PDHonline Course E260 (3 PDH)

2008 National Electric Code

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Course Content

Preface - The 1896 National Electrical Code was created to reduce the insurance losses from fires of electrical origin.

ARTICLE 90, Introduction - The Introduction is a non-enforceable portion of the National Electric Code (NEC). That means that a Plans Reviewer or Inspector is in error if he cites you for non-compliance with ARTICLE 90. The Fine Print Notes (FPN) in various sections are also non-enforceable as are references. Often the NEC references other NFPA publications. This information is offered to aid understanding of the section but the portion or document referenced is not enforceable as part of the NEC.

The Introduction mentions a goal of the NEC is to "harmonize" with European electrical standards, IEC publications. (IEC is the International Electrotechnical Commission.) This is good for US manufacturers and designers doing business around the world. In addition, it forced NFPA to address issues that are not interesting to US manufacturers and installers, but have safety importance recognized by a "foreign" viewpoint. For example, IEC has a very different view on electrician safety and explosion-proof installations. These ideas have slowly become part of the NEC and are responsible for several of the significant changes in the current edition.

SECTION 90 lists areas covered and excluded by the NEC. Beyond being in a non-enforceable Section of the Code, these lists give a directionally incorrect concept. The NEC is enforced wherever someone in charge chooses to enforce it. Railroads are specifically excluded, but railroad operating companies can choose to enforce it internally as an aid in avoiding liability in lawsuits, since the Judge will look at the NEC as a recognized standard of safe installation.

Further, the NEC is being revised more broadly each year outside NFPA and within the NFPA committees. For instance, NFPA embraced communications and data wiring several editions ago. This means that Plans Reviewers can demand details about communications and data equipment and planned wiring and hold up the project until they get it. Similarly, as Inspectors become more sophisticated, they will be closely examining details of communications and data installation. This is a massive change. Communications and data installers come from a different tradition than commercial and industrial electricians and, in the past, have often paid no attention to fire safety and grounding rules.

The question of "covered by NEC" or "not covered" frequently comes up in defining the "service point". When you buy electricity from a Utility, at some specific point responsibility for installation and maintenance shifts from the Seller to the Buyer. The NEC has vaguely stated opinions, but the matter is decided by State and local regulations and by the Utilities policies. It is common for the Utility to specify overhead wiring from the street or wiring and underground conduit, and the meter base, but the Owner's

Contractor must install it, subject to Utility inspection. The Utility does the final "hot" tie-in.

The message here is that questions regarding the service point should be discussed with the Utility and the results documented and saved. Experience indicates that different areas within a single Utility in a single city will have different area supervisors and different enforcement of the rules.

Article 100, Definitions

Sometimes we skip over the Definitions section of a document because we are familiar with the terms used in the field. This is an error with the National Electric Code. The Code writers have a habit of changing the rules by redefining or adding a term. For example there is a critical distinction among "accessible", "readily accessible (equipment)" and "readily accessible (wiring)".

"Accessible" means not guarded by locked doors or elevation. The concept is that a user should be able to get at a disconnect switch when a piece of equipment starts smoking. If the only switch or circuit breaker is in a locked closet, there is a problem. As you would guess, most Owners of public buildings don't want the general public turning off the lights or equipment and they lock the electric room. This produces a conflict which is satisfied by normal practice which is not documented in the Code – and varies from location to location. It is almost universal practice to lock the electric room and the Code references this in some places. On the other hand, ASHRAE 90.1, enforced by all 50 States, requires individual light switches in each area of use. In commercial occupancies, almost all equipment has a wall plug, which can be used for emergency disconnect. In industrial occupancies, almost all equipment has a nearby safety disconnect switch.

Is "accessible" provided if you need a ladder to get to the device? Yes. That is the difference between "accessible" and "readily accessible".

For wiring, "accessible" means you don't have to damage the building to get at the connections. This is the reason for access panels, junction boxes and surface-mounted and recessed-mounted equipment. Fully-concealed equipment must have some available screws to get at the innards. This comes up in renovations when a panelboard is replaced. The old panel box, with the connections for extension, must be left accessible. It is NOT permissible to make wiring extensions, then mount the new panel on top of the old panel box.

2008 changes to article 100, Definitions, include "equipment" now includes machinery. The NEC is sticking its nose inside the control cabinets in enforcing protection and short-circuit withstand. This is still part of the voluntary NFPA79, Industrial Machinery, but is now mandatory.

Definitions of grounding conductors have been revised, but are still confusing. "Equipment grounding conductor" means the green wire from the panel to the equipment. "Grounding electrode conductor" means the #6AWG (usually) wire from the service panel to the ground rod. (This wiring has expanded substantially in the 2008 Code. Stay tuned.)

"Qualified person" has been revised to require more training and documentation of training for persons working on electrical equipment. This is critical, but very vague as regards to Arc Flash permissible approach limit. The later Arc Flash section limits permissible locations for persons who do not have documented training in working with exposed electrical conductors. This means operators, supervisors, salesmen and contractors.

The definition for "authority having jurisdiction" (AHJ) hasn't changed and isn't confusing to persons in the electrical trade. It is, however, sometimes confusing to building owners and plant managers. On most commercial and industrial projects, the construction documents must be submitted to a city or county building standards department for approval before a building permit can be issued. The Plans Reviewer at the building standards department and his Electrical Inspector are the "authority having jurisdiction". These persons can make demands for changes in the equipment and materials used and the methods used to install them. The "stick" they wave is the building permit and the certificate of occupancy. Sometimes a State official or a military base commander has this responsibility. In very, very rare cases, the building owner or plant manager has the responsibility. The Code refers to insurance inspectors having AHJ responsibility, but this is a contractual relationship, not a legal relationship.

Your author is presently suffering significant pain in dealing with a manufacturing facility that doesn't want to put lights and receptacles on the roof at HVAC equipment and ground fault protection on their 2000A, 480Y277V switchboard. When a professional engineer places his seal on a set of construction documents, he is certifying that it complies with applicable Codes and includes provisions to safeguard the public.

The requirement for lights and receptacles at rooftop HVAC equipment comes from the Building Code, not the NEC, but the ground fault protection requirement is from 215.10 of the NEC.

The term "bonding" has been slightly revised and is now well explained in the NEC Handbook (a non-enforceable document from NFPA). Bonding means connection of something to ground - something that was not connected to ground previously or something that may have been poorly connect to ground previously. The purpose is to provide a good path to ground for fault current - to trip overcurrent protection or to trip ground-fault protection. The information technology (IT) guys are very prominent in facility design and installation these days and many do not understand the requirements for grounding and bonding. The new RCDD (registered computer data designer) training is helping to improve this situation.

The term "enclosure" is defined poorly in the NEC. NEMA-1 means (flimsy) general-purpose with ventilation holes. It is a violation of NEC to block the ventilation and 6-in of space for air flow may be required by the installation instructions, which are enforced via the UL listing and NEC "approved equipment". NEMA-3R is raintight, listed for outdoor installation but not limited to outdoor installation. NEMA-4X is dust-tight corrosion-proof and usually, but not always, heavy-duty. NEMA-12 is dust-tight and usually, but not always, heavy-duty. It is important to specify "heavy-duty", not just the NEMA rating. NEMA-7 is explosion-proof but should not be used in specifying equipment. Say, "Class I, Div 2, Group D explosion-proof". We will discuss the flavors later, but this is the most common.

The term "multi-wire branch circuit" is further developed in the 2008 edition, mostly because of new requirements (to be covered later). The example which causes the most trouble is two receptacle circuits fed from opposite sides of a 240/120V service. Two hot conductors and a single neutral constitute a multi-wire branch circuit. The new requirement is for a two-pole circuit breaker to feed the circuit. Similarly, three receptacle circuits fed from three phases of a 208Y120V. Three hot conductors and a single neutral constitute a multi-wire branch circuit and require a three-pole circuit breaker. This shows up often in residential living rooms and daisy-chained commercial receptacles. It also applies to 208/120V lighting circuits.

"Multi-outlet assembly" is a power-pole or power-strip. In schools, it is common to buy rows of moveable computer tables with power-strips. The power strips may be shipped in individual desks or field attached to the row of desks. Even with the 2008 changes, this is not quite legal. Flexible wiring must not be used for permanent installations (400.8) and must not be attached to building surfaces. Use of power-strips in data racks is legal if fed by flexible metal conduit, or equal. (There are special permissions for flexible cables in a properly protected data room, 645.5.) The Code Handbook gives an example of surface-mounted raceway above a residential kitchen counter; it is common to use surface-mounted raceway above the bench in shops and labs also. The old-style school computer labs with rows of computer along the walls successfully used permanently installed surface raceway with both power and data. CAUTION. Spaces for 40-persons or more may be classified by the building code as places of assembly and limit surface raceway to metallic construction only.

"Over current" and "overload" are defined in Article 100. The concept is clear - more amps flowing than the rating for the conductor or device. Interpretations and implementations muddy the concepts considerably. For conductors, the NEC-rating is not the manufacturer's rating. NEC conductor ratings are listed in Table 310.16. Be very careful to get the right table. Your author recommends using the column for 60C wire but specify 90C wire. Be warned that there are de-rating requirements for more than three current-carrying conductors in a raceway, for above roofs and in spaces above 86F. Also, be warned that the loads being connected for the current project can change and nobody tells you. These are some of the reasons to use 90C wire at its 60C rating. These are not reasons to not check on conductor count, location of the runs or load ratings.

The definition for "Qualified Person" was mentioned in the earlier discussion of "Arc Flash" It has been revised in the 2008 NEC. This is part of the NFPA effort to regulate construction and maintenance. It is not particularly significant as regards design for electrical construction. It is, rather, another "stick" to use on the Contractor or Owner if anyone gets hurt, for any reason, during construction or later maintenance. The change in the 2008 NEC requires explicit safety training. Experience alone is not adequate. Training implies documented training, both as Code compliance and in preparation for future lawsuits.

"Separately Derived System" is terminology to emphasize grounding in a special class of equipment. Everything has to be grounded (except gas pipes and some rare special cases). When you create a new voltage source using a transformer, inverter or generator, the source circuit must be grounded. It is usually a good idea to bond the new source to the incoming ground from its supply, but the Code requires a building ground and sometimes a water ground. There is controversy on how you ground a diesel- or gasoline- generator, because they are often portable. (They are separately derived sources.) Please read the fine print if you are under pressure to save money, but the clean and safe way is to drive a ground rod at the source and bond the new ground to everything around you - just like a service ground.

