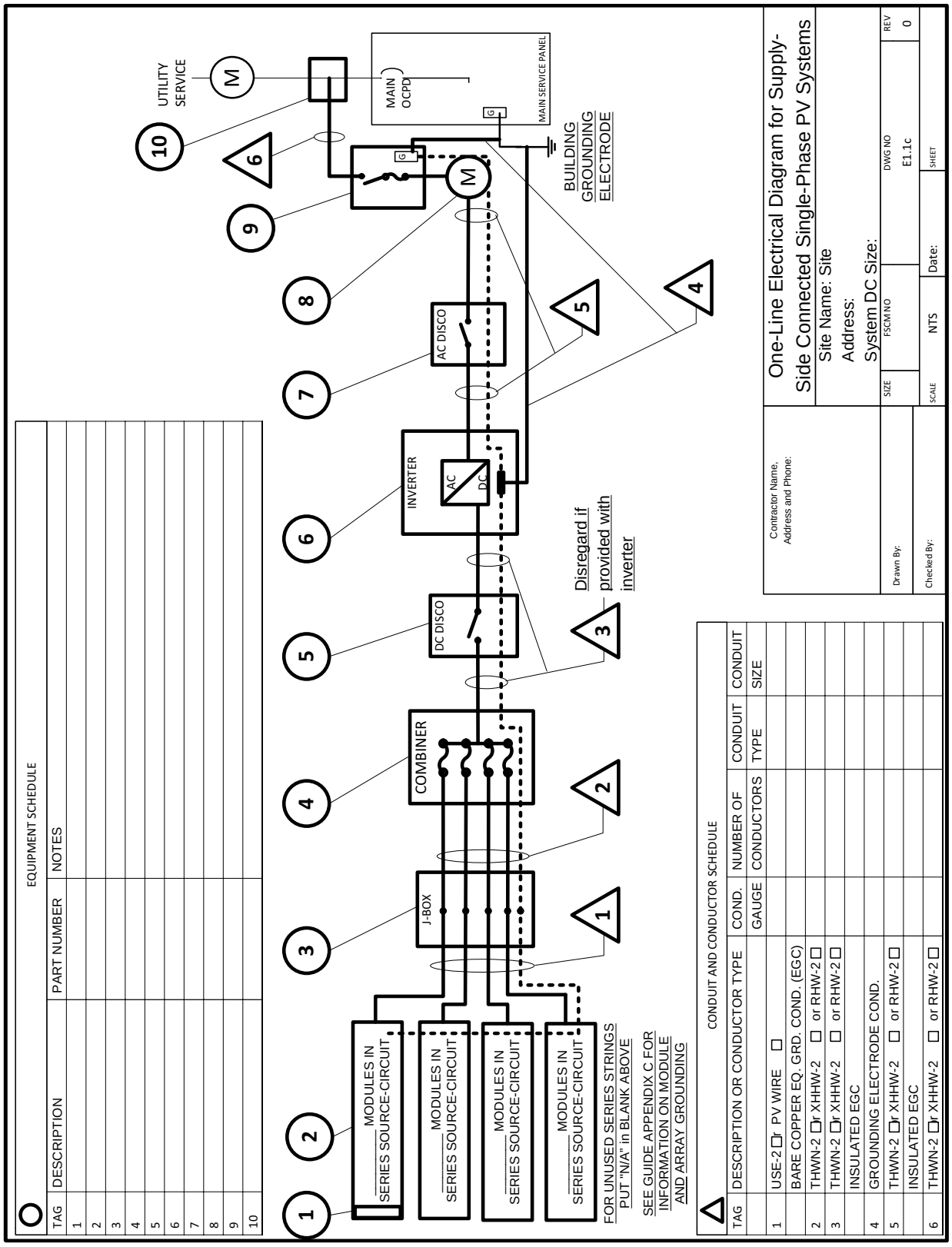
4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)

5) TOTAL OF _____ INVERTER OUTPUT CIRCUIT OCPD(s), ONE FOR EACH AC

Contractor Name, Address and Phone:	Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems Site Name: Site Address: System DC Size:			
Drawn By: Bill	SIZE	FSCM NO	DWG NO E1.2b	REV 0
Checked By: Ted	SCALE NTS	Date:	SHEET	

SUBMITTAL DIAGRAM TEMPLATES

SUPPLY-SIDE CONNECTED ELECTRICAL DIAGRAM



Solar America Board for Codes and Standards Report: Expedited Permit Process for PV Systems

