PDHonline Course E441 (4 PDH)

2014 National Electric Code

Instructor: Thomas Mason, P.E.

2020

PDH Online | PDH Center

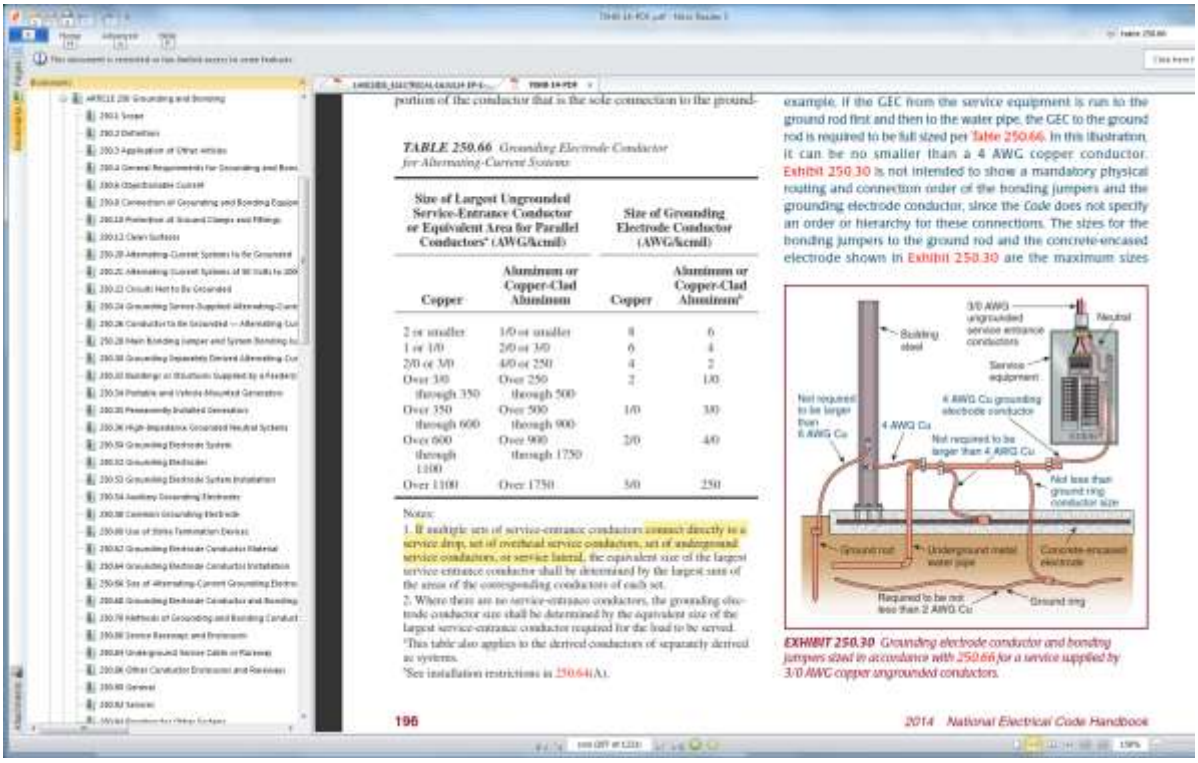
5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

2014 National Electric Code

Thomas Mason, P.E.

National Electrical Code Webinar, rev. 9May16
A student in AN EARLIER webinar session asked that we delete examples, discussion and comments and focus on the actual words of the National Electrical Code. On one hand, that is eminently reasonable. On the other hand, what is the "value added" of the webinar environment over simply reading the Code directly ? This version of the PDHonline webinar presentation will attempt to maximize actual Code content while retaining narrative which explains "what to do" in response to the Code mandates and problems and implications associated with the strict Code interpretations.
A CODE – ACTION – DISCUSSION form has been selected to assist those who wish to short-circuit the discussion portion and focus simply on Code and action.

CODE - 90.4, Enforcement; 110.2, Approval; 110.3, Use of Equipment - The Authority Having Jurisdiction (AHJ) is the criterion for acceptability of equipment and methods
ACTION - Follow the Code and normally accepted methods, but recognize that a Plans Reviewer or Inspector has the authority to void requirements of the Code or add new requirements.
DISCUSSION – It is a mistake to believe that closely following the Code is enough to get a design and installation approved. The AHJ has the authority to seriously delay a project, even if his ruling is reversed by an Appeals Board. A proactive stance is to discuss disagreements and attempt compromise. Referencing the NFPA HANDBOOK of the National Electric Code is very valuable. The .pdf version is very searchable and the document uses ordinary language and has many illustrations.



portion of the conductor that is the sole connection to the ground-

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

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors* (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).

example, if the GEC from the service equipment is run to the ground rod first and then to the water pipe, the GEC to the ground rod is required to be full sized per Table 250.66. In this illustration, it can be no smaller than a 4 AWG copper conductor. Exhibit 250.30 is not intended to show a mandatory physical routing and connection order of the bonding jumpers and the grounding electrode conductor, since the *Code* does not specify an order or hierarchy for these connections. The sizes for the bonding jumpers to the ground rod and the concrete-encased electrode shown in Exhibit 250.30 are the maximum sizes

EXHIBIT 250.30 *Grounding electrode conductor and bonding jumpers sized in accordance with 250.66 for a service supplied by 3/0 AWG copper ungrounded conductors.*

Note the Table of Contents, on the left, which expands down to individual paragraphs. Note the quality of the illustration. Note both the complete wording of the Code in black and the blue commentary, by the editors of the Code. Highlighted terms and labels permit jumps to that topic. Jump back is a single click.