QUESTION: How do you ground a motor-generator or PDU transformer for computers on the 8th floor of an office building? When the computer rep demands a "driven ground rod"?

ANSWER: Just like any other separately-derived source - bond to building steel and everything else around. Run a big copper conductor to the basement and drive a rod for him. The National Electric Code prevails (except in very rare cases, after a lot of arguing, and sign-off by the City Plans Review department). Computer technicians are becoming more sophisticated, but some, especially the legacy-experts, want to float their new system - ungrounded. Not permitted.

"Service Conductors" have a definition and extended discussion later. The key concepts are as follows:
1) Protect the service conductors. They have no real overload or short-circuit protection from the utility. (The utility has rapid-response maintenance available and considers continuity of operation during overload preferable to equipment protection.)
2) Install a SE-rated service switch where the service conductors first enter the building. (Some jurisdictions require the switch outside.) Remember that you can run the service conductors under a concrete slab and they first enter the building at a central electric room. This saves long feeder runs and voltage drop problems.
3) Do a real good job of grounding the service entrance. Driving three ground rods before the slab is poured is not a problem. Try real hard to get a cadweld or UL-rated ground clamp on some rebar and bring it up to the service entrance.
4) Provide a ground strip for telephone, data, cable, satellite, etc, at the utility meter.
5) Provide main protection for the facility. This means ground fault protection if the switch can carry over 1000 A. (Some tricky folk tried to get 950A circuit breakers to avoid this. Doesn't work. 950A is the trip rating on a 1000A switch. Needs GFP.)
6) Comply with labeling requirements for multiple services, ground locations and building wire color codes.

There is a joke that only a single service is permitted to a facility. Any sizable facility ends up with another service for the garage building or the pump house or for the auditorium addition. Multiple services minimize voltage drop, have some billing advantages and provide no problems, as long as labeling requirements are followed. (Each service must have a list of all the services - voltages and locations.)

"Short-Circuit Rating" has a definition that gives no indication of the problems and interpretations in following sections. Be warned that the Code requires that the worst-case bolted-fault short-circuit current be used for sizing and specifications. Unfortunately, this magnitude is a rare occurrence and real-world faults may not be handled well by using this sizing criterion. Specifically, there is a mid-range for short-circuit currents where the protective devices aren't sure if it is an overload and they don't clear instantaneously. Such an arc fault can keep blowing copper droplets at an electrician for a long time.

The Code is clear that equipment must be labeled with its short-circuit withstand capability and must be applied within this rating. It absolutely essential, but not mentioned, that the specifier must know the available short-circuit current at the point of application. Also essential, but not mentioned, is the requirement to do calculations to determine the available short-circuit current that the distribution system can deliver at that point. These calculations are normally referred to as the "distribution system model".

"Surge Protective Device" has a revised definition in the 2008 NEC which obsoletes all previous units. SPD's must be labeled Type 1, Type 2, Type 3 or Type 4. Older units without this labeling are non-compliant. Type 1 is for line-side of the service entrance. Type 2 is for load-side of the service entrance or at panels. Type 3 and 4 are at the load. The NEC does not require surge protection devices except for Critical Operation Power systems, to be discussed later.

"Nominal Voltage" is defined in the NEC as multiples of 120/240V and 208/120V. This works very well domestically and clears up a lot of earlier problems on system and distribution ratings. Unfortunately, special care is required for international projects. Mexico claims 127V receptacle voltage which has been measured at hotels with very bright incandescent lamps. Industrial occupancies install standard 480-120/208 transformers and use the voltage taps to deliver 127/220 for receptacles. US (and most international) industrial equipment will be supplied with 480/120 control transformers. The local 127V is within the NEMA limits for controls, but a utility which is running "hot" will apply over-voltage to US components. (Utilities with voltage regulation problems run "hot" at the transformer so they can accept more after voltage drop at the far end.) A job for South Korea was designed for 440V distribution, meaning that NEMA starters are being overloaded at their maximum US horsepower ratings. Transformer sizing required different multipliers for load HP than in being used on 480V nominal. Again, 440V is at the low-end of NEMA limits. However, voltage drop will be a more severe problem when you start out at the low end of the rating. The engineer should state the application voltage in each of his purchase specifications and not count on the front-end project definitions. There will be awkward phone calls.

<u>ARTICLE 110, Requirements for Electrical Installations</u>

These are the rules that the Inspector will enforce. Occasionally a Plans Examiner will pick up inadequate clearances, but it is much more obvious as the equipment is being installed. It is also more expensive to rip gear out and figure a new place to mount it.

Section 110.2, Approval

This section is tightening in each revision of the Code. The intention is that the designer and contractor are supposed to follow the Code. Exceptions are supposed to be rare, well thought-out, and documented in writing. As indicated in the introduction to this chapter of the Code, however, this part is enforced in the field, where procedures are different.

The Code is a very solid starting point, but the local inspector probably enforces some peculiar interpretations, based upon a bad experience in his past. Local contractors know. Out of town contractors learn, painfully. The local inspector and contractor are used to oral exceptions, which are immediately covered up by the drop ceiling, equipment cover or plaster.

Section 110.3, Examination, Identification, Installation and Use of Equipment
Examination means different things in different jurisdictions. In my experience, examination means that the equipment is UL-listed. Members of my live class on the New York State use of the National Electric Code report much more participation by the Building Standards reviewers and Inspectors in New York City.

This is the section which incorporates manufacturer's installation instructions into the Code. There is a very real gotcha here. The designer does not get to see the instructions, except in cases of full-disclosure at the manufacturer's website. That means that there are clearly indicated limitations and requirements which are unknown to the designer and discovered only by diligent contractor foremen. Individual lighting dimmers, in switchboxes have been a prominent and painful example. Many have cooling fins larger than the box space. They work fine in a single-gang application, but some fins have to be trimmed off for multi-gang use. This reduces the load capacity. It is clearly explained in the instructions, but a surprise the first time, nonetheless.

Section 110.9, Interrupting Rating
This section is so quiet and mild that it is hard to believe the problems it has created. Equipment must have rating to survive available current which flows into a downstream fault.

The problem is that you have to know the available fault current. This requires a calculation for each piece of equipment of the impedances between it and the source and the addition of any motor contribution which will back-flow during a fault. This effort is possible for installation of a single piece, but only a computer program can handle a large electrical design.

Also, this is a mandate to the equipment manufacturer to determine his withstand and interrupting ratings. As control panels, like machine controls and HVAC controls have been included under the Code, this becomes a challenge.

As panel manufacturers have started to attempt to comply with this section, they have discovered that a current-limiting fuse at the main disconnect is not enough. If there is enough fault current available (as in large industry), then a motor fault can pull enough short-circuit current to destroy the motor starter and overloads before the main operates. This is specifically addressed later in the Code, and the conclusion is NOT to let it happen.

Section 110.12, Mechanical Execution of Work
This is another stealth section to the neophyte designer or installer. It must be installed in a workmanlike manner. This appears unenforceable in its vagueness, but has been interpreted to mandate following ANSI/NECA 1-2006, *Standard Practices for Good Workmanship in Electrical Construction.*

The Standard itself is well-written and has meaningful content and is stringently enforced by Electrical Inspectors and engineers who want to have pride in the appearance of the work. My experience is that good contractors and foremen have the same goal and when shortcuts are taken in appearance, there are also shortcuts in wiring details.

Section 110.13, Mounting and Cooling of Equipment
This section specifically states that electrical equipment must be mounted so that required cooling is possible. This comes back to the manufacturer's instructions, which you don't get to see until it is uncrated. The wary designer knows which equipment generates a lot of waste heat which must be rejected into the environment. This means side and back clearances. Because of the common requirement for competitive bidding, it is essential to include generous cooling clearance in the plan layout. If a less costly, but larger unit is provided, it will still fit.

Section 110.14, Electrical Connections
There is a field problem that is recognized and addressed by this section – wires into lugs. Previously, electricians often made tee connections by placing incoming and outgoing conductors in a single lug. This now permitted only when the lug is rated for the count and size of conductors. Another place this shows up is on panel breaker lugs. One circuit per lug unless labeled otherwise.

The last place this shows up is when you choose over-size conductors to avoid voltage drop or provide future capacity. Big wires into small lugs don't go. There are reducing pin-crimps that handle this (they are intended for aluminum-to-copper) and a box extension and pigtail will work. This Code section says that trimming strands to use an unlisted size is not legal.

Section 110.14, Electrical Connections
This section specifically allows use of listed direct-burial splice kits. I normally recommend heavy-duty installation, building wire in Schedule 80 PVC conduit or Schedule 40 conduit in a concrete duct bank. But, there are situations, like a driveway that is constantly being dug up, or a long run to a pump house, that justify direct-burial power cable at the legal depth.

A later paragraph in this section mandates use of wire at its 60C rating for equipment connections. As discussed previously, the feeder circuit can be 90C wire, at its 90C rating, with a short, larger pig tail of wire used at its 60C rating. It is not legal to connect the pigtail in the gutter space, as this may exceed the cu-in rating of the gutter. To play this game, you need a gutter extension or external terminal box. To avoid the problem, use 90C wire at its 60C rating.

Section 110.16, Flash Protection (sic – labels)
This is the famous section requiring field-applied arc flash warning labels. To be Code-compliant, the designer must remind the installer to apply arc flash warning labels - with no particular wording beyond, "Warning – Arc Flash Hazard".

This is a point where the interpretation has far exceeded the wording of the Code. As you might guess, a label is not protection. Personal Protective Equipment (flame retardant shirt and pants over cotton underwear, goggles and gloves) and strictly followed safe procedures are protection. The procedure always starts with, "1. Work only on de-energized equipment except in extraordinary situations." Safety-conscious firms are now requiring tag-out, lock-out and safety grounds on supply feeders before working on equipment. Further, the feeders shall be considered energized and full PPE utilized until they have been tested and proved to be de-energized.

There is a group promoting the interpretation that operating a power switch on normal equipment, with the door closed is an arc flash hazard and PPE is required, along with standing beside the equipment (not in front) and looking away. This thought arises from documented cases of catastrophic failures taking place under these circumstances. See the Brookhaven National Laboratories report at http://www.efcog.org/wg/esh_es/events/DOE_Elec_Safety_Workshop-2007/BNL%20Arc-Flash%20Incident%206_19_07%20(Durnan).pdf.

This is the arc flash labeling section. An earlier section required that equipment be applied within its short-circuit withstand rating. Both are leading to a requirement for a short-circuit study for each electric power design. That step has been taken by some design firms as an NEC compliance step, whether required by the Authority Having Jurisdiction or not.