NOTES FOR SUPPLY-SIDE CONNECTED ELECTRICAL DIAGRAM

PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	
MODULE MODEL	
MAX POWER-POINT CURRENT (I_{MP})	A
MAX POWER-POINT VOLTAGE (V_{MP})	V
OPEN-CIRCUIT VOLTAGE (V_{OC})	V
SHORT-CIRCUIT CURRENT (I_{SC})	A
MAX SERIES FUSE (OCPD)	A
MAXIMUM POWER (P_{MAX})	W
MAX VOLTAGE (TYP 600V_{DC})	V
VOC TEMP COEFF (mV/ºC☐r %/ºC ☐)	
IF COEFF SUPPLIED, CIRCLE UNITS	

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE

NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS *(NEC XXX.XX)*

INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	
INVERTER MODEL	
MAX DC VOLT RATING	V
MAX POWER @ 40ºC	W
NOMINAL AC VOLTAGE	V
MAX AC CURRENT	A
MAX OCPD RATING	A

SIGNS–SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

PHOTOVOLTAIC POWER SOURCE	
RATED MPP CURRENT	A
RATED MPP VOLTAGE	V
MAX SYSTEM VOLTAGE	V
MAX CIRCUIT CURRENT	A
WARNING: ELECTRICAL SHOCK HAZARD–LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION	

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM AC POINT OF CONNECTION	
AC OUTPUT CURRENT	A
NOMINAL AC VOLTAGE	V
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)	

NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix D):

1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP _____ºC

2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE _____ºC

2.) 2005 ASHRAE FUNDEMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47ºC IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1ºC). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47ºC OR LESS (ALL OF UNITED STATES),

a) 12 AWG, 90ºC CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.
b) 10 AWG, 90ºC CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT

4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)

5) TOTAL OF _____ INVERTER OCPD(s), ONE FOR EACH INVERTER. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES ☐ NO ☐

Contractor Name, Address and Phone:

_____
_____
_____
_____

Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems

Site Name: _____
Site Address: _____
System DC Size: _____

Drawn By:	SIZE	FSCM NO	DWG NO	REV
			E1.2	
Checked By:	SCALE NTS	Date:	SHEET	

RESOURCES

1. *Expedited Permit Processes for PV Systems*, Solar America Board for Codes and Standards, July 2012, Revision 2 http://www.solarabcs.org./about/publications/reports/expedited-permit/index.html
2. *California Solar Permitting Guidebook*, Solar Permitting Working Group, Governor's Office of Planning and Research, State of California, August 2012 http://opr.ca.gov/docs/California_Solar_Permitting_Guidebook.pdf
3. *New York State Unified Solar Permit*, The NY-Sun Initiative, GEN-NYSUN-uspi-form-1-v3 October 2014 http://www.cuny.edu/about/resources/sustainability/nyssolar/NYSolarSmartPermitWorkshops/GEN-SUN-uspi-10_31.pdf

RESOURCE B
SOLAR SITE ACCESS

(Source: US DOE, http://energy.gov/eere/energybasics/articles/solar-energy-resource-basics
http://energy.gov/energysaver/articles/siting-your-solar-water-heating-system)

Solar Energy Resource Basics

Solar radiation, often called the solar resource, is a general term for the electromagnetic radiation emitted by the sun. Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies. However, the technical feasibility and economical operation of these technologies at a specific location depends on the available solar resource.

Basic Principles

Every location on Earth receives sunlight at least part of the year. The amount of solar radiation that reaches any one spot on the Earth's surface varies according to:

- Geographic location
- Time of day
- Season
- Local landscape
- Local weather.

Because the Earth is round, the sun strikes the surface at different angles, ranging from 0 degrees (just above the horizon) to 90 degrees (directly overhead). When the sun's rays are vertical, the Earth's surface gets all the energy possible. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse. Because the Earth is round, the frigid polar regions never get a high sun, and because of the tilted axis of rotation, these areas receive no sun at all during part of the year.

The Earth revolves around the sun in an elliptical orbit and is closer to the sun during part of the year. When the sun is nearer the Earth, the Earth's surface receives a little more solar energy. The Earth is nearer the sun when it is summer in the southern hemisphere and winter in the northern hemisphere. However, the presence of vast oceans moderates the hotter summers and colder winters one would expect to see in the southern hemisphere as a result of this difference.