CODE - 110.3, Examination of Equipment - UL is NOT required. AHJ approval IS required.
ACTION - Require UL label in specification and on-sheet notes if it is important to you.
DISCUSSION – Many Contractors find economy in using non-UL devices and materials. They can make a persuasive argument for "Nationally Recognized Testing Laboratory" (NRTL) as being equivalent and acceptable. Your webinar leader believes that UL listing is a protection for the Owner and for the designer. Requirements in the Specification are enforced by Contract Law and fully as binding as the Code, adopted by the State and enforced by Civil Law.

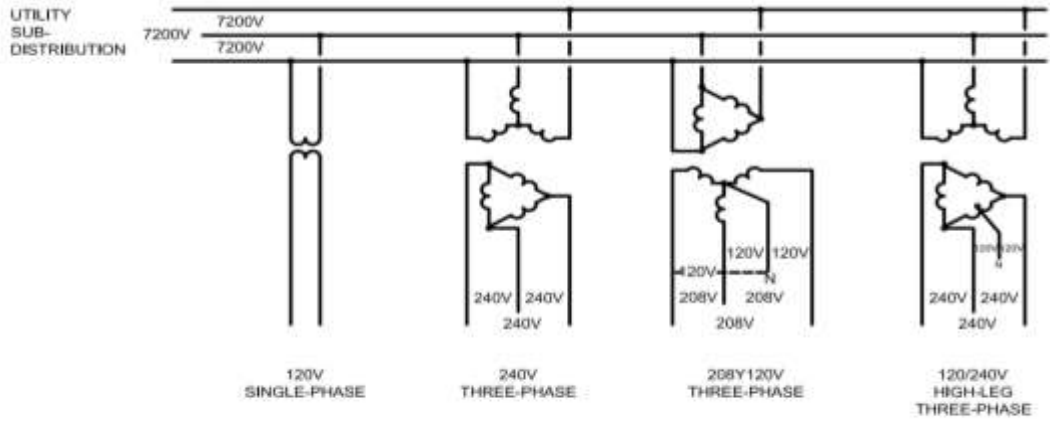
CODE - 220.5, Voltages - Calculations shall be made using the values 120, 120/240, 208Y120, 240, 347, 480Y277, 480, 600Y347 and 600V
ACTION - Verify project voltages at the very beginning. 120/240-240/3 is NOT the same as 208Y120V. Care must be used in interchanging 208/3 and 240/3 for supply and loads.
DISCUSSION – Most installation people are very familiar with the voltages they use every day. They are not familiar with the wide range available and the very

similar names for very different voltages. The example of *120/240-240/3 is NOT the same as 208Y120V* comes from a recent shopping center renovation in Detroit. The design was done by a national engineering firm, at 208Y120V. The existing shopping center had only 120/240-240/3. The HVAC equipment, already purchased, accepted either 208/3 or 240/3, but the service one-line diagram and panel schedules had to be revised.

Effect of Primary Voltage and Tap Settings on Delivered Voltage

V(l-n)	95	100	105	110	115	120	125	130
V(l-l)	165	173	182	191	199	208	217	225

FURTHER DISCUSSION - Formerly, precise voltage was important. Incandescent lamps burn our very early at a slight excess voltage. Today, compact fluorescents and LED's are extremely tolerant to off-voltage operation. Motors, unless continuously 100% loaded, are tolerant to off-voltages. This is discussed later.



120V AND 240V SERVICE VOLTAGES

This is an illustration, showing some of the sources of 120V and 240V services. Special caution is warned when a project involves high-leg three-phase power.

Nominal	*Service*	*Utilization*	*Nameplate*	*NEMA*
Standard	**-5%, +%5**	**-13%, +6%**	**Motor**	**-10%, +10%**
120	114 - 126	104.4 - 127.2	115	103.5 - 126.5
208	197.6 - 218.4	181 - 220.5	200	180 - 220
240	228 - 252	208.9 - 254.4	230	207 - 253
277	263.2 - 290.9	241 - 293.6		
480	456 - 504	417.6 - 508.8	460	414 - 506
	bandwidth 10%	bandwidth 19%		bandwidth 20%

This is a published comparison of voltages at different parts of a customer electrical distribution system and the standards which apply. *Nominal* is the NEC name of the system. *Service* indicates the limits at the service from the Utility. Some States enforce this. Ohio does not and many years have been invested by public housing agencies to try to force the serving Utility to deliver voltage within the range.
Utilization is at the receptacle or at the motor terminal. This is the important measurement. The NEC does not mandate the voltage but it does mandate the maximum voltage drop. Voltage drop is defined as the change in observed between no load and full load. A test instrument (Ideal Circuit Analyzer, 61-165) is available which tests voltage drop, along with GFI and AFCI operation.
The motor *nameplate* value is embossed or printed on the motor nameplate. Applying the NEMA tolerance to the measured voltage during operation tells you if your warranty has been voided by improper application. **There are big bucks associated with this pass-fail test.**

CODE - 110.9, Equipment shall have an interrupting rating sufficient for the current that is available. 110.24, mark available fault current at the service equipment.
ACTION - Find the utility available fault current. Specify equipment with greater withstand rating. Have Contractor mark it on the main disconnect switch enclosure.
DISCUSSION – Available fault current drops off slowly as you get farther from the main disconnect. Standard equipment is rated 10,000 A withstand. This level is often only reached more than 200’ from the service.