The National Electrical Code still requires only general arc-flash warning labels. NFPA-70E, Safe Electrical Work Practices, though, requires detailed labels indicating energy available in joules per sq-cm and required level of PPE.

110.21, Marking
Equipment (now including control panels, TVSS and such) must carry a label showing the manufacturer, voltage, current and short-circuit withstand. NEMA equipment has been doing this for years, but it is a new idea for panel builders, even when severely arm-twisted by large industrial buyers.

110.22, Identification of Disconnecting Means
Other sections require that disconnecting means be present, but this section requires that they be labeled. Unenforceable commentary suggests use of ordinary words which actually describe the equipment being disconnected, not just, "XB-212".

A later paragraph in this section requires labeling of series-combination-rated systems. The labels are pretty easy. Understanding series-combination-rated systems is not so easy.

Normally, when you have a panel fed by conductors which can deliver 25,000A fault current at the panel, you would buy a panel rated at 42,000A, or similar. It is legal, per the series-combination-rated systems section, to use a 42,000A main and 10,000A branch breakers, if the main will open before the branch (so the branches never see the 42,000A arc of operation). This is legal, and certainly much cheaper. This section says the box must be labeled to make sure that only identical breakers are used for maintenance replacement in the future. The underlying question is whether the designer is willing to trust a label to insure safe maintenance in the future. If not, do not use series-combination-rated systems. If so, make sure the labels are applied.

110.26, Spaces Around Electrical Equipment
The basic rusls are to provide a minimum of 42-in in front of 600V equipment (more for 4,160V, etc), minimum of 30-in wide workspace in front of equipment (like single FVNR starter or narrow panelboard), and clear space above and below.

There are exceptions, special cases, and interpretations which very slightly reduce these minimums. The special cases which increase these minimums are higher voltage, required ventilation and required access to sides and back. Note that ventilation behind equipment is required in damp environments (stand-off mounting).

I handle this for layout of an electric room by creating a block of the actual dimensions of the equipment, then make a dashed envelope which indicates required access space. (My wife taught me this, using pieces of paper to locate furniture in the living room.) As the equipment changes, or the electric room changes, or they change the door locations, you can move the equipment around while maintaining safety.

WARNING: It is common for designers to layout electrical gear on both sides of an aisle. If you assume that one side is closed, while only the other side is open, then you use 42-in spacing, front-to-front. This is legal, but a bad idea. When one side is open, and you are racking out a piece or have tools and maybe a ladder, the aisle is not clear as a path of egress. Much better to consider each side to have a 42-in clear space in front and an 84-in aisle. This is safer but a significant hazard still exists if the open door is on energized equipment. The arc-flash approach radius may still “block” the aisle if observed during emergency exit use.

The “clear space above and below” is relatively new. Some Inspectors are citing as non-compliant an 8-in trough below a 4-in panelboard. They say you must fur-out the panelboard to maintain clear space above and below. There is a reasonable response in the code, but please be aware of the requirement and this interpretation. A special (favorable) case is truss-mounted dry transformers. Since they don’t require maintenance, they need not be accessible. With a little cooperation by the Inspector, you can place them over other electrical equipment.

While you are looking at space around equipment, it is good to put in some extra pieces as “future”. Everyone agrees on capacity for expansion, but a physical representation helps build a consensus and makes sure the space is available. A spare 277/480V panelboard, a spare 120/208V panel and a spare mcc section are desirable. It is very common to add another dry transformer later for special equipment. Try to anticipate and accept the need to fight for valuable sq-ft of building space.

There is a requirement that electric rooms containing equipment rated 1200A or more and over 6-ft wide have outward-swinging doors with panic hardware at each end. If you take a moment to visualize an are-flash event and you are in the room, you will immediately agree that you need to get to a door without crossing the field of blowing copper droplets.

There are two special concerns when implementing this rule. First, you must have outward-swinging doors with panic hardware. You sometimes have to say this several times and circle it on check prints. Second, you don't want to create a preferred normal path of travel for unqualified person to use the electric room as a shortcut to the bathroom or to the outside door at quitting time.

Do provide good lighting and battery-powered emergency lights. Motion-sensing switches and energy conservation plans are not permitted. Exhaust fans are implicitly required by the Code to meet the operating temperatures of the equipment as part of the manufacturer's UL listing.

Article 200, Use and Identification of Grounded Conductors

The basic rule is that there are one or more "hot" conductors which carry electricity from the source to the load. There is often a "neutral", or "grounded power conductor" which carries unbalanced current back to the source. There is one or more "grounds" which keep the voltage down for personnel safety and provide a safety return path for fault current.

The neutral is not required for 480V power to motors and most large equipment. By the magic of balanced three-phase circuitry, all three current flows sum to zero. If they don't sum to zero the system adjusts and they DO sum to zero. The neutral or grounded conductor is not a problem in these circuits.

In 120/1/60, most 120/240V and most 208/120V circuits, a neutral is required. The 120V circuit is only supply and return (neutral). The 120/240V circuit may be only 240 supply (hot) and 240 return (also hot), but usually has a neutral to handle a small fan or timer in the equipment from one hot and the neutral.

Real 208V equipment, like rooftop HVAC units may be power-only, with no neutral, but it is important to check. 208V and 208/120V are not the same and it costs money to add the neutral later. Most 208/120V circuits are not balanced and will have a neutral current approaching or EXCEEDING the hot conductor current. (Switching power supplies, like "wall warts" on electronics pull heavy, short-duration pulses of current that do not balance on three-phase circuits or 120/240V circuits.)

You must recognize that current flows in the neutral circuit. Safety precautions in design and installation are necessary to avoid the same shocks an electrician can get from a hot conductor. If you open the neutral flow on an energized circuit, the line-to-neutral voltage appears on that break and an arc. For this reason, neutrals require the same insulation as hot conductors and as much care in labeling as hot conductors.

As mentioned previously, the Code requires that a facility containing 120V and 480V circuits use distinctive colors for both systems. The example given in the National Electric Code Handbook is as follows:

208Y/120V			480Y/277V	
Phase A	Black		Phase A	Brown
Phase B	Red		Phase B	Orange
Phase C	Blue		Phase C	Yellow
Neutral	White		Neutral	Grey

The text in the National Electrical Code Handbook states that the use of grey for 480Y/277V neutral is not required, but common. The wording of the Code permits phase conductors with longitudinal white stripes or lateral white stripes at terminations for either neutral. There must be different neutral colors when there is likelihood of both appearing in the same equipment or cabinet.

Article 210, Branch Circuits

This article contains requirements for branch circuits, as you might expect. However, it also contains requirements for residential ground fault circuit interrupters (GFCI) and arc-flash circuit interrupters (AFCI). This course has specifically excluded residential installations but will include GFCI and AFCI because they are new and not obvious.

Regarding branch circuits. The definition of multi-wire branch circuits is developing, as we speak. It clearly applies to residential where 120/240V and a single neutral go to a switchbox for a switched receptacle and a switched overhead light. Similarly, it applies to commercial and institutional where 208/120V and a single neutral loop around supplying a number of receptacle on three separate circuits. It appears to apply to 480/277V with a single neutral serving a lot of ceiling fluorescents with individual switch legs.

There are two special requirements in Article 210. First, the conductors making up the multi-wire circuit be grouped, physically tied, when they pass thru a junction box or at the originating panel. Second, all the hots must be opened by a single circuit disconnect. This second requirement makes sense and is easy at the panel - a three-pole breaker. It makes sense in the overhead space, near the fluorescents, but is not easy, unless all the lights are on a common switch leg.

More conventionally, up to 63 (16A x 277V / 70VA) fixtures are switched on one phase with a one-pole switch. When the switch is off, there likely are return currents flowing from the other phases. By disconnecting all three phases simultaneously, there cannot be return current flowing. Obviously the wall switch is not an adequate disconnect before doing maintenance.

Regarding ground fault circuit interrupters. Residential occupancies are required to have personnel GFCI's (5mA trip) in bathrooms, garages, outdoors, crawl spaces, unfinished basements, kitchens, at laundry, utility and wet bar sinks, and at boat houses. There are a range of details, but note that exceptions are being deleted one by one. The 2008 Code removes the exception for dedicated receptacles for appliances and inaccessible locations. The reasoning was that it is better to lose a freezer full of meat than take a chance on a shock. (Paraphrased from 2008 NEC seminar by National Association of Electrical Inspectors.)

Non-residential occupancies are required to have GFCI's in bathrooms, kitchens, rooftops, outdoors, at sinks and at boathouses. There are fine points regarding each location, but please note the trend is to provide a GFCI for general purpose receptacles. Industrial 120V shop and assembly line hand tools are not presently covered and outdoor receptacles for recharging autos and engine block heaters are not presently covered.

Personnel ground fault protection (same GFCI, but often cord-mounted) is required for construction hand tools.

Regarding arc flash circuit interrupters. AFCI's are required on all outlets in family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, or similar rooms or areas. AFCI is not required for basements, garages or fire alarm wiring in conduit.

Article 215, Feeders

Protection for feeder circuits must be sized at 125% the continuous load plus 100% the non-continuous load. This always works. There is an expensive exception for large loads by using "100%-rated" protective devices. The "100%-rated" devices are available only in electronic trip units, considerably more expensive than simple thermal-magnetic trips. On the other hand, circuits above 1000A on 277/480V require ground fault protection, which is another feature available only on electronic trips.

There are additional rules to permit adding additional load, including non-continuous load derating for some machine tools (often misused for general loads) and a demand factor, to reflect loads not operating at rated nameplate. I have used these special calculations when the calculated load is 1% above a circuit breaker fame size, requiring a step increase in enclosure sizes. Beyond that case, it is contrary to the Code's intent that the designer provide capacity for future growth.

This 125% requirement is usually referred to as the "80%-Rule" since a given circuit breaker can only be loaded to 80% of its rating under normal circumstances.

This article suggests a diagram of feeders, showing sources, loads, square feet of the facility served by each and any derating factors used. The diagram is discretionary to the Authority Having Jurisdiction. One of my supervisors assigned his staff to make such diagrams during a time of light workload. It is interesting how areas of service overlap after years of maintenance. The diagram was very valuable to newly hired maintenance electricians.