The 23.5 degree tilt in the Earth's axis of rotation is a more significant factor in determining the amount of sunlight striking the Earth at a particular location. Tilting results in longer days in the northern hemisphere from the spring (vernal) equinox to the fall (autumnal) equinox and longer days in the southern hemisphere during the other 6 months. Days and nights are both exactly 12 hours long on the equinoxes, which occur each year on or around March 23 and September 22.

Countries such as the United States, which lie in the middle latitudes, receive more solar energy in the summer not only because days are longer, but also because the sun is nearly overhead. The sun's rays are far more slanted during the shorter days of the winter months. Cities such as Denver, Colorado, (near 40 degrees latitude) receive nearly three times more solar energy in June than they do in December.

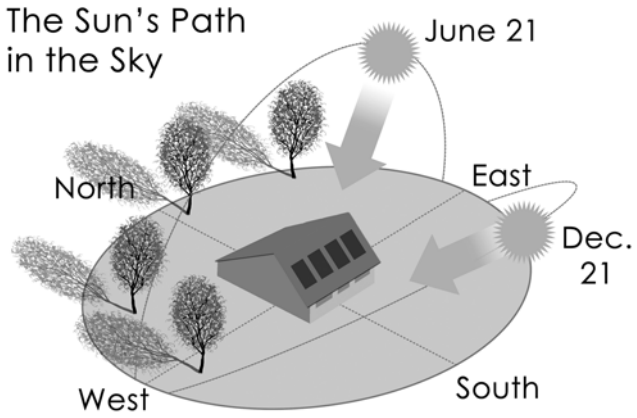
The rotation of the Earth is also responsible for hourly variations in sunlight. In the early morning and late afternoon, the sun is low in the sky. Its rays travel further through the atmosphere than at noon, when the sun is at its highest point. On a clear day, the greatest amount of solar energy reaches a solar collector around solar noon.

Diffuse and Direct Solar Radiation

As sunlight passes through the atmosphere, some of it is absorbed, scattered, and reflected by:

- Air molecules
- Water vapor
- Clouds
- Dust
- Pollutants
- Forest fires
- Volcanoes.

This is called diffuse solar radiation. The solar radiation that reaches the Earth's surface without being diffused is called direct beam solar radiation. The sum of the diffuse and direct solar radiation is called global solar radiation. Atmospheric conditions can reduce direct beam radiation by 10 percent on clear, dry days and by 100 percent during thick, cloudy days.



Measurement

Scientists measure the amount of sunlight falling on specific locations at different times of the year. They then estimate the amount of sunlight falling on regions at the same latitude with similar climates. Measurements of solar energy are typically expressed as total radiation on a horizontal surface, or as total radiation on a surface tracking the sun.

Radiation data for solar electric (photovoltaic) systems are often represented as kilowatt-hours per square meter (kWh/m^2). Direct estimates of solar energy may also be expressed as watts per square meter (W/m^2).

Radiation data for solar water heating and space heating systems are usually represented in British thermal units per square foot (Btu/ft^2).

Distribution

The solar resource across the United States is ample for photovoltaic (PV) systems because they use both direct and scattered sunlight. Other technologies may be more limited. However, the amount of power generated by any solar technology at a particular site depends on how much of the sun's energy reaches it. Thus, solar technologies function most efficiently in the southwestern United States, which receives the greatest amount of solar energy.

Siting Your Solar Water Heater

Before you buy and install a solar water heating system, you need to first consider your site's solar resource, as well as the optimal orientation and tilt of your solar collector. The efficiency and design of a solar water heating system depends on how much of the sun's energy reaches your building site.

Solar water heating systems use both direct and diffuse solar radiation. Even if you don't live in a climate that's warm and sunny most of the time -- like the southwestern United States -- your site still might have an adequate solar resource. If your building site has unshaded areas and generally faces south, it's a good candidate for a solar water heating system. Your local solar system supplier or installer can perform a solar site analysis.

Both the orientation and tilt of the collector will affect your solar water heating system's performance. Your contractor should consider both factors while evaluating your site's solar resource and sizing your system.

Collector Orientation

Solar hot water collectors should be oriented geographically to maximize the amount of daily and seasonal solar energy that they receive. In general, the optimum orientation for a solar collector in the northern hemisphere is true south. However, recent studies have shown that, depending on your location and collector tilt, your collector can face up to 90 degrees east or west of true south without significantly decreasing its performance.

