NEC Special Occupancies
A SunCam Online Continuing Education Course

NEC
Special Occupancies

Hazardous (Classified) Locations / Intrinsically Safe Conditions / Special Areas

Future Courses

IEEE Standard 45: A Guide to Electrical Installations on Shipboard

by

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Nomenclature[1]

AHJ	Authority Having Jurisdiction	-
ANSI	American National Standards Institute	-
ASTM	American Society for Testing and Materials (International)	-
CC	Committee Comment	-
CFR	Code of Federal Regulations	-
ESS	Essential Electrical Systems	-
ESWC	Electrically Safe Work Condition	-
ESA	Electrical Safety Authority	-
FR	First Revision	-
FR	Flame Resistant	-
GFCI	Ground-Fault Circuit-Interrupter	-
ICRP	International Commission on Radiological Protection	-
IEC	International Electrotechnical Commission	-
IS (I.S.)	Intrinsically Safe	-
ISEA	International Safety Equipment Association	-
ISO	International Organization for Standardization	-
LNG	Liquified Natural Gas	-
MESG	Maximum Experimental Safe Gap	mm
MIC	Minimum Igniting Current ratio	-
NEC	National Electrical Code	-
NETA	InterNational Electrical Testing Association	-
NFPA	National Fire Protection Association	-
NIOSH	National Institute for Occupation Safety and Health	-
OCPD	Over Current Protective Device	A
OEM	Original Equipment Manufacturer	-
OSHA	Occupational & Safety Health Administration	29CFR1903(b)(1)
SCR	Second Correlating Revision	-
SR	Second Revision	-
SCCR	Short-Circuit Current Rating	-
UL	Underwriters Laboratories, Inc.	-

[1] Not all the nomenclature, symbols, or subscripts may be used in this course—but they are related and may be found when reviewing the references listed for further information. Further, all the nomenclature, symbols, or subscripts will be found in of many electrical courses (on SunCam, PDH Academy, and also in many texts). For guidance on nomenclature, symbols, and electrical graphics: IEEE 280-2021. IEEE Standard Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering. New York: IEEE; and IEEE 315-1975. Graphic Symbols for Electrical and Electronics Diagrams. New York: IEEE, approved 1975, reaffirmed 1993.

Symbols

C	Capacitance	F
E, *E*	Energy	J
f	Frequency	Hz
I	Current	A
r	Distance	cm
T	Temperature	ºC
V	Voltage, Potential	V

Subscripts

a	ambient
amb	ambient

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TABLE OF CONTENTS

List of Figures

List of Tables

List of Equations

COURSE INTRODUCTION

The information is primarily from Ref [A].[2] A source for electrical information and phenomena in general is Ref [B]. Technical definitions are in Ref [C]. The standards for electrical diagram and symbols are in Ref [D] and Ref [E]. The "standard" for electrical analysis is in Ref [F]. Appendices are provided with useful information for the electrical engineer.

HISTORY AND CODE OVERVIEW[3]

Edison invented the first practical incandescent light bulb in 1879. In the very same year, the National Association of Fire Engineers met for the purpose of establishing requirements for electrical installations. As with many standards, in a few years there were six different standards in place. Therefore, in 1896 the various concerned groups convened a national meeting and one year later the *National Electrical Code* (NEC) (hereafter referred to as the "Code") was born.

The Code is official endorsed by ANSI (American National Standards Institute). The National Fire Protection Association (NFPA) committee responsible for the code is known as ANSI Standards Committee C1. The Code is utilized nationwide with local jurisdictions adoption en masse though with the occasional supplemental additions or deletions. The Code applies to electrical installations within or on public and private buildings up to and including connection to the providing power supply, see Fig. 1. Its overall purpose: prevent fires!

[2] This is a Handbook for NFPA 70 that contains the Code proper. Although not required, I highly recommend using NFPA's "Handbook" as the contain a wealth of interpretation and examples that will save and Engineer a great deal of research time.

[3] Paraphrased from the author's book published by Professional Publications Incorporated of Belmont, CA—now a Kaplan Company: John Camara, *Power Reference Manual for the PE Exam,* 3rd ed., (2018), (Kaplan, Inc., 2018), Chap. 56. In the 4th ed., the NEC is in. Chap. 44.

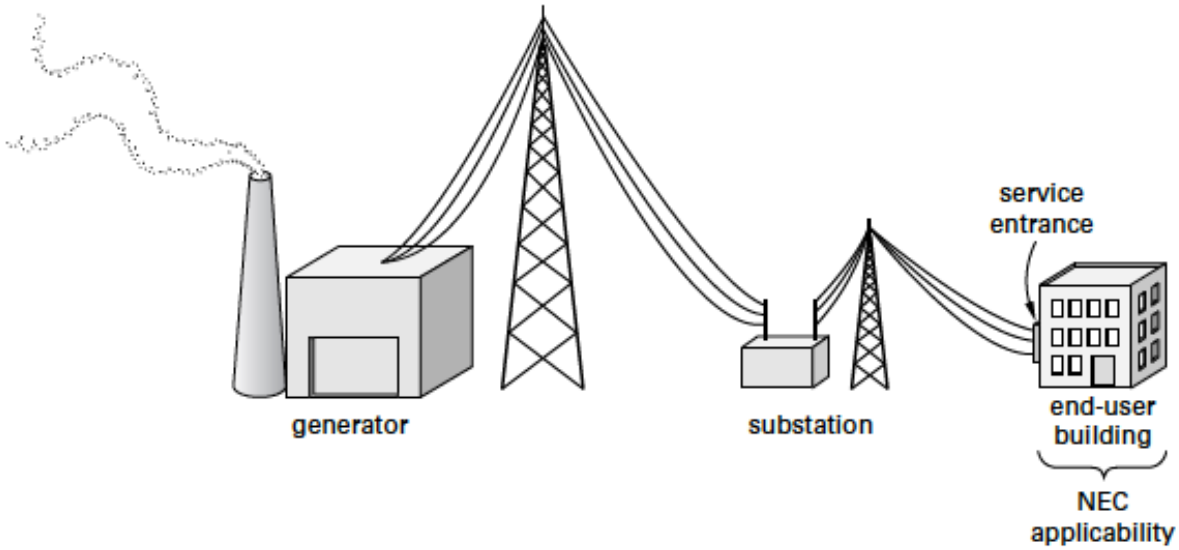

Figure 1: NEC Coverage
[Source: *Power Reference Manual for the PE Exam*]

The building code at the international level is International Electrotechnical Commission (IEC) Standard 60364-1, *Electrical Installations of Buildings*. The principles of protection and safety in the IEC code are addressed in the NEC, making it widely applicable.

Although the focus for the NEC is on requirements for such buildings (residential and commercial) and their internals for items with voltages less than 1000 V, this course will focus on Special Occupancies and their requirements in Chapter 5. Units will be both SI and USCS (United States Customary System)[4], reflecting their usage in the NEC. The code itself often displays both units with primary emphasis on SI units except where USCS units are still more often used. Conversion between the units in the Code are defined as either *soft* or *hard conversions.* Soft conversions are a change in the description of the measurement *without* changing the actual dimension—thus, the part will be interchangeable. Hard conversions change the dimensions making the part different than the original. As an example, a soft conversion of ½ is 12.7 mm, while a hard conversion is 13 mm.

[4] Informally referred to as the English Engineering System. Differences do exist but are unimportant for our purposes.