The requirement for identified conductor colors for each voltage level in the facility is restated, along with the recommendation of distinguished neutrals. As stated previously, the NEC Handbook provides a sample, as follows:

208Y/120V			**480Y/277V**	
Phase A	Black		Phase A	Brown
Phase B	Red		Phase B	Orange
Phase C	Blue		Phase C	Yellow
Neutral	White		Neutral	Grey

Peculiar observation: I was doing observation-of-construction this week on a massive data expansion. The data racks were in and the panels, but no equipment and only three cables of data wiring. I was examining the ground bus, 1/4"x3"x12" bar with building ground, panel ground and tapped holes for data grounds. There was only one data ground connected. It went to the overhead steel ladder tray. I was interested to see how they bonded connected sections of the data tray, since we go to a lot of trouble with bonding conductors on power trays. There was no bonding between sections, but I found some more green conductors, apparently identical to the #6AWG for the tray ground. They were the first data cables! All of the Cat 6 data cabling on the project has a green jacket and is the diameter of #6AWG insulated ground. I will follow up with the IT group to see if the single system ground is their intention.

<u>Article 230, Services</u>

This article presents the new labeling for surge protection devices and explains application better than previous issues of the Code. As discussed previously, SPD's must be labeled Type 1, Type 2, Type 3 or Type 4. Older units without this labeling are non-compliant. Type 1 is for line-side of the service entrance. Type 2 is for load-side of the service entrance or at panels. Type 3 and 4 are at the load. The NEC does not require surge protection devices except for Critical Operation Power systems, to be discussed later.

The line-side connection is not new, but is clearly presented now. The advantage is that SPD operation is cumulative. Each additional SPD device reduces the remaining surge that hits other connections to the same source. Keeping the SPD on-line when you take down the service means that the protection for other services remains intact.

The Code is moving into proper connection of parallel power production systems. As photovoltaic, fuel cell, water and wind generating systems are becoming more common, the NEC is including standards for proper connection and protection. This is non-trivial, since electric utilities have invested 100-years in learning how to connect power sources and the new systems are being installed by quick-profit vendors.

The greatest experience with parallel power production is at second-home cabins in the west. Rich folk need their satellite TV when they are roughing it. A moderate-size photovoltaic array and some deep-discharge wetcells support the necessary amenities, but not air conditioning or electric water heating.

Parallel power production means that both utility and local sources are available (and air conditioning and electric water heating can be provided). This is introduced by briefest reference in this article. The majority of the content of the article regards details of service conductors, service switches and service protection. The controlling requirements for service conductors and service switches, however, are the local utility regulations - usually clearly stated in a brochure. The utility may be more stringent than the NEC and/or have peculiarities. If you want them to energize the service, you do it their way. It is very desirable to have a utility representative review the installation before requesting it be energized.

This article introduces the requirement for equipment ground fault protection for 277/480V systems of 1,000A or more. A later section adds complexity to the situation. Emergency systems and critical operation power systems must be co-ordinated. That is, a low-level downstream fault must not cause a high-level protective device to operate, unnecessarily isolating the emergency or critical operation power system.

If you put a GFP sensor on the service, you have to do something to make sure it does not unnecessarily knock off the important loads at the bottom. This is not hard to do, but it is expensive, a little complicated and requires maintenance. The three obvious solutions are as follows: 1) Co-ordinated ground fault protection (delaying the high-level until the low-level has had time to clear); 2) Upstream inhibit (block the upstream protection while the downstream is taking care of a problem); and 3) Provide a separate service for the important loads. An advantage of the third choice is that it is similar to normal installation for a fire pump and installing contractors are familiar with this.

Article 240, Overcurrent Protection

It is the characteristic of electrical wires, transformers and most equipment that a small overload can be tolerated for a long time. A large overload can be tolerated for a short time. This relationship is called an inverse time-overcurrent curve. So, when we speak of overcurrent protection we do not mean "measure and disconnect if above the setpoint". Rather, we mean "follow the pattern and when the resulting time-overcurrent function exceeds the time-overcurrent protection curve, then disconnect."

This revision of the Code adds current limits, or ampacities, for small conductors, with some interpretations. 18AWG is 5.6A and 16AWG is 8A. Protection must be provided by circuit breakers or fuses listed for protection of these wire sizes or by current-limiting fuses. This change is important in accompanying the NEC taking regulatory control over industrial control panels, which have typically used the smaller conductors for internal wiring and some remote devices.

14AWG is 15A; 12AWG is 20A; and, 10AWG is 30A. These are not exactly conductor ratings but NEC limits for conductor use. The values for 14-10AWG are now new, but were hidden previously in notes to the ampacity tables.

Tap conductors are regulated by this article. The idea is that a feeder goes from the source to the load, with protection of the feeder conductor size at the source. It is very often desirable to tap onto the feeder at some midpoint to supply another load.

The cleanest and easiest was to do this is by tapping with the same size as the feeder. This is a full-capacity tap and requires no limitation, since the source protection is exactly right for the tap.

It is more common, however, to have a really large feeder and only need a small amount of current for the intermediary load. Special cases have been set up to permit this. Please consider a circuit breaker or fused disconnect being installed for the intermediary load. If it is a small load, then it will be a small protective device, with small incoming wire lugs. The tap conductor from the feeder to the protective device is limited by the “10-ft -- 1/10 Rule”, the “25-ft -- 1/3 Rule”, the “100-ft industrial drop - 1/3 Rule”, and the “Outdoor – unlimited rule”. In general you can run a tap for 10-ft if it at least 1/10 the amp rating of the feeder. You can run a tap for 25-ft if it is at least 1/3 the amp rating of the feeder. You can run a tap for 100-ft as an industrial drop if it is at least 1/3 the amp rating of the feeder. And, you can run a tap of any length or any size on an outdoor feed, with some restrictions on how it enters a building.

Another restriction is that you “cannot tap a tap”. That is, you can tap after the protective device, but not before it.

This article requires that overcurrent devices be readily accessible and the handle cannot be more than 6-1/2-ft above the floor. Remember from the definitions section that readily accessible means that a ladder is not required. However, protective devices above drop ceilings are specifically permitted and disconnects at very awkward locations, but adjacent to the device being protected.

Some screwy things come up on odd electrical distribution systems. You are always safe if the rating of the protective device matches the rating of the system. For instance, three-phase delta systems are still in use. As they are not normally grounded, protective devices must be rated for the line-to-line voltage. A circuit breaker rated 480V is satisfactory. A circuit breaker rated 277/480 is not - when one leg is inadvertently grounded, the line-to-ground applied is 480, not 277. The slash-voltage rating is critical. High-leg delta systems are still in service and, again, apply stress to the protective devices not quite obvious. The high-leg has a line-to-ground higher than the line-to-line rating. Special high-leg delta circuit breakers are required.

This article discusses series-rated protective devices. As discussed previously, normally, when you have a panel fed by conductors which can deliver 25,000A fault current at the panel, you would buy a panel rated at 42,000A, or similar. It is legal, per the series-combination-rated systems section, to use a 42,000A main and 10,000A branch breakers, if the main will open before the branch (so the branches never see the 42,000A arc of operation). This is legal, and certainly much cheaper. This section and the earlier section say the box must be labeled to make sure that only identical breakers are used for maintenance replacement in the future. The underlying question is whether the designer is willing to trust a label to insure safe maintenance in the future. If not, do not use series-combination-rated systems. If so, make sure the labels are applied.

This article applies the ground fault protection for 1000A services to feeders of 1000A or larger. The wording is different here, requiring GFP if the TOTAL service is 1000A, not just an individual service switch.

Article 250, Grounding and Bonding

This article states very clearly that "all metallic systems must be grounded", and explains this mean there must be an intentional copper conductor back to the service ground. Usually the common tie-point for downstream grounds is the ground bar in the main distribution. Connection of the ground bar to the ground rods is a special topic. Another special topic is grounding around the utility service transformer. This, too, will be discussed.

Of course, intermediate points and systems may get their ground connection from any particular ground going back to the service ground. There are only two real restrictions, relating to equipment grounds which accompany particular feeder or branch supply conductors - they must closely accompany the supply conductors and they must be of sufficient size to safely carry the fault current in the event of a line-to-ground fault at the equipment served.

Ground conductors for incidental systems, such as HVAC ducts, and CATV or data systems can be anything larger than #6 AWG copper. There are other sections which require a larger conductor for expected grounding of lightning strikes. It is common to use bare 500 kcmil or 4/0AWG for a perimeter loop, with #2 AWG connection to individual building steel columns and motor bases. These are auxiliary ground fault return paths, but primarily equalization means for lightning. They are intended to minimize the voltage present rather than trip the supply circuit breaker.

Beyond these concepts, this Code article is dedicated to listing mistakes to avoid and a few good practices to avoid problems. The lists are mandatory and make up a good part of the Electrical Inspector's job - to find violations.

Sidebar Discussion of the Importance of Grounding
Since the Millennium, we consider grounded power systems to be normal. As recently as 1960, however, US industry was building plants with ungrounded three-phase power systems. The reasoning, then, was that ground faults are fairly common and do little damage. With reasonable maintenance, the ground can be found and fixed without interrupting production. Mostly, this worked. Unfortunately, when it didn't work, lightning or an intermittent line-to-ground fault on an ungrounded system could start "ringing" or resonating at its natural frequency. This happened very rapidly and initiated very destructive line-to-line faults at switchboards, control panels and equipment. Lots of line-to-line faults if the 480V system reached 10,000V above ground. As major manufacturers embraced employee safety, they converted the power systems to grounded form, so a line-to-ground fault trips the breaker and maintenance is done on a de-energized system. By the way, this is the same reasoning behind adoption of arc-fault protection. The line-to-ground fault creates ionized gas which is conductive and escalates into a line-to-line fault. By tripping at the beginning of the small arc-fault, the destructive high-current line-to-line fault is avoided.

Section 250.4 requires grounding metal that is not part of the electrical distribution circuit. The requirement is for personnel safety. In the event of a hot conductor touching an HVAC duct, they want the breaker to trip - not wait for someone to touch the duct with one hand and a grounded conduit with the other hand.

This costs money and, in rare cases, Architects or Owners will question the investment. My answer is always the same, "We build to the Code." They view it as gold-plating but go along. The only area of genuine question is natural gas piping. We don't want to pull an arc when the piper opens a union. Natural gas piping does not require intentional grounding by the electrical contractor. Hot water does, as does cold water, steam, process gas, ducting, non-electrical equipment and structural steel.

There is a very specialized field of hospital patient-area grounding. That will not be addressed here, but be aware that the requirements are much more stringent and the methods applied are much more complex.

Section 250.6 tries to address the legacy knowledge of information technology professionals. For many years, the data equipment was installed after the Electrical Inspector had left. When the IT people asked for strange electrical installations, they could hire their own contractor - often a low-voltage contractor - and get what they wanted.