FURTHER DISCUSSION: This requirement is not closely followed by designers or installers. Probably because strict compliance requires difficult communication with the Utility and some difficult computations. It is rarely enforced by the AHJ, but has devastating consequences.
PDHonline offers a course on SIMPLIFIED SHORT-CIRCUIT CALCULATIONS (E270). This course provides tables, which can be downloaded for free. You must know the rating of the supplying transformer, usually 300, 500 or 1,000KVA, the impedance, usually 5.5%, how far your equipment is from the main service switch and what wire size you are using. The table tells you a conservative available short-circuit current. Buy equipment for this location rated more than the table value.

SC kA	480V, 1000 kVA, 5.5%, 1203FLA							
						Busduct		
	4/0	250	350	500	2@500	1200A	1600A	2000A
Feet	21.865							
0								
10								
20	20.365	20.389	20.483	20.554	21.191	21.455	21.648	21.690
50	18.349	18.428	18.665	18.836	20.248	20.846	21.323	21.429
100	15.389	15.585	16.063	16.406	18.766	19.860	20.786	20.999
200	11.786	12.067	12.713	13.172	16.500	18.026	19.736	20.161
500	6.619	6.926	7.618	8.140	11.953	13.741	16.890	17.864
1000					8.140	9.550	13.283	14.780
2000						5.803	9.040	10.739
5000								5.716
10000	0.427	0.461	0.541	0.610	1.181			

This transformer delivers more than 10,000 short-circuit amps on #4/0 cable more than 200-ft from the switchboard. It delivers more than 10,000 short-circuit amps on parallel 500kCMIL more than 500-ft from the switchboard.

DANGER WARNING: This week, I was checking equipment provided to the job against design specifications. The Panel Schedule said "22,000 Amps Interrupting Capacity". The Contratctor installed circuit breakers and a panel rated 18,000 AIC. If an electrical tragedy occurs at this location, someone will be explaining market economies to the Judge.

CODE - Article 100, *Accessible* vs *readily accessible* - Readily accessible means no ladder to get to it.
ACTION - Locate electrical equipment where is can be accessed for inspection and service.
DISCUSSION – There are many entries in the Code identifying accessibility, as light switches going into attics and aisle ways to get to electrical controls. There are also sections which permit overhead transformers with no maintainable parts and overhead switches for industrial occupancies.

FURTHER DISCUSSION: Recent interpretations require that a GFCI reset button or AFCI reset button must be readily accessible (NEC 210.18). Some AHJ are red-tagging designs which show such a receptacle behind furniture. The same AHJ stated that panel-mounted GFCI and AFCI are not readily accessible.

The Action Item is to daisy-chain the receptacles from a location which is readily accessible.

It may be desirable to turn off the furniture layer before printing sheets to be given the Plans Reviewer and installing Contractor.

CODE - 110.13, Cooling clearance; 110.26, working space; width of working space; height of working space - equipment which gets hot must have air circulation space; ~42"(d) must be left clear in front of equipment; 30"(w) must be kept clear in front of equipment; 6' above equipment or to structural ceiling must be clear; 404.8, 6' 7" maximum switch height.
ACTION - Mark cross-hatched space around equipment on plans to show required clearances and spaces. Fight Architects and HVAC designers to keep pipes and ducts away from equipment.
DISCUSSION – It seems that every design job has conflicts on reserved spaces, especially the *no pipes or ducts* rule. Some Inspectors are very strict. Note that "flaky" equipment may have special needs for access for maintenance and reserved space. An inverter for a fuels cell generating plant required side access and 42" clear on each side.

CODE - 110.26, 1200A, 6' two-door rule; lighting.
ACTION - Any electric room which contains equipment which adds up to 1200A or is 6' wide must have two doors, swinging out, with panic bar or push-pad operation. Lighting must not be motion-controlled. Include emergency egress light for panel when power off.
DISCUSSION – There are exceptions to this which may not be good compromises on electrician safety.
CODE - 110.31, 7' fence for electrical enclosures over 600V.
ACTION - Install a fence at least 7'(h) or 6' fabric plus 1' of 3 or more strands barb wire.
DISCUSSION – This is big-bucks liability if there is an accident associated with vandalism. Note that post bases and foundations heave and initial 7' may not be the same as final 7'.

Closely read the exact words of 110.26 if an argument develops with the Architect. Most Architects are sympathetic to the safety argument, but some will spend no funds beyond the absolute Code minimum.

CODE - 200.3, Grounded electrical systems; 250.50, Grounding system (7 connections).
ACTION - Every electrical system must be grounded, with just a few exceptions for industrial DC chemical systems and legacy delta systems. Alarms are required on these exempted systems. Each electrical distribution circuit must have a safety ground conductor, in addition to supply and return conductors. The building utility service must be bonded to

water pipe, metal frame of building, concrete encased electrode, ground ring, 3-10' rods, plate electrodes, other metal underground systems, lightning protection, low-voltage data services and HVAC ducts.
DISCUSSION – 60 years ago, insulation was considered the best protection from electrical hazards. This has changed to grounding. Intentional grounding conductors are required. The service grounds must be connected "if available", which has been interpreted to be, "if you can make them available".

Lately, I have done QA on many jobs which did not have three 10' rods, on an equilateral triangle. Historically, this and burying the rod heads flush or below the surface were required. I don't think that physics and earth conductivity characteristics have changed.