The course will refer directly to Code Chapters (1-9), Parts (I, II…) Articles (###), Sections (A, A(1), B, B(1)…), and Informative Annexes (A–J).[5] While a copy of the code will be adequate for verification and usage, for those whose occupations require a deeper understanding of the Code and its three-year updates, I recommend the following.[6]

NFPA 70®
National Electrical Code®
HANDBOOK
by
Mark W. Earley, PE
Editor-in-Chief
2023

This is an official publication of the NFPA with numerous advantages over a mere copy of the Code. For instance, the Handbook contains commentary text in blue, which is used to explain the reasons for the requirement or its application. Revised Code text is shaded gray for ease of noting changes. A single circular bullet on an empty line space, such as that below, indicates deleted sections of the code.

•

The Greek delta symbol ("change"), Δ, when used by a section number indicates words were deleted; when used beside a table it signifies a revision of the data within. An italic *N* reveals a new article, section, table, or figure. The Handbook also contains a "See also" marking bringing to the reader's attention other Code areas where additional information is found.[7] Finally, and arguably the most useful features, are the Exhibits containing figures or pictures that bring the words to visual life, Calculation Examples providing scenarios for application of the Code requirements, and a Summary of Technical Changes listed prior to the Code itself.

The Code consists of an introduction followed by nine chapters, which are further subdivided into articles, parts, and sections. It ends with "informative annexes" that provide useful information but no actual requirements.

[5] Articles are single-subject entries and Sections and Sub-Sections contain the rules themselves. The word "Article" is often used for "Section" though technically the terminology "Section" should be used. Additionally, in this course, not all Parts are mentioned. They are mentioned when the topics are considered significant.
[6] The author is not associated with this text or the NFPA. I have simply found this handbook extremely useful throughout the years. Also, regardless of the NEC update year, the principles provided in this course will be useful guidance—some article locations may change with the occasional technical update or addition as well.
[7] The "see also" feature is new and extremely helpful. This course will focus on the methodology of finding all the information required to ensure compliance. The Handbook's use of this feature is very much along these lines.

- Introduction
-
- Chapter 1: General
- Chapter 2: Wiring and Protection
- Chapter 3: Wiring Methods and Materials
- Chapter 4: Equipment for General Use
-
- Chapter 5: Special Occupancies
- Chapter 6: Special Equipment
- Chapter 7: Special Conditions
-
- Chapter 8: Communications Systems
-
- Chapter 9: Tables
-
- Annex A: Product Safety Standards
- Annex B: Application Information for Ampacity Calculations
- Annex C: Conduit, Tubing, and Cable Tray Fill Tables…
- Annex D: Examples
- Annex E: Types of Construction
- Annex F: Critical Operations Power Systems…
- Annex G: Supervisory Control and Data Acquisition (SCADA)
- Annex H: Administration and Enforcement
- Annex I: Recommended Torque Tables…
- Annex J: ADA Standards for Accessible Design
- Annex K: Use of Medical Equipment in Dwellings…

The breaks shown in the bullet list are to resolve the NEC into relevant areas. The Introduction is just that. Chapters 1–4 generally applies to all electrical installations. Chapter 5–7 supplements or modifies the information in Chaps. 1–7. Chapter 8 stands alone unless it specifically references an earlier requirement. Chapter 9 contains major tables and are used when referenced as applicable in the Code. The annexes are for information only and are not mandatory for compliance with the Code.[8]

[8] For a complete overview of the NEC, refer to the course *NEC Overview*. This course will give a quick introduction, present some important definitions, and cover terminology useful for understanding the Special Occupancies chapter.

SUMMARY OF TECHNICAL CHANGES

Technical changes occur with each update. A review of this section is a good place to start when evaluating if any of the changes impact your work or documents.

Article 90 Introduction

The Introduction of the code explains its purpose as the "practical safeguarding of persons and property from hazards arising from the use of electricity." Such hazards may exist due to a lack of conformity to the code or not allowing for future expansion of electrical system loading.

The scope of the Code includes public and private building, parking lots, industrial substations, carnivals, installations that connect to the electricity supply, and those electric utility installations that are not an integral part of the power generation, among others. Relatively new (in 2020) is application of the Code to power to ships, marinas, and shipyards.[9] Also new is coverage of installations that allow power from vehicles to be exported into premises. Check Art. 90.2 for a complete list of items covered and exempted.

The Code is meant to be a legal document for interpretation and implementation by local governmental bodies. Most implement the Code en masse. However, some may adjust portions of the Code as required for local needs. Mandatory Rules are those where action is specifically required or prohibited. The words "shall" or "shall not" are indicative of such rules. Permissive Rules are those where action is allowed but not required. The words "*shall be permitted*" or "*shall not be required*" are indicative of such rules. Explanatory Materials is contained in Informational Notes. Such notes are just that, "*information*," and as such are not enforceable portions of the Code. Another unenforceable portion of the Code are the Informational Annexes, which provide guidance on Code use.

[9] This is a timely addition given the increased prevalence of ESD—Electric Shock Drowning. Many "drownings" around boats are labeled as such when in fact they may be due to electric current flowing in the water due to a faulty wiring condition on a nearby boat.

CHAPTER 1 GENERAL

Article 100 Definitions

This article contains essential definitions; that is, those indispensable to the Code while exempting common technical terms found in other codes and standards.

Accessible equipment is capable of being reached for "operation, renewal, and inspection." Accessible wiring is that capable of being "removed or exposed without damaging" a structure or finish. Readily Accessible indicates the ability to reach equipment or items without using tools (except for keys) or having to remove interfering equipment.

Ampacity is the maximum current a conductor can carry without exceeding its temperature rating. The Authority having Jurisdiction (AHJ) is the authority with responsibility for enforcing the Code or approving installations, equipment, et cetera.

Bond and Bonding is the connection or cable/wire, and process used to ensure electrical continuity and conductivity. Bonding is NOT grounding, do not confuse the two. A Ground is the earth with "Grounding" indicating the connection to the ground or the connective body that extends to the ground.

Consider a typical distribution system as shown in Fig. 2. The definitions for the individual portions, though somewhat self-explanatory, are also contained in Art. 100. A *branch circuit* are the conductors between the final overcurrent device and the outlet(s). A *continuous load* is one in which the maximum current is expected to last for 3 hours or more. *Continuous duty* is operation at a substantially constant load for an infinitely long time.

Electrical circuits are subject to overcurrent conditions and as such a system should be designed for *selective coordination*; that is, localization of an overcurrent condition to the circuit or equipment effected. Meaning, should a fault occur, it impacts the circuit or equipment with the fault and not the rest of the system. This is isolating closest to the fault and as far from the source as possible. Also, of note for those designing protective systems, overcurrent is a fault condition exceeding the range of the equipment, which could result in damage. *Overcurrent* (faults) can ripple through a poorly designed system and are defined as any current in excess of rated equipment current or ampacity of the conductor and may result from short circuit, ground fault, or

overload. *Overload* is a condition where current is slightly above the maximum, which could result in overheating. Overloads generally impact one circuit or piece of equipment only. Per Fig. 2, a fault on the lower branch circuit should open the fixed overcurrent protective device in the panelboard and not any protection for the feeders in the power supply source.