However, as IT became a core business function, we started building computer rooms, designed to be computer rooms. We submitted them to the Department of Building Standards for a Building Permit and they started looking at the grounding details.

Olden-times computer field engineers demanded complete isolation of the computer room grounding from the building power grounding and a separate ground rod, often to be driven below the raised floor in the computer room. This was illegal then, is illegal now and usually impossible on a 6th story computer room.

The building electrical designer doesn't have to read Section 250.6 until the IT department starts making demands. Each demand is clearly answered and denied.

Section 250.8 addresses legal ways of connecting the ground wire. Hose clamps and self-tapping metal screws are forbidden. There are special "three-lobe" thread-forming machine screws that are legal (and don't drop shavings into the electrical equipment).

The best electrical connection results from a "double-lug, double-crimp" lug on a wire-brushed surface with no-ox paste. The Code permits spring-connectors (wire nuts) and there are special wire-nut-plus-pigtail that make very tidy connections in wall switch boxes. Exothermic welded connections are very good, but labor-intensive. Approved crimp connections work very well. As always, "UL-approved for the application" is a key specification entry.

Section 250.20 lists various systems that must be grounded or may be ungrounded. Be warned, however, systems that are ungrounded must be in grounded raceway and all other metal items still need to be grounded.

Legal ungrounded systems you may run into are low-voltage controls, legacy industrial power systems and chemical processes using extremely high currents. The legacy industrial systems (240V, 480V and 575V) require ground alarms, but do not require automatic action result from alarm activation. It is very common to have ground alarms on these specialized systems and perform maintenance to keep them ground-free.

Separately derived systems are discussed in this article. A transformer, generator and some static devices are separately derived sources - they create new electricity. The general rule is that the new source must be grounded. The question arises when it is connected to the plant or office electrical system - only one ground connection is permitted for the building service. What to do?

There are two answers and very strong opinions on both sides. One is to ground the generator and switch the system ground to the generator with a 4-pole transfer switch. The other is to solidly connect generator neutral to the building neutral and have fault current go back to the building bonding connection, then back thru the neutral to the generator.

My reasoning is that grounding the generator and using a 4-pole switch provides maintenance safety when the generator is off-line and minimizes ground return impedance on a fault. The 4-pole transfer switch costs more and they don't sell too many.

Section 250.50 addresses the utility service ground. As stated previously, the reasons for grounding the electrical distribution system are to stabilize it from voltage swings, shunt lightning before it gets into the building, provide a fault return path to trip protective devices and to provide safe surfaces for staff and visitors.

The Code says that "all seven grounding electrodes that are present shall be bonded together to form a grounding electrode system." This is not confusing, but interpretations are. It is not onerously expensive to actually create and bond all seven and I recommend this (and see them all frequently on construction designs). The only one that gets serious complaint is number 3), tying to foundation reinforcing steel. This requires coordination with the foundation contractor and a visit, at the right time, by an electrician.

The seven grounding electrodes are as follows:
1) Metal Underground Water Pipe
2) Metal Frame of Building or Structure
3) Concrete-Encased Electrode
4) Perimeter Ground Ring
5) Ground Rod
6) Other Listed Electrode
7) Ground Plate
8) Other Metal Underground Systems or Structures

You might notice that there are eight items in the list of seven. Well, neither number 8 nor 6 really says anything.

There are details on the sizes installation details for each of these electrodes. It is important for the field inspector to be aware of these details, but the designer only has to say, "per NEC". He should leave wire size selection, connectors and piece selection to the contractor under "means and methods". One exception is the basic ground electrode. For years, this was the only earth ground and got a lot of attention. Careful designers call for a minimum of three driven rods, spaces at least 6-ft apart (often in a triangle).

I just got a clamp-on ground tester and plan to check existing and new construction ground electrodes ohmic values. The PDH 2011 NEC course should include the results.

Another special case for electric distribution grounding is high-resistance grounding. This is often used in mining, fairly common in utility transmission and one really strange animal regarding marine power. Mining is controlled by MSA, not NEC. Utility transmission is not NEC and, until recently, ship power was not NEC.

However, marine ports tend to be in environmentally sensitive areas and the diesel fuel used is nasty. Several ports are experimenting with "cold ironing". This is a shore-side (sic) substation and flexible cable to the ship. There is an IEEE paper which describes the installation at Long Beach. The shore-side substation is on a barge and flexible cables hang from the dock to the barge, then a separately derived source goes by flexible cable to the ship. Seattle is also trying this, for cruise ships.

We may see further strange grounding schemes for electric cars.

Section 250.94 introduces intersystem bonding. This is not a new idea, but is greatly expanded in the 2008 Code and new equipment requirements are introduced. An accessible tie-point must be present in one of the three forms discussed in the Code, as follows:

1) A set of terminals mounted on the meter enclosure.
2) A ground bus near the service equipment enclosure with a min #6 AWG copper conductor to a ground in the service equipment enclosure.
3) A ground bus near the grounding electrode conductor, connected with a min #6 AWG copper conductor.

The intersystem bond must tie together power, data, telephone, CATV, satellite and any other electrical services. [Be careful regarding fiber optic. Almost all real-world fiber optic cables have a metallic sheath or strength member which must be grounded.] A commercial intersystem bonding terminal is described below:

ERITECH®

Intersystem Bonding Termination for Residential and Small Commercial Facilities

Features

- Meets the requirements of 2008 NEC® Article 250.94
- UL® Listed
- Accommodates (5) 14 - 6 AWG bonding conductors and (1) 6 - 2 AWG grounding electrode conductor
- Integral mounting base enables easy installation
- Includes mounting hardware
- Connects to grounding electrode conductor – does not rely on meter base enclosure bonding connection

The Intersystem Bonding Termination (IBTB), part of the ERITECH® line of Facility Electrical Protection products, is designed to meet the requirements of the 2008 NEC® Article 250.94 “Bonding for Other Systems.” The IBTB is mounted adjacent to the meter base or service entrance equipment and is a convenient way to interconnect and terminate grounding conductors from telephone, CATV or radio and television antennas.

The IBTB includes corrosion-resistant, stainless steel mounting hardware and is easily accessible for connection and inspection. The lay-in connection clamp (#6 AWG - #2 AWG) allows easy installation of the grounding electrode conductor in one continuous length, where possible. The polymeric base and housing is impact-resistant,

Residential and Small Commercial Facilities

ERITECH Intersystem Bonding Termination - Typical installation bonding the electrical system to the telephone and CATV systems.

ERITECH IBTB, with cover on

ERITECH IBTB, with cover off

ERITECH Intersystem Bonding Termination is also used to bond grounding conductors from satellite dish cable, antenna discharge units and lightning protection systems.

Approvals: UL® 467

Part #	Weight (lbs)	Depth (in)	Width (in)	Length	Conductor Size Range
IBTB	0.3	1.41	2.01 in	4 in	14 AWG - 2 AWG

This is not the section that requires a lightning protection system to be bonded to the electric service ground, but that is a requirement of 250.106. It is also the source of the perimeter ring ground. The ring is especially effective for lightning protection on high-rise buildings.

Section 250.102 discusses equipment bonding jumpers. What we are talking about is the equipment ground conductor which accompanies the power conductors from the panel to the load. 250.102 includes a provision that you can wrap a short section of the green conductor around the outside of the oiltight flexible steel conduit going up to a motor junction box. It is common to find an entire plant, often a water or waste water plant, with all the motor connections displaying an external green wire at the motor junction box.

My guess is that the whole topic goes back to the early days of flexible steel conduit and fluorescent lighting circuits. Contractors discovered tremendous labor savings by using "whips" that were shop-connected to the fixtures and field-connected to junction boxes on the ceiling. The same savings were available for motor connections, but the super-cheap armored cable they were using for fluorescents did not contain an adequate ground conductor to handle a motor winding fault. The Code came back with the external ground wire, which solved the problem. Today, however, we buy a hank of empty oiltight flexible steel conduit and pull four conductors through it. And, there is a ground screw inside the motor junction box.

I have asked the design firms who were installing external grounds at water plants why and the board-level designers had no idea - it was their firm's signature way of doing motor installations.

Section 250.118 says that it is still legal to use rigid steel, intermediate steel, thinwall for flexible conduit as the grounding conductor - with limitations. All specifications I have read in the last ten years call for a separate grounding conductor. Too many times, I see conduit connections pulled loose in the field. Sometimes equipment sinks because of inadequate foundation. It is a bad idea to use the raceway as the ground.

Section 250.122.F requires that ground for parallel circuits each be sized for the entire load. This applies only to individual conduits, where the ground impedance will be different for each run of the circuit and fault current may choose to follow only the lowest impedance path.

The equipment grounding conductor is selected from Table 250.122, based upon the size of the protective device for the circuit. Note that the ground is not a current-carrying conductor. It is intended to carry fault current for a few one-thousandths of a second only.

Section 250.170 discusses grounding of meter and protective relay circuits - voltage transformers and current transformers. It would be nice if we could just let the factory install metering and relaying for the switchboard or motor control center. Unfortunately, these circuits are capable of very dangerous mis-operation and catastrophic failure if mis-wired. Also, someday, business leaders will notice how much money they are spending on electric power each month and they have no ideas where it is going. We will be retrofitting check-metering wholesale.

The answer is that (mostly) we ground one side of the secondary of a voltage transformer and (mostly) we ground one side of the secondary of a current transformer. If we do this, then any wiring fault will make a big spark and blow a fuse or melt the conductor. The exceptions relate to special three-phase connections.

Section 280 Surge Arrestors

Section 280 is Surge Arrestors for systems over 1,000V. This is very meaningful for plant internal medium voltage power distribution and large motors. Typically switchboard and unit substation manufacturers are very careful, because their technicians will be doing startup and they will have liability for associated injuries for the life of the equipment.

Section 285 Surge-Protective Devices

Section 285 is Surge-Protective Devices for systems 1,000V or less. This section was revised for 2008 in a way that obsoletes existing dealer stock and requires close attention to labeling to be compliant. Starting with the 2008 Code, surge-protective devices must be labeled Type 1, 2, 3 or 4. Yes, there is a relationship between the specifications and the Type, but that doesn't count. The Codes requires the Type label for the applications.

Types and applications are as follows:

Type 1 -- Supply-side of main disconnecting means, or any location downstream. These are also permitted to be labeled Surge arrestors.

Type 2 -- Load-side of main disconnecting means and protection, or any location downstream

Type 3 -- Load side of a protective device at least 30-ft from the service entrance.