CODE - 250.92, Bond all low-voltage services to a terminal at service meter.
ACTION -
DISCUSSION - Earth ground is a floating reference. That is, as a cloud flies over, is pulls a complementary charge along the ground. The ground rods at two buildings will have a voltage between them, enough to damage electronics or shock a person. By connecting all ground conductors that enter a building to a common terminal, all the ground at this end are forced to a common voltage. Small currents will flow but there will be no shock hazard between an electronics enclosure and the power ground. Note that fiber optic cables often have a steel strength member which must be grounded. Yes, you will have to battle IT designers.

CODE - 200.6, Neutral color grey or white or white bands; 210.5 Colors for phase conductors, posting at all panels; 250.119 green or green / yellow or bare for safety ground.
ACTION - Use black, red, blue, white for 208Y120V; brown, orange, yellow, grey for 480Y277V. Traditionally, yellow was used for "foreign voltages" between control cabinets. NEC requires warning of foreign voltages and posting of the colors used.
DISCUSSION – It is a challenge to get contractors to post the color codes at panels and where different voltages are present.

CODE - 210.3, Branch circuits shall be rated 15A, 20A, 30A, 40A, 50A and larger. 210.19, 215.2, 3% voltage drop maximum.
ACTION - Use 20A circuit breakers and #12 (20A) conductors for lights and receptacles. Use 20A circuit breakers and #10 (30A) conductors for lights and receptacles more than 65' from the panel.
DISCUSSION – 15A (#14 conductors) are not used commercially or industrially

except in the most severe Value-Engineered jobs. 30A, 40A, 50A and larger are used for dryers, stoves and industrial equipment.
The 3% voltage drop limit is referenced in the Code by mandated in the IECC and ASHRAE 90.1. It is often noted in design documents but rarely installed.

FURTHER DISCUSSION: I just learned about use of 30A branch lighting circuits on #10 wire to feed outdoor lights. This is legal if each light has its own fuse. Such fuses are a standard option in lighting catalogs. It is considered a tap.

The 3% voltage drop from the panel is in the Code, but nearly impossible to validate. The corresponding 5% voltage drop from the Service is easy to measure (see the Ideal Receptacle Analyzer, mentioned earlier).

CODE - 218.8, GFCI receptacle (sic); 210.12, AFCI receptacle; 210.13 GFCI for equipment.

ACTION - Use GFCI for bathrooms, kitchens, at sinks, wet locations, for audio equipment, drinking fountains, elevators, 1000A 480V feeders, health care, pools, space heating, garage, shed, outdoors, dishwasher and disposal.
AFCI required for dormitory units; not required in health care.
For dwelling units, use AFCI for kitchen, family room, dining room, living room, parlor, library, den, bedroom, sunroom, recreation room, closet, hallway, laundry area. (AFCI includes GFCI.)

DISCUSSION – With each Code revision, the requirements for GFCI and AFCI expand. Listed above are the 2014 requirements in States which have adopted the entire Code. Many States have excluded the AFCI requirement as Contractors estimate it adds $10,000 to the cost of a home.
GFCI are required on dishwashers and disposal even if they are hard-wired.
A GFCI circuit breaker or AFCI circuit breaker is permitted in some locations but there have been installation problems. GFCI or AFCI protection can be provided by a single device feeding downstream devices.
1000A 480V is a different device, 50mA trip vs 10mA trip.

FURTHER DISCUSSION: There is partial overlap between GFCI and AFCI requirements, as in the kitchen. Some AHJ are requiring BOTH. Some devices provide separate protections. There is no mention of GFCI in most AFCI product descriptions. Be warned.

MARVELOUS INSIGHT: A web search, as part of the last webinar session of this course, produced stand-alone Eaton-Cooper brand GFCI receptacles for ~$12 ea, stand-alone Eaton-Cooper brand AFCI receptacles for ~$12 ea and combined GFCI / AFCI Home Depot receptacles for ~$29 ea. Alternatives of smart circuit breakers and daisy-chained receptacles are available, but it is cheap and easy to

provide stand-alone receptacles. There is no labor premium for installing a smart receptacle.

CODE - 210.19, 80% rule
ACTION - Do not load a protective device more than 80% of its rating
DISCUSSION – The Code actually says you must size the conductor at 125% the load, but most designers view the rule as limiting the protective device. There are 100% circuit breakers available at premium price, which are sometimes used in main switchboards or motor control centers for net cost savings.

FURTHER DISCUSSION: Some engineers quote the NEC definition of "continuous load" as 3-hour use. They conclude that an overheated circuit breaker will cool in not in service for the full three hours. This is logically tenable, but not consistent with a tilt towards safety nor the stated goal of NEC to provide capacity for future growth. Your author always assumes that unknown situations will develop in the unfavorable direction. You must use your professional judgement.

CODE - 220.3, 180 va per duplex receptacle.
ACTION - Do not connect more than 10 general purpose receptacles to a 20A circuit. 6 is preferable.
DISCUSSION – A refrigerator gets a dedicated receptacle. A counter where a coffee pot will be placed gets a dedicated receptacle. A vending machine gets a dedicated GFCI receptacle. Other places get shared general purpose receptacle circuits, unless you think the user may connect a space heater.

FURTHER DISCUSSION: The Code Handbook specifically states, in Exhibit 220.4, that 13 receptacles are permitted on a 20A circuit in dwellings. Again professional judgement must be applied. Field measurements confirm that a few circuits will be highly loaded and the remainder will carry little or no load. Be careful providing receptacle power to counters which will be filled with appliances and lab or service counters which may collect many powered devices.