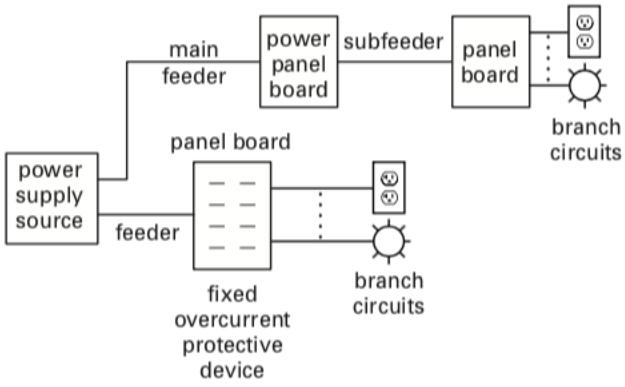

Figure 2: Typical Distribution System
[Source: *Power Reference Manual for the PE Exam*]

Figure 3 should be referred to for the bonding and grounding explanation that follows. The generic terms used by electricians and engineers for the grounding wiring doesn't match-up with the technical names provided by the NEC, so understanding the differences is very helpful in the field.

A *Bonding Conductor* or *Jumper* is a reliable conductor necessary to ensure electrical conductivity between metal parts. The Bonding Jumper is shown as yellow in the NEC figures. An *Equipment Bonding* Jumper provides connection between two or more portions of the *Equipment Grounding Conductor*, the latter of which is the green wiring. That is, when all the metal parts are not electrically connected, the bonding jumper provides the continuity to the grounding (green) system. Of note, the equipment grounding conductor (green) is NOT meant to carry current under normal conditions. It is there for safety in the event of a fault to prevent the metal parts from achieving a voltage above that of earth ground and thus presenting a hazard to people. The *grounding electrode* is a conducting object through which a direct connection to Earth. The *grounding electrode conductor* connects the system *grounded conductor* (intentional grounded

conductor—white wire, the neutral) or the *equipment grounding conductor* (safety ground—green wire), or both, or to a point on the grounding electrode system.[10]

The *Main Bonding Jumper* is the connection between the *grounded circuit (service) conductor* (white—commonly called the "neutral") and the *equipment grounding conductor* (green—commonly called the "ground") or the *supply-side bonding jumper*, or both. All are shown in Fig. 3. The terminology shown in quotations represents the name one might hear in the field, from electricians, or those familiar with wiring and its usage.

The numbering and connection scheme on the panelboard in Fig. 3 are standard. The black "hot" wire is connected to breaker slots #1 and #2. The red "hot" wire is connected to breaker slots #3 and #4. The potential between the red and black wires is 208 V for most households. The potential between the red and neutral, or black and neutral, is 120 V. Therefore, if a double breaker setup is used between slots #1 and #3, the voltage is 208 V. Now consider the single receptacle shown in the diagram. The red-hot wire in slot #36 (not labeled in order to show the circuit breaker) connects to the hot side of the receptacle. The neutral white wire connects to the larger receptacle opening. The voltage on the receptacle and between slot #36 and neutral is 120 V. The equipment grounding conductor, the green wire, is connected to the grounding input on the receptacle—no current intentionally flows on this green wire, only during as fault does current use this path thus keeping the potential at Earth ground potential, 0 V, and protecting anyone touching the receptacle metal.

Breakers used in the household panel boards provide overcurrent, overload, arc fault circuit interruption (AFCI), and ground fault circuit interruption (GFCI), all of which will be covered in the appropriate articles.

[10] The "grounded conductor" is almost always the neutral conductor; that is, the white wire. One exception is a corner grounded delta, which does not have a neutral point but instead grounds one end of two different phases.

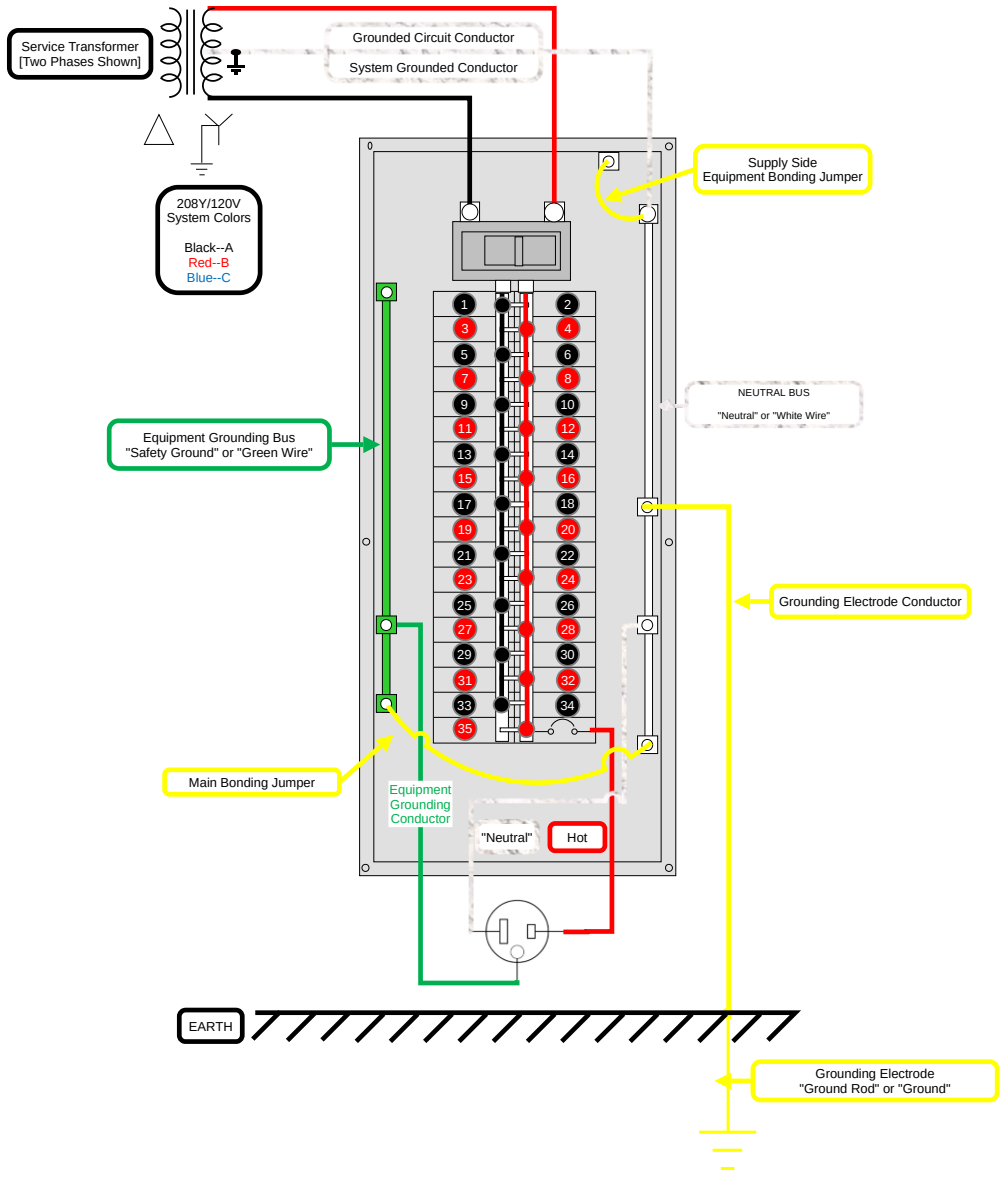

Figure 3: Bonding and Grounding Terminology

Continuing with definitions from Art. 100, an *electrical datum plane* is a specified distance above a water level above which electrical equipment can be installed and electrical connections made. This includes rain and snowfall, the opening of dams and floodgates but NOT manmade or natural

disasters. An *equipotential plane* are the accessible conductive parts bonded together to reduce voltage gradients.