Type 4 -- Point-of-use, as TVSS receptacle or power strip with TVSS or simple plug-in MOV.

Sidebar Discussion on Surge protective Devices - Smoke-and-Mirrors vs functionality.
The kind of surge protectors we are talking about are sacrificial devices. That is, they function by shunting the energy of a lightning strike or switching surge through themselves to ground. This implies several things, as follows: 1) In a high-lightning area, even the best surge protector will eventually fail (months, not decades). 2) In a low-lightning area, the likelihood of surge protector operation is low. This certainly means that an effective salesman can point to success on installations of his special product. 3) Because they are sacrificial, you should buy units with out-of-service lights, or two identical non-indicating units for the same location (which costs the same). 4) It is of critical importance to follow IEEE guidelines and put a Type 1 or 2 unit at the service and a Type 2 or 3 at each panel. 5) Because they are shunt devices on an energized line, simple surge protectors are limited to about 600V clipping on 120V and about 1200V clipping on 277V. This means that electronic devices still need withstand ratings and the need for isolation transformers and UPS is not eliminated.

Article 300 Wiring Methods

Article 300 lists available wiring methods and identifies proper uses and forbidden uses. As technology keeps advancing, innovations are offered to the marketplace to reduce materials costs and labor. This describes most of the additions to Article 300 in the last 50-years.

The old methods are individual conductors in raceways of rigid steel, intermediate steel, thinwall tubing, flexible conduit and liquidtight flexible conduit. For institutional and industrial occupancies with an expected life exceeding 20-yr, these are still the preferred methods. For speculative office buildings and warehouses or retail buildings, the innovative methods often make the difference between financial success and failure.

With the understanding that many of the innovations trade low first-cost for higher life-cycle-cost, the decision resolves to risk tolerance of the Owner, designer and Building Standards Office. Some Building Standards Offices are extremely risk-adverse. This is usually well-known in the community, but may be a surprise to outside investors.

I am presently working on a job which is considering direct-bury 15kV cable for a remote treatment plant. This has been an accepted utility means for many decades, but is considered innovative and risky in the water treatment industry. I am recommending it because of the higher reliability than the existing overhead utility service, so that we can avoid the permitting hassle for an emergency generator.

Section 310, Conductors

Section 310 lists all the variations of conductors, insulations and jackets that are approved and limitations regarding their application. The key summary is Table 310.16, Allowable Ampacities for not more than three current-carrying conductors in raceway, cable or direct buried. Anyone who is doing detailed electrical design must have a copy of this table at his workplace. The conservative design standard is to call for 90C cable (XHHW) and apply it at a 60C (TW) rating.

A very powerful design aid is a table with columns for circuit breaker, power conductor size, ground conductor size and conduit size. A further aid is to include a key, perhaps in a hex box, and use the key on one-line diagrams instead of repeating the information on each 10HP pump. A sample is included below:

FEEDER SCHEDULE

HTR 208V KW	HTR 460V KW	#	3 PH 208V HP	3 PH 460V HP	MAX AMPS	# OF PARALLEL RUNS	ø WIRES AND NEUTRAL PER CONDUIT	PHASE CONDUCTOR SIZE	GROUND SIZE	CONDUIT SIZE
3KW	7KW	1			20	1	2	12	12	3/4"
5KW	11KW	2			30	1	2	10	10	3/4"
6KW	15KW	3			40	1	2	8	10	3/4"
8KW	19KW	4			50	1	2	6	10	1"
11KW	26KW	5			70	1	2	4	8	1"-1/4"
5KW	13KW	6	3	10	20	1	3	12	12	3/4"
		7			20	1	4			
8KW	20KW	8	5	15	30	1	3	10	10	3/4"
		9			30	1	4			
11KW	26KW	10	10	20	40	1	3	8	10	3/4"
		11			40	1	4			
14KW	33KW	12	–	30	50	1	3	6	10	3/4"
		13			50	1	4			1"
20KW	46KW	14	15	40	70	1	3	4	8	1-1/4"
		15			70	1	4			
28KW	66KW	16	25	60	100	1	3	2	8	1-1/4"
		17			100	1	4			
36KW	83KW	18	–	75	125	1	3	1	6	1-1/2"
		19			125	1	4			
43KW	100KW	20	40	–	150	1	3	1/0	6	1-1/2"
		21			150	1	4			2"
		22	–	100	175	1	3	2/0	6	2"
		23			175	1	4			
		24	50	125	200	1	3	3/0	6	2"
		25			200	1	4			
		26	60	150	225	1	3	4/0	4	2"
		27			225	1	4			2-1/2"
		28	–	–	250	1	3	250KCMIL	4	2-1/2"
		29			250	1	4			3"
		30	75	200	300	1	3	350KCMIL	4	3"
		31			300	1	4			4"
		32	100	250	400	1	3	500KCMIL	3	4"
		33			400	1	4			
		34	150	300	500	2	3	250KCMIL	2	2-1/2"
		35			500	2	4			3"
		36	–	400	600	2	3	350KCMIL	1	3"
		37			600	2	4			4"
		38	200	450	700	2	3	500KCMIL	1/0	4"
		39			700	2	4			
		40	–	500	800	2	3	600KCMIL	1/0	3"
		41			800	2	4			4"
		42			1000	3	3	500KCMIL	2/0	4"
		43			1000	3	4			
		44			1200	4	3	350KCMIL	3/0	3"
		45			1200	4	4			4"
		46			1600	5	3	500KCMIL	4/0	4"
		47			1600	5	4			
		48			2000	6	3	500KCMIL	250KCMIL	4"
		49			2000	6	4			

In this version, the seven left-hand columns are in a non-plotting color and used for design, but not shared with the installing contractor. If the color red shows up on Key 16 phase conductor, that is because we used this chart for over ten years with a wrong value in this cell. The red is a reminder that this is the revised chart.

There are three important derating factors for Table 310.16, as follows:

1) This is for no more than three current-carrying conductors. If harmonics are present, flowing through the neutral, then there are four current-carrying conductors and the ampacities are reduced to 80%, per Table 310.15.B.2.a. 80% applies to 4 – 6 current-carrying conductors and further derating is required for 7+ current-carrying conductors.

Sidebar Discussion of Special Case of WireMold 4000 in Section 376.22
Section 376.22 provides an exception for medium-large wireway, similar to WireMold 4000. Up to 30 conductors can be used without derating. This is extremely powerful for situations where you must relocate a panelboard or must accommodate especially intractable interferences.

2) Table 310.17, Temperature Correction Factors requires 13% upsizing of 90C wire (XHHW) at temperatures above 104F. The correction is 29% upsizing for 60C wire at 104F. 104F is special because it is the temp limit for most NEMA devices, plc's, etc.

Sidebar Discussion of Derating for Temperature - mostly ignored in the past
The comment in the main text suggests that 104F is a reasonable limit for industrial ambient. That is true at floor level but grossly in error for steam tunnels, inside near the roof or outside on the roof. I was tiring easily when I was pulling some data cable in a steam tunnel, near the ceiling. A precision thermometer reported 140F where I was working. [By OSHA, this is life-threatening. By Table 310.17 Corrections, it requires 42% upsizing of 90C wire (XHHW) and 60C wire is not permitted.] Further, 140F is commonly reached in poorly ventilated attics and inside near the roof of plants. In the past it has been extremely rare (unknown) to upsize such conductors. The 2008 NEC includes a Table 319.15.B.2.c for derating conductors run across a roof. A 30F derating factor must be added to the measured ambient for heating by the sun. We reach 104F in a 70F ambient. A 110F ambient means derating for 140F. It will be interesting to see if we get comments back from Plans Review on this. I will certainly mention the requirement to our HVAC designers.

3) Don't do "diversity". There are several sections in the Code that suggest that equipment running at less than full-load can be fed by less than nameplate amps. This is forbidden in other sections.

There are several sections in the Code that permit "overloading" a feeder for non-coincident loads (not on at the same time). If you read the wording closely they almost never apply. If you have two pumps, you must lock-out the second while the first is operating. No Process Engineer is ever going to agree to this. He wants a lead-lag connection so the second pump comes on when the first can't keep up with the load (and is probably fouled on the impeller). There is a section in cranes that has been quoted for reduced supply capacity. It only applies to cranes.

The correct way is to size your motor control center for the expected loads, plus a reasonable future capacity, then size the feeder to the motor control center by the nameplate you chose for the motor control center. There is a hidden "diversity" here, but you are following the exact wording of the Code.

Similarly, when you size the main distribution panel for a building, you do not sum the installed circuit breakers and use that for the main. We know that it is rare for a feeder to run at 50% load and less than 20% is common. This has been verified by field measurements consistently for many decades. After you tell the Utility you have 500kVA of load, they have you share a 200kVA transformer with the next guy in the industrial part. They know and they don't have to follow the NEC.

Section 314.21 forbids a crack more than 1/8-in wide around a recessed electrical box. This is a wonderful explicit measure of craftsmanship that the Contractor must respond to, per the Code. When you see un-patched cracks, go to the roof and inspect the liquidtight flexible steel conduits to the HVAC equipment. Unless they are supported properly (within 6-in of box) they pull out the first time snagged by a ladder. Another craftsmanship issue. Also look inside electric panels to see if the outgoing conductors are "trained" within the gutterspace. This has been good practice for years, but is now required by 210.14.D

Article 404 Switches

Article 404 discusses switches, mostly light switches. There are rules which must be followed but no hidden problems for the designer. Unfortunately, the 2008 NEC does not address a very real problem in lighting control - energy conservation.

Most States have an Energy Code and many construction projects are seeking LEED certification. The result is that the electrical designer who does lighting control must consider daylight harvesting, dimming, motion detectors, BAS override, emergency override, janitorial override and more local switches than he would like. Why? One State Energy Code explicitly requires a daylight harvesting controller with a local photocell and an analog dimming command to dimming ballasts. True, the only commands are 100%, 50% and OFF, but that Code mandates dimming controls.

There are three considerations on an energy conservation lighting design, as follows:

1) Copy the controlling requirements from the State Code or the LEED Manual and put it in the Construction Documents. You do this to help the later battle with a Construction Manager who sees a Value Engineering opportunity.

2) Find a well-documented product which is certified to the State Code or LEED and use their installation details.

And, or,

3) Let a lighting consultant or lighting rep do the detailed design to earn his commission.

Article 409 Industrial Control Panels

Article 409 discusses Industrial Control Panels, which have been interpreted to include Building Automation system (BAS) panels. Panels must be fed with a circuit rated 125% of the nameplate full-load current. The requirements for the 2008 NEC include a nameplate with the following six items:

1) Manufacturer identification. (Not easy when an OEM subs out fabrication. Check the titleblock on the shop drawings and installation manual).