CODE - 225.26, Vegetation shall not be used for support of overhead conductors. 400.8, not flexible wiring.
ACTION - Put up a pole to support temporary overhead conductors. Can't use flexible cord in place of fixed wiring, thru holes in walls, suspended ceilings, dropped ceilings, floors, doorways, windows or attached to building surfaces.
DISCUSSION – Every restaurant in the US has a flexible cord going from a receptacle thru a hole in the drop ceiling to source who knows what. This is not a good thing.

CODE - 225.30, 230.2, Single service; 225.32, closest point of entrance; 225.33,

230.71, 6 switch rule
ACTION - In theory, keep service to a building or outbuilding to one circuit, with the service switch at the point closest to the power entrance; in fact, many exceptions permit multiple services, especially not more than six service switches, reasonably close together or with a map posted.
DISCUSSION – The intent is to make it easy for fire fighters to shut down power and spray water safely. There are many practical reasons that this doesn't work well and exceptions provided.

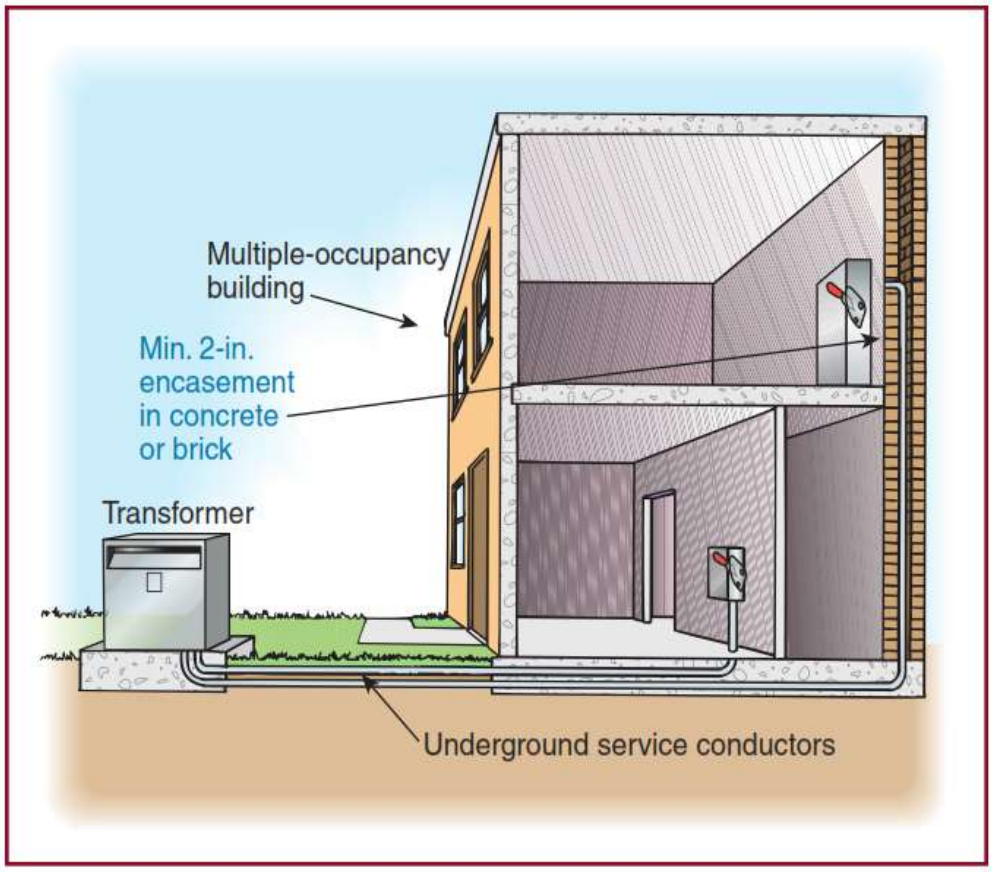


EXHIBIT 230.15 *Service conductors considered outside a building where installed under not less than 2 inches of concrete beneath the building or in a raceway encased by not less than 2 inches of concrete or brick within the building.*

Substantial cost savings on the power distribution system are possible by utilizing a central electric room. (That is, center of the building.) This is completely legal, if the service is delivered under the concrete slab. It enters the building where it pokes through.

This provides a problem for firefighters. They must travel through energized spaces in order to remove power from the facility. Some State and Municipal amendments require a service disconnect on the outside wall of the facility.

CODE - 300.5, Seal or plug wet underground conduit, as power or data service.
ACTION - Use a compression seal or a cementitious seal if water runs from a conduit.
DISCUSSION – All underground conduits leak. It is important to specify insulation on conductors which is impervious to water (as THWN or XHHWN). Maintenance people worry about the running water and want to route it to a drain. The Code says to block the flow at one or both ends. Do not use plumbing fittings.

CODE - 225.37, Identification of multiple services.
ACTION - Put up a sign at each service noting the location of all services.
DISCUSSION – This is for the benefit of fire fighters. Another good idea, never, ever, followed.

CODE - 240.4, Protection of copper conductors - #18, 8A; #16, 10A, #14, 15A; #12, 20A; #10, 30A
ACTION - Regardless of insulation, these conductors must be protected at these values or less.
DISCUSSION – The concept of overcurrent protection is to keep the temperature of the insulation below its melting point. There are several tables with different ambient temperatures and insulations and many detailed rules. However, for small conductors (#18 to #10) the specified maximum currents apply, regardless. By the way, #22 (telephone or LAN wire) is rated at 3A.