Available fault current is the largest amount of current delivered to the fault point in a system during a short circuit. The current available can be limited by wiring resistance, overcurrent protective devices, and transformer capability (rating).[11]

When applied to a conductor, free air indicates an open or ventilated (italics are the author's) environment allowing for heat dissipation and air flow around said conductor.

Island mode is an operational mode of a stand-alone power production equipment or isolated microgrid. Such island mode setups are increasing common and involve the use of solar equipment as well as standard diesel generators. Isolated microgrids differ from interconnected microgrids whose latter requirements are in Art. 705.

Locations are classified as damp—subject to moisture, wet—underground or in direct contact with the earth, and dry—which is a location not normally subjected to dampness or wetness but could be temporarily exposed.

A service is the conductors and equipment connecting the serving utility to the wiring of the premises. A separately derived system is one other than a source. Examples include generators, transformers, or solar systems that have no direct connection (other than incidentally through grounding or metal enclosures) to another source.

The voltage of a circuit is the greatest root mean square (rms), also known as effective, difference in potential between any two conductors. For example, 208Y/120 V and 480Y/277 V. The first voltages listed are those between ungrounded (phase) conductors whereas the voltages listed second (i.e., 120 V and 277 V) are the voltages from a conductor (phase) to the grounded conductor (neutral). A nominal voltage is a value assigned for the purpose of conveniently designating a circuit's or system's voltage class. For example, 240/120 V, 480/277 V, and 600 V.

[11] Once a transformer saturates, it can no longer deliver any additional energy to its secondary windings.

CHAPTER 5: SPECIAL OCCUPANCIES

Article 500 Hazardous (Classified) Locations, Classes I, II, and III, Divisions 1 and 2

500.1: Scope

The NEC does not classify hazardous locations. Rather, the NEC provides the guidance for electrical equipment and wiring in such locations. Such locations are called “hazardous” or “classified”; and the terms are used interchangeably by the NFPA.

Common materials in such locations are flammable and combustible liquids. A flammable liquid is one with a flashpoint below 100ºF. A combustible liquid is one with a flashpoint above 100ºF. Such liquids must be at its flashpoint before an explosion may occur.

Article 500 covers Class I, II, and III locations and their associated Divisions, which are explained in Articles 501, 502, and 503 respectively. Zone classification is in Articles 505 and 506. Article 504 explains the requirements for an intrinsically safe system, which is used by both Class and Zone systems.

The NEC does not specifically apply to areas where ammunition, blasting powder, or dynamite are stored though they may use the methods mentioned.

500.4: Documentation[12]

Areas designated as hazardous (classified) shall be documented on an *area classification drawing*, see Fig. 1. This section also lists a great deal of references applicable to various locations and specific substances in the informational notes.

[12] Of note, this entire section and much of Chap. 5 lists many explanatory references in Informational Notes.

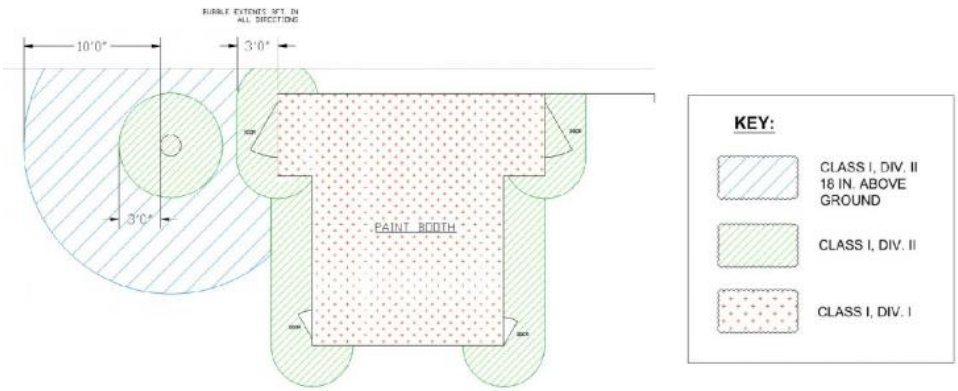

Figure 4: Example Area Classification Drawing
(Source: *https://www.utieng.com/electrical-area-classification-and-equipment/*)

505.5: Classification of Locations

New to the code is the case of a refrigerant machinery room using ammonia. Specifically, in 500.5(A)(2) it specifies that with continuous ventilation or ventilation initiated at a level not exceeding 150 ppm, the area may be considered unclassified.

A *Class I Location* is one in which flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors are or may be in air in sufficient quantities to produce ignitible or explosive mixtures. [500.5(B)]

A *Class I, Division 1 Location* is where the vapors mentioned above can exist during *normal operating conditions,* during *repair or maintenance,* or because of *leakage*. [500.5(B)(1)]

A *Class I, Division 2 Location* is where the vapors mentioned above are handled but are in containers or closed systems and can escape only due to an accident, or positive ventilation failure, or is adjacent to a Class I Division 1 area. [500.5(B)(2), (1)(2) and (3)]

A *Class II Location* are those that are hazardous due to the presence of combustible dust. [500.5(C)]

A *Class II, Division 1 Location* is one in which dust is in the air in sufficient quantities to produce ignitible or explosive mixtures, or where *failure or abnormal operation* might cause such a

condition, or where Group E dust may be present in *normal (or abnormal) operating conditions*. [500.5(C)(1), (1)(2) and (3)]

A Class II, Division 2 Location where dust is present in *abnormal operating conditions* but is normally insufficient to produce explosive or ignitible, where dust could result from malfunctioning equipment, or dust could interfere with electrical equipment. [500.5(C)(2), (1), (2), and (3)]

500.6: Materials

500.6(A): Class I Group Classifications

Class I locations Groups B through D use the terms Maximum Experimental Safe Gap (MESG) and Minimum Igniting Current ratio (MIC). MESG is the maximum clearance between two parallel metal surfaces that has been found, under specified test conditions, to prevent an explosion in a test chamber from being propagated to a secondary chamber containing the same gas or vapor at the same concentration. MIC is the ratio of the minimum current required from an inductive spark discharge to ignite the most easily ignitible mixture of a gas or vapor, divided by the minimum current required from an inductive spark discharge to ignite methane under the same test conditions.

Group A: Acetylene

Group B: Flammable or Combustible liquid-produced vapor with MESG ≤0.45 mm or MIC ratio ≤0.40.

Group C: Flammable or Combustible liquid-produced vapor with MESG >0.45 mm or MIC ratio >0.40.

Group D: Flammable or Combustible liquid-produced vapor with MESG >0.75 mm or MIC ratio >0.800.

500.6(B): Class II Group Classifications

Group E: Atmospheres with combustible dusts…that present hazards to electrical equipment.

Group F: Atmospheres with combustible carbonaceous dusts containing more that 8% total entrapped volatiles. Coal, carbon black, and coke are examples.

500.6(C) and (D): Class III Combustible and Ignitible Fibers/Flyings

Class III items shall not be further grouped.