2) Supply voltage, phases, frequency and full-load current for each incoming supply circuit. (Fabricators really don't like to look at separate control power sources they require or external signals that qualify as voltage sources.)

3) Short-circuit withstand. (Bussman has an excellent discussion on their website on why a substantial incoming protective device may not protect against a downstream fault. The reasoning is that a large industrial machine may have a full-load current so high that an impedance-limited downstream fault is less than full-load and just sits there and burns.)

4) Service entrance sticker if used as service entrance. (It is common for a motor control center at a remote pumphouse to use its main as the service disconnect switch.)

5) Electrical wiring diagram.

6) The NEMA enclosure type number.

Please note the following three significant items missing from the NEC requirements:

1) Prominent identification of each entering energized conductor. The Code recognizes multiple sources and requires external disconnects for each, but does not include notification INSIDE the enclosure as to the locations of each. A good control panel spec calls out a color, usually yellow, for energized external wiring. A good control spec calls for prominent labeling of each incoming power connection block

2) "Touch-safe connections". This is an IEC standard and can be provided by all major US suppliers. It looks like a bolt-on Lexan cover. Again, the Big Guys who buy a lot of panels put it in their spec. Be especially careful on door-mounted pilot lights. Old-style oiltight 120V pilot lights have big terminals on the back and the fabricator may even have loose conductor strands sticking out. Not nice to back into while you are noodling a controls problem.

3) Use of a sub-panel and adequate wireways. NEMA figured this out many years ago. UL certainly knows. Established panel fabricators know. New engineers, just out of college don't know and a firm just starting out in panel fabrication may see a Value

Engineering opportunity. Controls devices should be mounted on one or more sub-panels which bolt into the main enclosure and each carry a grounding conductor. There must be room to bring in a bundle of control conductors - make a 90-degree bend - and fan-out to the controls devices. A line in the purchase spec gives you something to talk about when you review the shop drawings or first take delivery and don't like what you see.

Section 410 Lighting Fixtures

Section 410 is about lighting fixtures, mostly residential. Please consider the following field-test data regarding industrial fixtures.

I wondered why I was getting advertisements for $13 jelly-jar maintenance lighting fixtures. I really, really like jelly-jar maintenance fixtures, with a screw-in compact fluorescent light source.

So, I bought six fixtures from major US (sic) manufactures, mounted them on a 2x6 and smashed them in turn with a baseball bat.

The $13 unit is worth $13. The $65 Hubbell unit is worth $65. It is the only unit to survive the "standard whack". The "whack with extreme prejudice" broke the guard and globe, but left the base intact (the only intact base in the series).

The test sequence was recorded with still and video cameras. It is exactly what you would expect - not very interesting except how far the glass and guard pieces flew.

Section 410.30 relates to pole-mounted outside lighting fixtures. There several little-known requirements, as follows:

1) A non-hinged pole must have a hand-hole giving access to the incoming conductors and ground lug. A hinged pole still needs a ground lug.

2) You can put a security CCTV camera on a light pole but you must maintain separation between the power and low-voltage conductors. The Code vaguely suggests a raceway or cabled power conductors instead of loose conductors. It also mandates vertical support of all conductors, per Section 300.19.

3) It is good design to provide a local ground rod for each light pole. Some state highway departments require two ground rods for each pole.

4) Metal-halide lamps must have a lens. The Code reports fires from arc-tube failures.

5) 410.130 requires individual disconnects for non-dwelling fluorescent fixtures. This is easy if they are plug-connected, as the plug is a qualifying disconnect. Perhaps the manufacturer will start putting a Molex pull-apart connector on the power leads, inside the enclosure. This would be a lot cheaper than a switch. I haven't seen them in commercial fixtures yet, but they are common on high-bay industrials and roadway lighting.

6) 410.141 requires locking disconnects or disconnect within view of the fixture for outdoor electric discharge lighting over 1000V at the lamp.

7) Section 600.6 requires a disconnect with locking means on outside signs. This has been a local requirement for many years, but goes national with the 2008 Code.

8) Section 600.21 says that a (neon sign) ballast located in an attic or soffit requires a worklight.

Section 430 Motors

Section 430 is about installing motors. Nothing much has changed for 50-years and contractors are still skipping local safety disconnects and it is still rare to find labeling identifying the voltage, load served or power source. Worse, firms with strong specifications accompany them with un-readable alpha-numeric sequences which are supposed to communicate. I feel very differently about a 208V Size 1 motor starter and a 480V Size 1 motor starter. Actually, most interpretations of OSHA arc-flash regulations feel very differently about 208V and 480V.

Article 445 Generators

Article 445 discusses generators. The world is presently changing rapidly and generators are being used differently than they were 10 years ago. Important considerations are different than they were 10 years ago. The products are much better than they were 10 years ago.

This is very bare-bones requirements for safe installation of a generator. We will address emergency systems later, in Article 700.

Sidebar Discussion on Advances in Emergency Generators
There are many specialty areas in electrical design which can be handled by letting the vendor help you work through the project needs and write the specification and, sometimes, provide the installation diagrams. Generator specification is a topic that lends itself to heavy reliance on the vendor. Even if you have your own spreadsheet to total the loads and consider starting requirements, it is good to have the vendor verify it - either informally before bid or as part of the procurement specification. We got into a discussion this week about an emergency power generator for a biological treatment plant. It needs two 60HP pumps in continuous operation or the bugs die. The Process Engineer was proud that we wouldn't have to upsize the generator for harmonics from variable frequency drives - he wanted fixed-speed pumps. We answered that we agreed. Now we only have to upsize the generator to provide starting inrush for the second pump after the first pump has started. In the last ten years, the generator manufacturers have embraced electronic controls for the generator and switching. This has produced reliable zero-crossing power switching and reliable power-line paralleling (though the Utilities are very slow to accept it). Many engineering specifications still contain paragraphs on third party exciters and relaying. This is not needed or possible any longer. I like the idea of a vendor switching out a

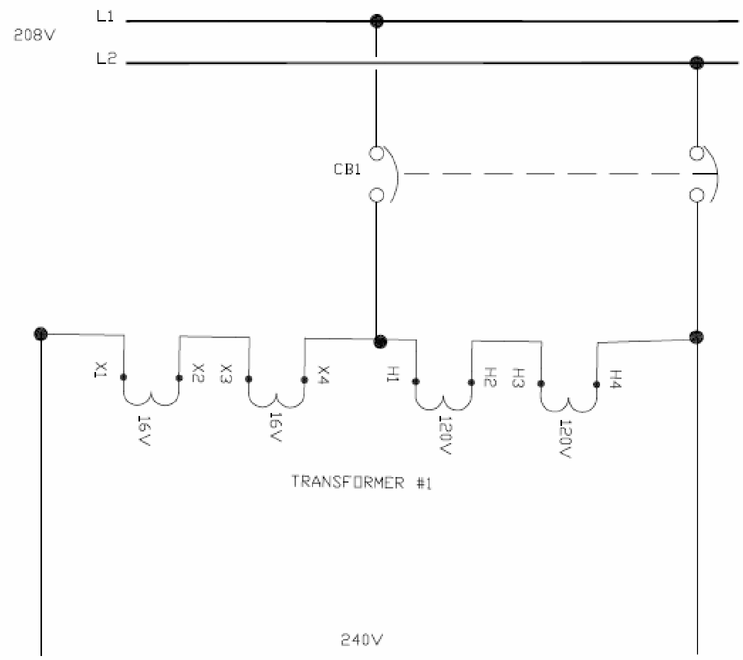
module during warranty rather than everyone trying to figure out which part is malfunctioning.

Section 450 Transformers

Section 450 discusses transformers. The hard part of specifying transformers is to provide protection but not trip out on inrush. The Code addresses this in many and confusing ways. For small, general-purpose transformers, the manufacturer will give you a table of recommended protection. Ignore this at your own risk. The NEC requires UL listing, which includes the requirement of installing the equipment per the manufacturer's instructions.

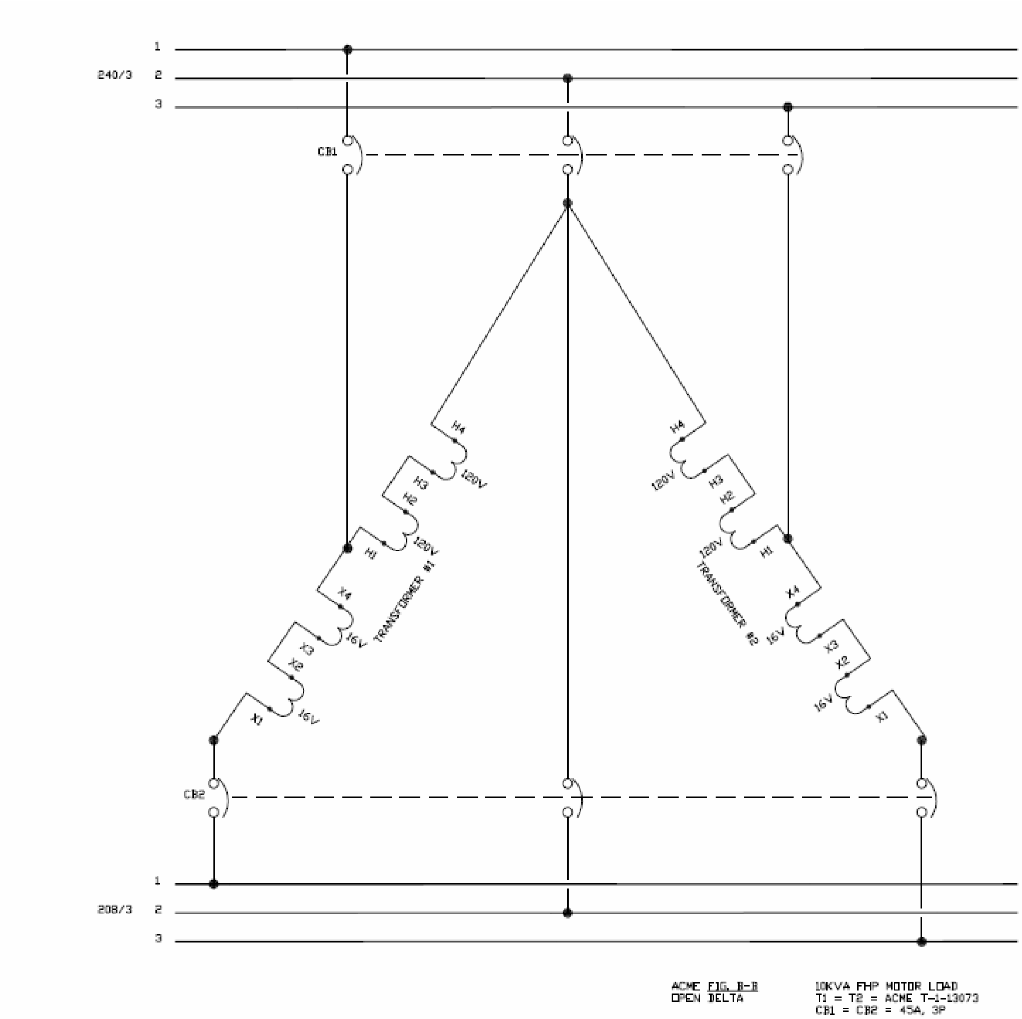
For larger transformers, perhaps 30kVA and larger, the inrush is a bigger problem and the hardship of a false-trip is bigger. Table 450.3.B requires maximum 125% protection on the secondary (separate protective or main on downstream panel) and maximum 250% protection on the primary.