CODE - Table 310.15(B)(16), protection of 3 current-carrying copper conductors

ACTION -

	Capacity of not more than 3 current-carryi			
Insulation				
90C	25	30	40	55
75C	20	25	35	50
60C	15	20	30	40
Conductor	#14	#12	#10	#8

DISCUSSION – The higher capacity of 75C and 90C wire cannot be used for #14-#8, but it is there. Your webinar leader recommends specifying 90C wire applied at its 60C rating to provide safety margin.

Some designers use this Table to ignore 240.4. Your author believe that 240.4 prevails.

Aluminum conductors are not discussed here, but substantial construction economies are

available.

FURTHER DISCUSSION: There is an opinion that derating more than 3 current-carrying conductors applies to 90C rating, so that copper need not be upsized. Your author disagrees with this.

CODE - Table 310.15(B)(2)(a), temperature derating of copper conductors

ACTION -

Ambient	Conductor Temp Upsizing 60C	75C	90C
86F	100%(#12)	100%(#12)	100%(#12)
104F	122%(#10)	114%(#10)	110%(#10)
140F	X	172%(#8)	141%(#10)
167F	X	X	200%(#8)
185F	X	X	X

DISCUSSION – Your webinar leader recommends always using 90C wire and upsizing in hot environments. NEMA equipment is rated to a maximum of 104F; 140F exists in tunnel ceilings, attics and industrial high-bays.

FURTHER DISCUSSION: Again, the alternate opinion exists that the derating is applied to the 90C rating and no upsizing of copper is required. Your author finds this specious.

CODE - 240.6, Standard fuse and circuit breaker ratings – 15, 10, 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.

ACTION - For off-the-shelf-delivery, specify these sizes.

DISCUSSION – Standard circuit breaker frame sizes are 100, 125, 150, 250, 400, 600, 800, 1200, 1600, 3000 and others. Typically, a trip rating at the frame size is permitted and smaller breakers can co-exist in the same panel (sometimes requiring adapter hardware).

CODE - Table 250.122, Circuit Grounding Conductor based upon Circuit Protection.

ACTION - Provide a grounding conductor for each circuit per the table.

DISCUSSION – Note that circuit wire size is determined by the insulation on the conductor, ambient temperature and how many current-carrying conductors in the conduit. The ground wire size is determined only by the branch protective device.

Table 250.122 Minimum Copper Grounding Conductor for Rating of Circuit

Protection	15A	20A	60A	100A	200A	300A	400A	500A
Ground	#14	#12	#10	#8	#6	#4	#3	#2

CODE - 240.21, 10' tap(unlimited); 25', 1/3 supply rating; outside, unlimited

ACTION - Within equipment, any size conductors can feed a device with its own overload protection if less than 10'; outside of the equipment enclosure, a tap of less than 25' can be used if the conductors are rated at least 1/3 supply conductor rating; outdoors, taps are not regulated.

DISCUSSION – The concern is the effect of conductor overload in the event of a fault. Within an equipment enclosure, the effect of insulation melting and a resulting ground fault is not considered serious. The 2014 Code revision requires overload protection at the connected device, usually a light, receptacle or transformer. The 25' rule is often used for transformers. The outdoors unlimited rule assumes that insulation melting and a ground fault outside will not cause much damage or personnel hazard. With care, use of the tap rules can avoid congestion problems around automatic transfer switches.

CODE - 250.24, Single neutral ground.

ACTION - Provide multiple safety grounds, including a circuit safety ground with each circuit and bonding to all exposed metal. Only connect the neutral to ground at one point at the utility service.

DISCUSSION – For single-phase circuits, we have a supply conductor and a return conductor (neutral). Because current flows in the neutral and it has impedance, there will be a small voltage under normal conditions. This causes arcs when the neutral is opened and line voltage is present at the open neutral. For this reason, the neutral must be an insulated conductor and the safety ground is kept completely separate. During a fault or lightning event, there is current in the ground wire (and building steel and piping) and extremely hazardous voltages may present between two metallic systems if not bonded.

CODE - 250.30, Grounding separately derived systems (transformer, generator, PV, wind). 690, PV.

ACTION - Ground a separately derived system very similar to grounding of the utility service. Choice of 3 pole or 4 pole generator transfer switch.

DISCUSSION – Grounding for safety applies for all electric power systems, and, arguably, for all low-voltage systems. Photo voltaic installers have historically not

grounded the DC side of the system. They also don't like protective devices on the DC side or frame grounding. The Code claims jurisdiction but enforcement is spotty. A 3 pole transfer switch considers the generator to NOT be a separately derived source, but using the utility service ground-neutral connection. The 4 pole transfer switch uses a new ground-neutral connection at the generator and switches the load neutral away from the utility service ground-neutral connection. 3 pole are cheaper and almost universally used.

FURTHER DISCUSSION: Controversies today regard backfeeding the facility panel from the alternate source inverter. There is no technical problem synchronizing the inverter with the utility and solid-sate protection is a mature science. The problems relate to a locally energized distribution system while the Utility and service people think it is dead. There are also quirky rules, just now being clarified, relating to size and location of the backfeed breaker in the panel.

CODE - 250.32, Outbuilding grounding, with ground-neutral connection.
ACTION - At separate structures, drive a ground rod and bond to water line, if present.
DISCUSSION - It is now felt that more safety is provided by shortening the ground return path than would be provided by keeping the neutral and ground separate.

CODE - 250.64, Grounding electrode conductor protection
ACTION - Use PVC conduit around the conductors from ground rods, etc, to the common service grounding point. If metallic conduit is used, it must be bonded to the conductor at both ends.
DISCUSSION – Bonding the metallic conduit at both ends makes sure it does not form an inductive impedance to fault or lightning current.