500.7: Protection Techniques

Techniques include Explosion Proof for Class I, Division 1 or 2; Dust Ignition Proof for Class II, Division 1 or 2; Dust Tight[13] for Class II, Division 2 or Class III; and Purged and Pressurized for any area in which it has been analyzed.[14]

500.7(E): Intrinsic Safety

An *intrinsically safe* (IS) *system* is one in which any spark or thermal effect is not capable of causing ignition under prescribed conditions. An *intrinsically safe* (IS) *circuit* called a nonincendive *circuit* is one in which any spark or thermal effect is not capable of causing ignition under prescribed conditions.

Intrinsic Safety as a protection is allowed for all classes and divisions with certain restrictions depending on the technique utilized. Examples follow.

A nonincendive circuit, equipment, or component is allowed in Class I, Division 2; Class II, Division 2; or Class III, Division 1 or 2. Oil immersion for current-interrupting contacts in Class 1, Division 2 locations. Hermetically sealed protection is allowed for Class I, Division 2; Class II, Division 2; or Class III, Division 1 or 2.

Detection of flammable gasses is permitted as protection only in restricted industrial establishments. Several other conditions for the detection equipment are in 500.7(K)(1), which is a new requirement for code year 2023.

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[13] Shown as one word in the NEC: dusttight.
[14] The Purge and Pressurized method can be used to lower the classification of an area. See NFPA 496 for details.

Protection techniques and exceptions continue through 500.7(A) through (T). Equipment requirements exist in 500.8. Of note, if the ambient temperature range is −25ºC to +40ºC shall no temperature marking; if outside this range, the equipment shall be marked with the actual ambient temperature using the symbol Ta or Tamb.

Article 501 Class I Locations

This article lists the requirements in Class I locations. For example, the zone equipment that may be used [501.5] (zones are covered later); wiring methods, conduit and wire to be utilized [501.10(A)(1)]; flexible connections allowed, boxes and fittings (all of which must be marked for use as "Class 1, Division #) [501.5(A)(3)]. Similar coverage exists for Class I, Division 2 [501.5(B)].

Sealing requirements for conduits and entry points at boundaries are covered in 501.15. Detailed study of these sections should be done when installing or modifying such an area (through 501.150).

Article 502 Class II Locations

Similar requirements exist for Class II locations. Detailed study of these sections should be done when installing or modifying such an area (through 502.150).

Article 503 Class III Locations

Similar requirements exist for Class III locations. Detailed study of these sections should be done when installing or modifying such an area (through 502.150).

Article 504 Intrinsically Safe Systems

This article covers the use of intrinsically safe (I.S. or IS) equipment, wiring, and systems for use in hazardous (classified) locations. Similar requirements exist for Class II locations. Detailed study of these sections should be done when installing or modifying such an area (through 502.150).

The two most important standards for use in this area are ANSI/UL 913, *Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous*

(Classified) Locations and ANSI/UL 60079-11, *Electrical Apparatus for Explosive Gas Atmospheres—Part 11: Equipment Protection by Intrinsic Safety "I"*, which is based on IEC 60079-11.

IS wiring is most likely *power* limited. See Art. 725 and 760 for such wiring. Article 800 may also be applicable.[15]

IS conductor in a raceway, cable tray, or cable must be separated from other conductors by 50 mm (2 in) and from grounded *metal* by 0.91 mm (0.0359 in) minimum or have an approved insulating partition. [504.30(A)(1)] The separation requirements are similar for enclosures and other routing. [504.30(A)(2) and (3)] Terminals for different IS conductors must be separated by 6 mm (0.25 in). [504.30(B)] Grounding is in 504.50, bonding in 504.60, sealing in 504.70, and identification requirements in 504.80.

Article 505 Zone 0, 1, and 2 Locations

This article covers an alternative to the division classification method for fire and explosion hazards due to flammable gases, vapors, or liquids ONLY. Extensive additional documentation worthy of study is in 505.4.
A Zone 0 location is one where flammable gases or vapors are in the air *continuously or for a long period of time*. A Zone 1 location is one where such gases or vapors are *likely in normal operating conditions*, or are frequently in the air due to *repair or maintenance*, or where *breakdowns or faulty operations* could result is such a condition, or *adjacent to* Zone 0. A Zone 2 location is one in which flammable gases or vapors are *not likely during normal operation*, or where such gases or vapors are contained but during an *accident, breakdown, or abnormal operation* could exist in the air, or *is adjacent to* Zone 1.

For classification purposes, the zones depend upon the materials present and their quantities and are defined in groups. **Group IIC** are those containing acetylene, hydrogen,…with a MESG of ≤0.50 mm or MIC ratio ≤0.45. **Group IIB** are those containing acetaldehyde, ethylene,…with MESG of >0.50 mm but ≤0.90 mm or a MIC ratio >0.45 but ≤0.80. **Group IIA** are those

[15] It should be obvious by this point there is too much detailed information in this chapter to allow for memorization. Once one knows the classification of the area, detailed study is warranted.

containing acetone, ammonia, ethyl alcohol, gasoline, methane, propane,…with MESG >0.90 mm or a MIC of >0.80.

Table 1: Zone / Division Comparison

Zone Classification	Division Classification
Group IIC	Groups A and B
Group IIB	Group C
Group IIA	Group D
Group I	Group D

Protection techniques for zones are listed in 505.8(A)-(I) and most are given acronyms/designators one might see on equipment or drawings. Flameproof is “d”. Pressurized Enclosure is “p”. Intrinsic Safety is “i” followed by a letter: “ia” for Zone 0, “ib” for Zone 1, and “ic” for Zone 2. There are several others as well.

Marking, which can be extensive, is covered in 505.9(C). Wiring methods for each zone are in 505.15. Sealing and Draining requirements are in 505.16 which contains a number of changes in this code year.

Article 506 Zone 20, 21, and 22 Locations for Combustible Dusts or Ignitible Fibers/Flyings

This article is similar to the Art. 505 structure for dust and fibers/flyings.

Article 511 Commercial Garages, Repair and Storage

This covers service or repair locations that have operations with self-propelled vehicles in which volatile flammable liquids or gases are used for fuel or power. The first section contains Table 511.2 that refers one to earlier applicable sections. Of note, parking garages are permitted to be unclassified. Classifications by Division and Zones for heavier than air and lighter than air fuels are located in Tables 511.3(C) and (D), respectively. Battery charging equipment shall not be located in these locations. Electric vehicle charging equipment shall be installed per Part III of Art. 625 except that connectors shall not be located in Class I locations and overhead cords the sag must remain 150 mm (6 in) above the floor. [511.10(B)(2) and (3)]

Article 512 Cannabis Oil Equipment and Cannabis Oil Systems Using Flammable Materials

This section is new in the code.

Article 513 Aircraft Hangers

This article applies to areas where aircraft are stored or housed in which the aircraft contain Class I (flammable) or Class II (combustible) liquids whose temperature is above their flashpoints. It does not apply to areas where aircraft have never contained fuel or unfueled aircraft are located.

One of the first sections contains Table 513.2 that refers one to earlier applicable sections. Of note, aircraft batteries shall not be charged when the aircraft is inside or partially inside a hangar. [513.10(A)(2)]

Article 514 Motor Fuel Dispensing Facilities

Again, one of the first sections contains Table 514.2 that refers one to earlier applicable sections. Motor fuel dispensing facilities are specified as per their divisions or zones in Table 514.3(B)(1) and (B)(2) for LNG. Of note, fuel dispensing facilities shall be provided with clearly identified emergency shutoff devices or electrical disconnects located not less than 6 m (20 ft) but not more than 30 m (100 ft) from the fuel dispensing devices they serve [514.11(A)].