You'll also want to consider factors such as roof orientation (if you plan to mount the collector on your roof), local landscape features that shade the collector daily or seasonally, and local weather conditions (foggy mornings or cloudy afternoons), as these factors may affect your collector's optimal orientation.

Collector Tilt

Today, most solar water heating collectors are mounted flat on the roof. This is more aesthetically pleasing than rack-mounted collectors, which stick up from the roof at odd angles. Thus, most collectors have the same tilt as the roof.

Although the optimal tilt angle for your collector is an angle equal to your latitude, fixing your collector flat on an angled roof will not result in a big decrease in system performance. You will, however, want to take roof angle into account when sizing your system.

ICC-SRCC

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The industry experts in Clean and Renewable Energy since 1980, ICC-SRCC fulfills the industry's need for a single, national program that allows manufacturers to rate and test the efficiency of solar equipment.

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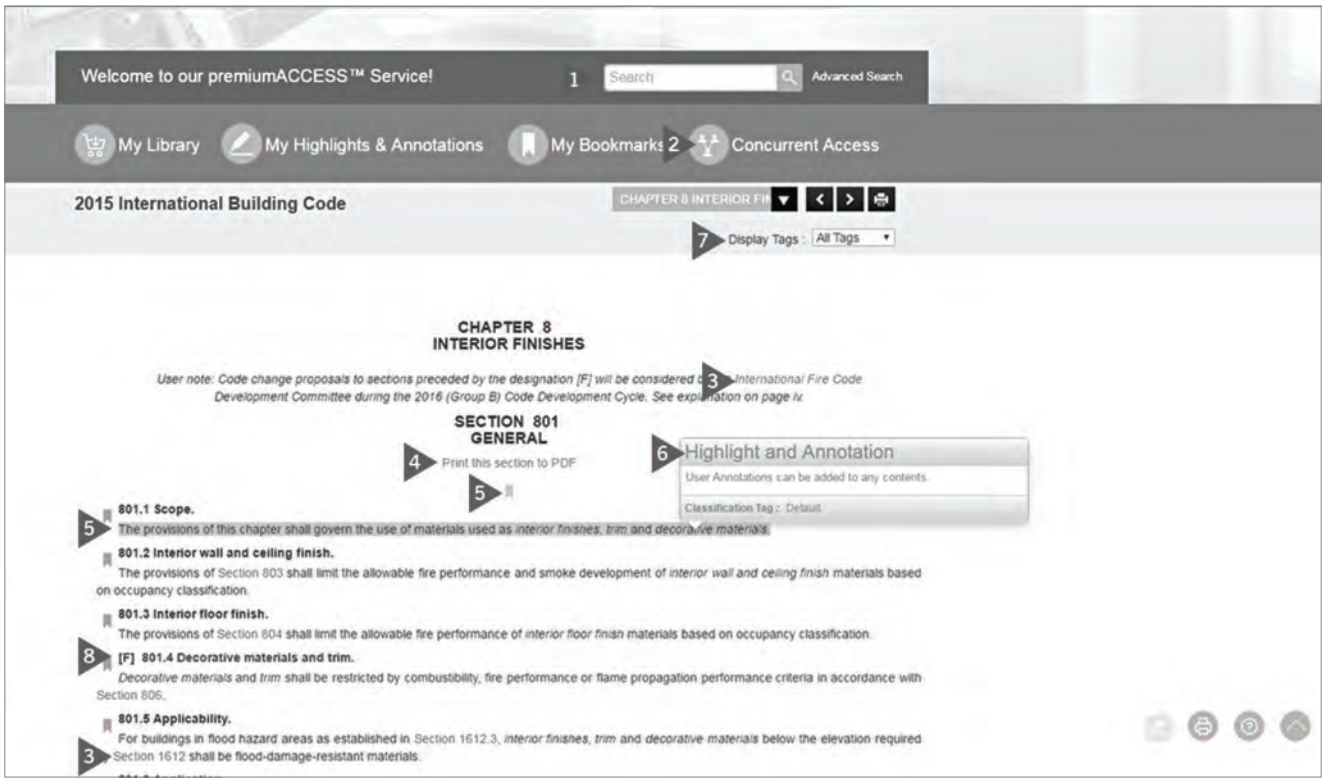

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