CODE - Table 250.66, grounding electrode conductor size.
ACTION - Use #4/0 copper for wires to ground rods and to data backboards.
DISCUSSION – Code requires only #4 for most grounding conductors but Plans Reviewers, Inspectors and IT designers often demand #4/0. In industrial occupancies, #4/0 grounds among power grounds, equipment frames and building steel eliminate intermittent problems with automatic controls.

FURTHER DISCUSSION: Flow of current through the earth is a science unto itself and will not be discussed here. Amateur radio operators sincerely believe that #6 coper will carry a lightning strike. Commercial radio antennas use multiple braided conductors to a ground bed. A portion of Table 250.66 is reproduced below:

Copper Service-Entrance Conductor	Copper Grounding Electrode Conductor
#2 or smaller	#8
#1 to 1/0	#6
2/0 or 3/0	#4
3/0 through 350 kCMIL	#2
350 through 600 kCMIL	1/0
600 through 1100 kCMIL	2/0
Over 1100 kCMIL	3/0

CODE - 285, Surge-Protective Devices (SPD, TVSS)- Type 1, Type 2 and Type 3.
ACTION - Install a Type 2 SPD on the service, after a 30/3 circuit breaker; same on every distribution panel.
DISCUSSION – Most transient surges originate within the facility. By dissipating them at the source, e.g., the HVAC panel, they never get to the computer panel. The computer panel SPD provides a second level of protection, as recommended by IEEE (tiered protection). Note that lights, counters, alarm relays and modular construction add no value to the SPD. kA and applied voltage are the only meaningful specifications.

CODE - 110.12, Neat and workmanlike.
ACTION - Installation required to comply with ANSI / NECA 1-2010
DISCUSSION – There is a published standard on details of workmanship and it is referenced in the Code.

FURTHER DISCUSSION: This section of the Code is commonly used by AHJ to red-tag workmanship they don't like. Usually, a corresponding paragraph in NECA-1 can be found.

CODE - 300.4, Protection against physical damage.
ACTION - Provide PVC or steel conduit protection for line voltage and low voltage conductors.
DISCUSSION - This is a Contractor responsibility but this section gives many details, as 1-1/2" spacing from roof to prevent roof nails from penetrating conduits.

CODE - Table 300.5, Burial depth; splices; expansion fittings.
ACTION - PVC conduit min 18" below surface ; Rigid or intermediate conduit min 6", 24" under driveways; Direct burial of rated conductors, min 24".

Use approved underground splice kit for underground cable splice. Use expansion fitting or cable S-loop at exit from earth to avoid damage from freeze heave.
DISCUSSION – Traceable red tape recommended 6" below grade. Huge tanks heave between full and empty. Note that PVC conduit requires expansion fittings when exposed to temperature changes. Metallic conduit is also required to have expansion fittings at architectural expansion joints.

CODE - 310.11, Supporting raceways, cable assemblies, boxes and fittings.
ACTION - Support electrical independently – no use of ceiling grid wires. Distinctly colored dedicated ceiling wires are recommended or all-thread into anchors. Support box separately of conduit; exception, two conduits from earth are required to support a junction box or fixture support box.
DISCUSSION – Especially, sign flood lights mounted at ground level are damaged by mowers and vandals. We would put in concrete-filled bumper posts if these were above ground. It is a Code requirement to protect the electrical components.

CODE - 300.23, access to junction boxes and equipment.
ACTION - There must be an access to an attic or chase that contains equipment or junction boxes with removable covers.
DISCUSSION – I am having trouble on a current renovation job where demolition of existing conduits requires installation of new conduits. The junction box MUST be accessible. This is often in a new wall and an access cover is required. Such covers are common for access to plumbing and HVAC. Note that access to the attic often requires that the space be sprinklered and a service receptacle and light be provided. You are changing the space from inaccessible to accessible.

CODE - 310, Conductors for general wiring.
ACTION - Note temperature ratings, ambient temperatures and conduit fill as indicated previously.
DISCUSSION – This chapter includes many details for many types of conductors and raceways. Note especially the "Uses Permitted" and "Uses Not Permitted" paragraphs. There has been a historic aversion to the use of Aluminum conductors and flexible metallic conduit assemblies, as MC. This is diminishing, as economies force their consideration. With quality workmanship, there is no technical reason to avoid them.

CODE - 344.41, Support of rigid metallic conduit.

ACTION - Support rigid metallic conduit every 10’ and within 3’ of each box or fitting.
DISCUSSION – Similar rules apply to thin wall conduit (EMT), plastic conduit, flexible conduit and loose wiring.

CODE - Article 380, Multioutlet assemblies; 220.14, multioutlet loads.
ACTION - Read this section closely before using multioutlet assemblies (WireMold).
DISCUSSION – Multioutlet assemblies solve the problem of congested electrical equipment, as test benches and data racks. When provided with adequate electrical capacity and in a protected environment, they serve well, for the life of the facility. However, they are frequently abused. Even the best metallic assemblies do not survive long in an exposed location in schools. The kids step on them to get at stuff or just for the joy of demolishing them. There is a generous electrical loading standard (180 va for 5’) but if you know there will be large loads, as coffee pots, copiers, or high-density data equipment, use three phase assemblies and provide adequate capacity. Gratuitous advice: Motorola requires an SPD type receptacle for racks containing radio equipment.