Article 515 Bulk Storage Plants

Again, one of the first sections contains Table 515.2 that refers one to earlier applicable sections. Bulk storage plants are specified as per their divisions or zones in Table 515.3.

Article 516 Spray Application, Dipping, Coating, and Printing Processes

The indicated facilities are specified as per their divisions or zones in Table 516.2. Area classifications are in 516.4 vice a table in this article. Grounding and electrostatic equipment are of concerns during such operations.

Article 517 Health Care Facilities

In health care facilities it is difficult to keep a capacitive or conductive path away from a patient's body especially since instrumentation may be directly connected to the patient. The requirements in Part II and III of this article apply to single-function and multiuse buildings (such as a doctor's office).

Reconditioned equipment is governed by Art. 110, but this article is not applicable to patient care-related electrical equipment. [517.6]

Part II, Wiring and Protection applies to patient care spaces but not offices, corridors, et cetera. [517.10(A) and (B)]

517.13 Equipment Grounding

In patient care spaces all branch circuit must have an effective ground-fault current path via the use of a raceway or armored cable. The insulation on such a conductor shall be green. Panelboard bonding wiring shall be not smaller than 10 AWG.

Patient bed areas (Category 2 spaces) shall be supplied by two branch circuits, one from critical branch and one from the normal system. The critical branch circuits shall be a distinctive color (see Fig. 5). (Another common color is international orange.) A critical branch circuit is one related to patient care that automatically connects to an alternate power source when normal power is lost. Hospital grade receptacles meet the requirements of NEC 517 and UL 498 which include additional properties of grounding reliability, assembly integrity, strength and durability tests as well as being tamper proof (see Fig. 6).

Figure 5: Critical Receptacle

Figure 6: Hospital Grade Receptacle

Further, each patient bed must have a minimum of 14 receptacles, all of which must be hospital grade.

517.29 Type 1 Essential Electrical Systems

Type 1 Essential Electrical Systems (ESS) consists of three branches: life safety, critical, and equipment. One power source for the system is on-site and the other may be off-site. Requirements for ESS exist in NFPA 99-2021, *Health Care Facilities* (see Sec. 6.7.5 and 6.7.6). In the NEC there also exist requirements for Type 2 ESS in 517.40-44 which applies to Category 2 facilities (see NFPA 99-2021).[16] The categories are summarized in Table 2 and the type of ESS required for each is in Table 3.

[16] In the NEC, one should note a bold notation after a given requirement which refers to the previously mentioned reference. For example, in this case (**99**: A.6.7.6.2.1).

Table 2: Health Facility Categories

[Source: *https://electrical-engineering-portal.com/electrical-design-healthcare-facilities*]

Risk Category	Failure of Such Equipment or System is Likely to Cause:
Category 1	…major injury or death of patients or caregivers…
Category 2	…minor injury to patients or caregivers…
Category 3	…patient discomfort…
Category 4	…no impact on patient care…

Table 3: ESS Required per Category

[Source: *https://electrical-engineering-portal.com/electrical-design-healthcare-facilities*]

Risk Category	Essential Electrical System (EES) Type	Example
Category 1	Type 1	Critical Care Space
Category 1	Type 2	General Care Space
Category 1	EES not required	Basic Examination Space
Category 1	EES not required	Waiting Room

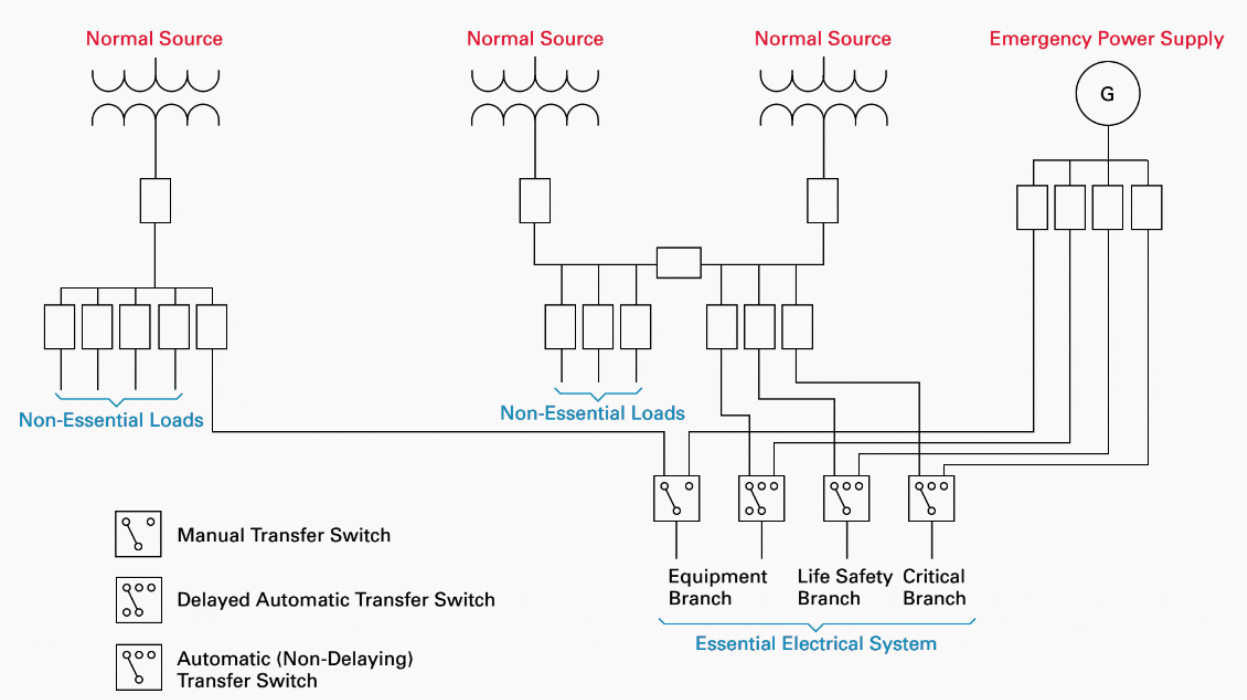

Figure 7: Large Health Care Facility ESS

[Source: *https://electrical-engineering-portal.com/electrical-design-healthcare-facilities*]

517.45 Other Health Care Facilities

Other facilities and equipment are covered from 517.45 through 517.160, which includes patient care spaces; anesthetizing locations; low voltage equipment; diagnostic equipment; communication, signaling, data, and fire alarm systems; isolation power systems and transformers.

Article 518 Assembly Occupancies

This article lists the requirements for building or portions thereof where 100 or more people[17] gather for the purposes of deliberation, worship, entertainment, eating, drinking, amusement, awaiting transportation, or similar purposes.[18]

Article 520 Theater, Audience Areas of Motion Picture and Television Studios…

This differs from Art. 518 in that the focuses on the theater portion of a building, an auditorium, stage, and corridors to the same. The cables used are MI, MC, and AC cable must be used. These have standard ground wire or jacket cover used for grounding and are protected by armor or a mineral sheath. They are also rated for higher than normal temperatures.

Requirements for specialized equipment used in such productions are covered and should be reviewed if working on such projects.

Article 522 Control Systems for Permanent Amusement Attractions

Voltage is limited to a maximum of 150 V ac to ground or 300 V dc to ground. Only qualified persons are allowed to perform maintenance. Power-limited control circuits must have rated outputs of not more than 30 V and 1000 VA. Power sources for such circuits must be protected by an over current protective device (OCPD) with a value as indicated by Eq. 1.

Equation 1: OCPD Rating for Permanent Amusement Attractions

$$\mathrm{OCPD}_{\mathrm{rating}} = (1.67)\left(\frac{VA_{\mathrm{source\ rating}}}{V_{\mathrm{rated}}}\right)$$

[17] For more information, see NFPA 101®, *Life Safety Code*®.
[18] It does not cover those items in Art. 520, think “theaters” and the like.

Much smaller gauge wires than normally encountered may be used with the ampacities limited by Table 522.22. For example, a 16 AWG wire is only allowed 10 A.

Article 525 Carnivals, Circuses, Fairs, and Similar Events

Article 525 overrides other portions of the code for portable wiring and equipment. Attractions using water must comply with Article 680 (Pools…). Portable structures must be 4.5 m (15 ft) in any direction from overhead line operating at 600 V or less. Portable structures must be 4.5 m (15 ft) distance vertically and horizontally from an conductors operating at 600 V or more (Fig. 8).

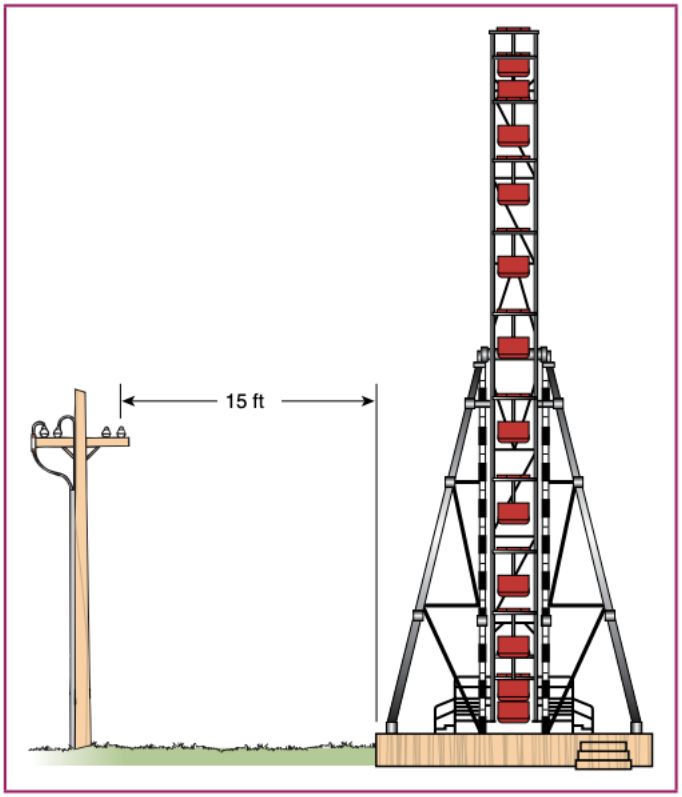

Figure 8: Separation Distance
[Source: *NEC Handbook Exhibit 525.1, 2017*]

A disconnecting means is required for rides, tents, and concessions. It must be located within sight of the operator's station, meaning, no greater than 1.8 m (6 ft) from said station.

Article 530 Motion Picture and Television Studios and Remote Locations

Such areas must have restricted public access. The cables used are MI, MC, and AC cable must be used. These have standard ground wire or jacket cover used for grounding and are protected by armor or a mineral sheath. They are also rated for higher than normal temperatures. Demand factors for stage lighting are allowed and can be found in Table 530.7. A demand factor of 100% is only for the first 50,000 VA.

GFCIs are required per 210.8(B) excluding 210.8(B)(6). But note, those branch circuits necessary for egress, life-critical stunts or special effects where a non-normal shutdown presents a hazard are NOT required to use GFCIs (530.11).

Article 540 Motion Picture Projection Rooms

Specialized study as required.[19]

Article 545 Manufactured Buildings and Relocatable Structures

Specialized study as required.

Article 547 Agricultural Buildings

Specialized study as required.

Article 550 Mobile Homes, Manufactured Homes, and Mobile Home Parks

The Department of Housing and Urban Development (HUD) regulates such items. Those regulations incorporate much Art. 550. Additional information can be found in NFPA 501-2017, *Standard on Manufactured Housing* and the HUD requirements in Part 3280, *Manufacture Home Construction and Safety Standards*, specifically, 24 CFR 3280.801 through 3280.816 for electrical systems.

If a mobile home is connected by a cord, the cord must not exceed 50 A. If the loads exceed 50 A, the feeder must be permanently installed.

[19] Such a statement is a judgment call on the author's part. Should one be responsible for such areas in the normal requirements of the job, by all means explore the details in this section, and others so marked.

Determination of the number of branch circuits differs from earlier in the NEC. For example, to determine the number of 15- or 20-ampere branch circuits required for lighting one uses the following equation, which is based on length (L) and width (W) of the outside dimensions of the home.

Equation 2: Manufactured Home Lighting Branch Circuits

$$\text{Circuits}_{\text{branch, 15A/20A}} = \frac{\left(3\ \frac{\text{VA}}{\text{ft}^2}\right)\left(L \times W\right)}{120\ \text{V} \times (15\ \text{A or}\ 20\ \text{A})}$$

The methods for the remaining items are also supplied: small appliances, laundry, general appliances, and bathrooms. [See 550.12] A specialized receptacle, not counted as part of the items mentioned is located on the underside of the unit to allow for trace heating on cold water piping. The method for figuring the actual loads of the above is in Sec. 550.18.

Article 551 Recreational Vehicles and Recreational Vehicle Parks

Many of the items in this article are accepted by the RV Industry and the AHJ over parks. See also NFPA 1192, *Standard on Recreational Vehicles*. The 215 V, NEMA 5, 15 A, 20 A, and 30 A 2-pole, 3-wire receptacles and plugs are shown in Fig. 9.[20] The 125 V, 50 A 3-pole, 4-wire receptacle and plug is shown in Fig. 10.

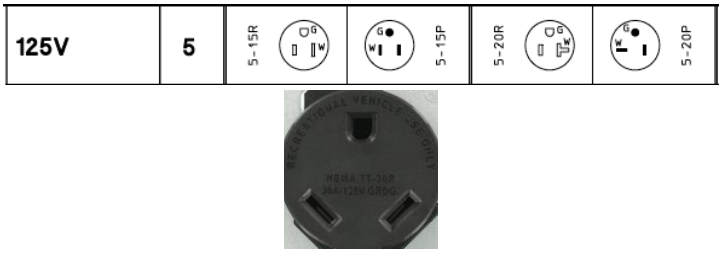

Figure 9: RV 15-, 20-, and 30-A Receptacles and Plugs

[20] The 15 A and 20 A versions are NEMA 5 while the 30 A version is NEMA TT, which stands for "travel trailer". The two pole three wire, and others similar, are often abbreviated as 2P, 3W. The 50 A three pole, 4 wire would be 3P, 4W. If the conductor is not meant to carry electricity during normal operation (such as the ground conductor) it is consider a "wire" not a "pole".