CODE - Table 400.5(A)(1), Ampacity for flexible cords.
ACTION - Do not exceed these limits.
DISCUSSION – Flexible cords solve a critical need for very-flexible electrical connections, as on moving equipment assemblies. Most focus is on the jacket, which is critical, but note also the stranding (extra-fine lasts longer) and strain relief at connection points. Gland-type fittings are best.

Table 400.5(A)(1) Allowable Ampacity for 3 Current-Carrying Flexible Conductors in 86F ambient

Cu Cond	18	16	14	12	10	8	6	4
Amps	7	10	15	20	25	35	45	60

CODE - 404.6, Up = on, blades de-energized when open; 110.22, label unless obvious.
ACTION - Mount switches so that they are on in the up position and the blades are de-energized in the off position. Label each switch unless operation is obvious.
DISCUSSION – The labeling provision is for switches at gym entrances where one switch operates the curtain and for living rooms where one switch controls an outlet. There is now a receptacle with an international “remotely switched”

symbol.

FURTHER DISCUSSION: 406.3(E) An automatically switched receptacle, as required in some locations for energy conservation, requires labeling also. Leviton says,

To meet the requirements for identifying receptacles that will be automatically de-energized as part of an overall plug load control program, the 2014 National Electrical Code requires all 15A & 20A, 125V receptacles that are automatically controlled to be marked with a specific symbol ⏻.

Leviton offers two solutions to help comply with the new marking regulations:

Wallplate Decals:
For the most economical retrofit application, these decals allow you to mark existing receptacle wallplates with the required symbol, and the word "CONTROLLED" (optional) for easy identification. Decals use a UL approved material for marking and labeling. 70 decals of each/pk.

Imprinted Receptacles:
For new construction and renovation applications, custom imprinting directly on the receptacle is available for our most popular specification grade receptacles, both back and side wired and side wired standard, tamper-resistant and Decora® platforms. These devices are identical to our standard receptacles with just the word "CONTROLLED" imprinted on the face to meet NEC requirements and are compatible with any manufacturer's controllers.

CODE - 404.8, 6' 7" maximum height; max 300V between adjacent devices.
ACTION - The center of the grip handle on any switch must not be more than 6' 7" above the floor or working platform when in the on position. When switches are on different phases of 480Y277, there must be metal separation plates between switchbox sections.
DISCUSSION -

CODE - 406.4, Replace with GFCI or AFCI if such is required by currently adopted Code.
ACTION - In commercial, industrial or dwelling occupancies, a failed receptacle must be replaced with the type required by the present Code, as GFCI or AFCI.
DISCUSSION – This section is retroactive. Remember, stand-alone Eaton-Cooper brand GFCI receptacles for ~$12 ea, stand-alone Eaton-Cooper brand AFCI receptacles for ~$12 ea and combined GFCI / AFCI Home Depot receptacles for ~$29 ea.

CODE - 409.1, Industrial Control Panels.

ACTION - Study this section when you install control panels, as for HVAC. Panels field fabricated by the HVAC installer have a poor record of NEC compliance.
DISCUSSION - Most requirements are on the manufacturer or fabricator, but you get the project delay if the Inspector says it is non-compliant. This section may apply to building automation panels, which, presently, do not comply.

CODE - 410.51, Lighting track installation; 220.43, lighting track load.
ACTION - Study these sections before installation of lighting track in a store. Consider use of LED instead of incandescent.
DISCUSSION – The load restrictions for lighting track are severe for a jewelry store, where intense lighting sells merchandise. They are not a problem when track light is being use to show off paintings. LED lighting is a perfect fit for both applications because of the high intensity, low power and lack of infrared component.

CODE - 501.1, Class I, Div 2, Group D hazardous areas.
ACTION - Install cementitous seals on conduits entering the hazardous area. Use explosion-proof switches and devices in Div 1 areas where explosive concentrations of hazardous fumes are NORMALLY present. Use explosion-proof switches and general purpose non-arcing devices in Div 2 areas where explosive concentrations of hazardous fumes are NOT NORMALLY present. Place general purpose switches well beyond the demarcation of the Division 2 Hazardous Area.
DISCUSSION - This summary is extremely condensed, but accurate. Group D means gasoline fumes, or similar. Read adjacent sections if you have fuel oil, coal dust, cotton flyings or whatever. The warning on general purpose switches is in response to common non-compliant installations at paint booths, industrial and petro-chemical plants. If fumes are present in the Division 2 area, they will spread beyond when the door is opened. Do not place a general purpose switch at the outside door knob.

CODE - 517.30, Health care essential systems, previously emergency power.
ACTION - Install four completely independent power delivery systems, normal, equipment, critical and life safety.
DISCUSSION – There is still an emergency generator, but now there are four independent distribution systems, to facilitate coordination and load-shedding. Normal means that all patient care activities can continue with these circuits out-of-service. Equipment means, “nice to have” but not essential. I put HVAC for common areas on these circuits.

Critical means that patients must be evacuated if these loads are not in service. I include kitchen and patient room HVAC.

Life safety means emergency egress lights, exit signs, communications and fire alarm. I put these on batteries or UPS and charge them from the critical branch. Fire alarm voice notification is essential with annunciator and handset at nurse stations.

CODE - 517.18, Patient bed areas require 4 hospital-grade GFCI normal power receptacles and 4 hospital-grade GFCI critical power red, lighted receptacles.
ACTION - Upstream GFCI protection is permitted.
DISCUSSION – Normally, these required receptacles are at the "bed stand", for appliances and medical equipment. Additional receptacles are recommended for power bed, tv and housekeeping.

[eof]