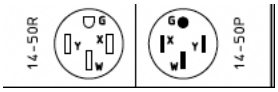

Figure 10: RV 50 A, 3P, 4W Receptacle and Plug

Article 552 Park Trailers

This article applies to trailers having a single chassis, no more than 400 ft^2, and are not intended as a permanent residence.

Roughly the same format and requirements coverage exists here as in Art. 551.

Article 555 Marinas, Boatyards, Floating Buildings,…Docking Facilities

The electrical datum plane has numerous height requirements depending on conditions (Sec. 555.3). Service equipment must be a minimum of 300 mm (12 in) above the datum plane and no closer than 1.5 m (5 ft) from the structure served but never located on any floating surface (555.4). Pier power system shall not exceed 250 V unless only qualified personnel service the system under engineering supervision (555.5). Load calculations fall back on the requirements in Art. 220.

Electrical shock hazards exist in the water around boat (specifically, in the water between boats and electrical services) and thus special "no swimming" signage is required (555.10).

Shore power for boats shall be not less than 30 A. Those at 50 A are to be locking and grounding type receptacles. At 60 A they are to be pin and sleeve to ensure proper protection.

Ground-Fault Protection of Equipment (GFPE) and GFCI are required in docking facilities. Feeders are set for ≤100 mA while receptacles are set for ≤30 mA.[21]

Article 590 Temporary Installations

Although all other the requirements of the Code, a few are modified by this article for construction sites and other similar situations where temporary power and lighting may be required.

[21] The Coast Guard considers 30 mA the acceptable level to prevent "electric shock drowning" (ESD) incidents.

Summary

Although some items mentioned should be memorized, especially if one works often on given projects, the Code is detailed and specific. Therefore, it's important to know that the information exists and where it might be found to allow for detailed review. It is in this vein that the course is written. I hope it serves you well.

Although not an "occupancy" special "equipment" exists with varying requirements. This equipment is found in Chap. 6 of the NEC. It includes coverage of signs; EV charging; welders; pools, spas, and hot tubs; solar power; wind power; and fire pumps.

REFERENCES

A. Earley, Mark, ed. *NFPA 70, National Electrical Code Handbook*. Quincy, Massachusetts: NFPA, 2020.

NOTE

Electrical refers to something related to electricity while "electric" refers to a device or machine that runs on electricity. Nevertheless, the NEC is sometimes referred to as the National Electric Code.

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NEC Special Occupancies
A SunCam Online Continuing Education Course

Appendix A: Equivalent Units Of Derived And Common SI Units

Symbol	Equivalent Units			
A	C/s	W/V	V/W	$J/(s \times V)$
C	$A \times s$	J/V	$(N \times m)/V$	$V \times F$
F	C/V	C^2/J	s/W	$(A \times s)/V$
F/m	$C/(V \times m)$	$C^2/(J \times m)$	$C^2/(N \times m^2)$	$s/(\Omega \times m)$
H	W/A	$(V \times s)/A$	$\Omega \times s$	$(T \times m^2)/A$
Hz	1/s	s^{-1}	cycles/s	radians/$(2p \times s)$
J	$N \times m$	$V \times C$	$W \times s$	$(kg \times m^2)/s^2$
m^2/s^2	J/kg	$(N \times m)/kg$	$(V \times C)/kg$	$(C \times m^2)/(A \times s^3)$
N	J/m	$(V \times C)/m$	$(W \times C)/(A \times m)$	$(kg \times m)/s^2$
N/A^2	$Wb/(N \times m^2)$	$(V \times s)/(N \times m^2)$	T/N	$1/(A \times m)$
Pa	N/m^2	J/m^3	$(W \times s)/m^3$	$kg/(m \times s^2)$
W	V/A	W/A^2	V^2/W	$(kg \times m^2)/(A^2 \times s^3)$
S	A/V	1/W	A^2/W	$(A^2 \times s^3)/(kg \times m^2)$
T	Wb/m^2	$N/(A \times m)$	$(N \times s)/(C \times m)$	$kg/(A \times s^2)$
V	J/C	W/A	C/F	$(kg \times m^2)/(A \times s^3)$
V/m	N/C	$W/(A \times m)$	$J/(A \times m \times s)$	$(kg \times m)/(A \times s^3)$
W	J/s	$V \times A$	V^2/W	$(kg \times m^2)/s^3$
Wb	$V \times s$	$H \times A$	T/m^2	$(kg \times m^2)/(A \times s^2)$

Appendix B: Fundamental Constants

Table Note 1

Quantity	Symbols	US Customary	SI Units
Avogadro's number	N_A, L		6.022×10^{23} mol^{-1}
Bohr magneton	μ_B		9.2732×10^{-24} J/T
Boltzmann constant	k	5.65×10^{-24} ft-lbf / R	1.3805×10^{-23} J/T
electron volt: $\left(\frac{e}{C}\right)$ J	eV		1.602×10^{-19} J
Faraday constant, $N_A e$	F		96485 C/mol
fine structure constant, inverse α^{-1}	α α^{-1}		7.297×10^{-3} ($\approx$1/137) 137.035
gravitational constant	g_c	32.174 lbm-ft/lbf-sec^2	
Newtonian gravitational constant	G	3.44×10^{-8} ft^4 / lbf-sec^4	6.672×10^{-11} N$\times$m^2 / kg^2
nuclear magneton	μ_N		5.050×10^{-27} J/T
permeability of a vacuum	μ_0		1.2566×10^{-6} N/A^2 (H/m)
permittivity of a vacuum, electric constant $1/\mu_0 c^2$	ε_0		8.854×10^{-12} C^2 / N$\times$m^2 (F/m)
Planck's constant	h		6.6256×10^{-34} J$\times$s
Planck's constant: h/2π			1.0546×10^{-34} J$\times$s
Rydberg constant	R_∞		1.097×10^{7} m^{-1}
specific gas constant, air	R	53.3 ft-lbf/lbm- R	287 J/kg$\times$K
Stefan-Boltzmann constant		1.71×10^{-9} BTU/ft^2-hr-^{o}R^4	5.670×10^{-8} W/m$^2\times$K^4
triple point, water		32.02 F, 0.0888 psia	0.01109 C, 0.6123 kPa
universal gas constant	R*	1545 ft-lbf/lbmol- R 1.986 BTU/lbmol- R	8314 J/kmol$\times$K

Table Notes

1. Units come from a variety of sources, but primarily from the Handbook of Chemistry and Physics, The Standard Handbook for Aeronautical and Astronautical Engineers, and the Electrical Engineering Reference Manual for the PE Exam. See also the NIST website at https://pml.nist.gov/cuu/Constants/. The unit in Volume of "lbmol" is an actual unit, not a misspelling.

Appendix C: Mathematical Constants

Quantity	Symbol	Value
Archimedes' constant (pi)	p	3.1415926536
base of natural logs	*e*	2.7182818285
Euler's constant	*C* or t	0.5772156649

Appendix D: The Greek Alphabet

A	*a*	alpha	N	*u*	nu
B	*b*	beta	X	x	xi
G	*g*	gamma	O	*o*	omicron
D	*d*	delta	P	*p*	pi
E	*e*	epsilon	R	*r*	rho
Z	z	zeta	S	*s*	sigma
H	*h*	eta	T	*t*	tau
Q	*q*	theta	ϒ	*u*	upsilon
I	i	iota	F	*f*	phi
K	*k*	kappa	C	*c*	chi
L	*l*	lambda	Y	*y*	psi
M	*m*	mu	W	*w*	omega