Section 450.4 presents autotransformers. Autotransformers are sufficiently confusing that a separate PDHonline course is offered on connecting 230V motors on 208V systems using an auto transformer. Surprisingly, a properly sized autotransformer does not need separate protection. It is a series element. If the supply is sized for the load and the autotransformer is sized for the load, no extra protection is required. Two illustrations from PDHonline Course #E-162 are included below:



SINGLE PHASE BUCK–BOOST TRANSFORMER CONNECTION DETAIL

2.5KW HEATER LOAD
T1 = .75KVA, 120/240-16/32V
CB1 = 20A, 1P



THREE-PHASE BUCK-BOOST TRANSFORMER CONNECTION DETAIL

Section 460 Capacitors

Section 450 discusses capacitors. During the first energy shortage, ~1973, building owners became exited about energy savings and monthly billing savings by installing power factor correction capacitors. Ten years later, most of the installations had at least one leg open, due to a blown fuse. This does bad things to the electrical system, but nobody cared then or now.

The Code gives rules for installing power factor capacitors. Vendor guides give very detailed instructions for sizing and installing them. Nobody emphasizes the importance of maintenance.

Large industrials may require individual capacitors for each large motor or buy step-capacitors with controllers for installation at the motor control center or substation. Both are good plans. A fixed capacitor at the motor control center or substation will cause leading power factor when the plant is down. This can be very bad.

Article 470 Resistors and Reactors

Article 470 discusses resistors and reactors. Both are a little exotic in today's plants. Formerly, DC motors had resistors for the armature and for the field. Today, you occasionally see resistors for dynamic braking on variable frequency drives. They are part of purchased equipment and require no special care beyond following manufacturer's instructions than making sure you can reject the heat from the electric room (thermostatically controlled exhaust fan).

Reactors were once offered in place of the more expensive isolation transformers for variable frequency drives. Today, most variable frequency drives are direct-connected to the supplying branch circuit. Reactors remain a component on the load-side of variable frequency drives, to limit high-frequency ringing on motor leads.

Application guides and application specialists are ambiguous on specific cut-points for the addition of motor reactors. I recommend a 3% reactor in each motor leg on lead-lengths in excess of 30-ft. This will help on IEEE-519 harmonic mitigation. A 3% reactor on each drive incoming leg will help even more.

Section 480 Batteries

Section 480 relates to batteries. Be aware that sealed lead-acid batteries perform well and require minimal safety accommodations, beyond short-circuit and overcurrent protection and disconnects. Vented lead-acid batteries require considerably more spill containment and ventilation. Exotic chemistries are being commercialized daily and will become part of our lives during the next decade.

Chapter 5, Hazardous Locations

Chapter 5, Articles 500+, discusses hazardous locations. This deserves close attention, beyond the scope of this course. If you are new to designing electric power, controls and lighting in hazardous areas, a good starting point is the application guides from Crouse-Hinds and Appleton. The only consistent error I encounter in the field is ignoring the Div 2 buffer between Div 1 and non-hazardous areas. Typically there should be a 3-ft buffer - just where Architects put the light switch. (Must be an explosion-proof switch, even though outside the Div 1 hazardous area.)

Article 517, Health Care Facilities

Article 517 discusses details of health care facilities. It is grouped under hazardous locations because of explosive anesthetics and oxygen. There are a wide range of special health care requirements - in the NEC, in IEEE publications and in government publications relating to licensing the institutions. Your author has no experience in these areas to share.

Article 518, Assembly Occupancies

Article 518 relates to assembly occupancies. For the most part, this means spaces intended for 50 or more persons (per the International Building Code, but, 100, per the 2008 NEC and in some cases, 30 or more persons). The National Electric Code

Handbook includes a table to convert room sq-ft to expected occupancy. For "Concentrated use, without fixed seating", the number is 7 sq-ft per person. A typical classroom is 900 sq-ft. Without furniture, this computes as 900 / 7 = 129 persons. Thus, an empty classroom in the basement that is kept empty as a tornado shelter is a Place of Assembly for the Building Code and National Electric Code. This invokes special exit requirements that usually aren't met by classrooms.

A quirk of both the Building Code and NEC regards stages. If a permanent stage is present, the space is automatically deemed a place of assembly and NEC 520 applies. If portable risers are used, it may still be a place of assembly, but special fire rules for theaters and NEC 520 do not apply.

Conference centers are a special problem, because individual vendor booths usually want power and temporary flexible cords can be trip hazards, beyond fire hazards. The NEC responds to this with in-floor heavy-duty receptacles, temporary power distribution units which may be 480/3-in and 208/120 panelboard-out. A treadle (hard rubber short ramp over floor flexible cord) is illustrated in the National Electrical Code Handbook.

These temporary power distribution methods are also very appropriate for outdoor "River Walks", multi-use park spaces, being installed in many urban areas. Music festivals, food concessions and wedding platforms can be accommodated in a first-class manner, leaving little afterwards for vandals' attention.

Nonmetallic raceways (conduit and surface raceway) are forbidden in places of assembly. Most computer classroom upgrades may be non-conforming. One major manufacturer of combined surface raceway, for power and data, does not sell a metallic product. All they have is non-metallic. This is not appropriate for large computer labs.

This course is not addressing theaters, carnivals, amusement parks, manufactured buildings, projection rooms, tv or motion picture studios, agricultural buildings, mobile homes, floating buildings, marinas or temporary installations. Each is addressed with special requirements by the 2008 NEC.

Chapter 6, Special Machinery

All of Chapter 6, Special Machinery, is not covered by this course. These sections include electric signs, modular office furnishings, cranes and hoists, elevators, electric vehicle charging, electrified truck parking spaces, electric welders, audio signal processing, information technology equipment, electronics, induction heating, electrolytic cells, electroplating, industrial machines, irrigation, swimming pouts and fountains, photovoltaics, fuel cells and fire pumps.

Note that several of these are emerging technologies, being sold and installed by market-oriented firms rather than technology firms with a deep safety ethic. Both photovoltaics and fuel cells involve extremely high DC currents, and, disconnect switches, protective devices and raceways for conductors have been overlooked in many installations. The National Electric Code does apply and your author's interpretation is that a building permit, plans review and Electrical Inspection should be associated with each.

Chapter 7, Special Conditions

Chapter 7 has become a strange animal in the 2008 National Electrical Code. The present name is “Special Conditions”. As in previous editions, it contains requirements and prohibitions for emergency systems, legally required standby systems and optional standby systems. Originally, this meant generators and wiring between emergency generators and emergency loads. These requirements and prohibitions are still present, elaborated slightly, but the big change is the addition of a new class, “Critical Operations Power Systems (COPS)”. COPS requirements are more stringent than life-safety systems, but the Code is very ambiguous under what conditions this section applies.

I was doing electrical design for a large municipal central security monitoring facility, which, incidentally, was to include all the billing computers for municipal services and utilities. The City decided this was not a Critical Operation, in the meaning of the National Electrical Code. (They also lost Homeland Security funding because it wasn’t underground.)

As suggested in the introduction, “Emergency Systems” are life-safety loads. You must purchase a generator set with emergency-system UL listing; it must start in 10-seconds; run for 90-minutes; the transfer switch must be UL listed for emergency system and all load wiring must be kept separate from general-purpose wiring.

Note that general-purpose loads may be fed by the generator, but they must have a separate transfer switch which automatically sheds when there is system trouble. NFPA recommends this use, believing that it is an incentive for generator installation and maintenance.

Because both emergency and general-purposes can be fed from the generator, there is no reason to distinguish emergency, legal standby and optional standby generators. Spend a very little more and get a premium installation capable of supporting emergency loads in the future, even if battery-pack emergency egress lighting is being used in the present project.

Article 705, Parallel Connections to the Utility

Section 705 of the 2008 National Electrical Code relates to (parallel) interconnection with Utility service. This is intended for co-generation installations for large industrials as well as vacation cabin photovoltaic arrays or wind-power or water-power generators. The reason for the interconnection is that cogeneration and eco-friendly generation typically do not meet all the load requirements, including start-up and maintenance. With utility deregulation, generation and transmission shortages and heavy ecological marketing, interconnection has been accepted by some utilities.

Note that this is a seriously bad idea for many reasons. First, Utility linemen repairing downed lines depend upon radio information and their dispatchers that the lines are dead. Yes, they can put on ground jumpers, and probably will someday, but a customer backfeed would be bad.

Second, most of the cogeneration and eco-friendly installations are "hobby quality". The Utilities are extremely careful about all aspects of their generation and switching. A paperboard mill that exports a few MW will not have the same level of maintenance or care. The eco-friendly generator installations I have inspected have been abominations. It is bad enough when the local battery storage faults, but when it is hard-connected to the utility, it can produce a really big flash. And, utility protection is from shorts. An arcing load fault at the end of a long secondary service line may not be picked up by the primary fuse feeding the transformer for the area.

Article 708, Critical Operations Power Systems

Article 708 introduces Critical Operations Power Systems (COPS). Two interesting requirements are that the generator must have a full-load test capability (implies load-bank). This need has been debated by engineers and salesmen for years. The information technology people appear to have agreed (see TIA-942). Now it is required by the National Electric Code.

The second somewhat interesting requirement is for shielding on all signal and communications cables. Shielding is somewhat new to economical local area data networks (strongly recommended for 10Gbps data rates). Shielding on telephone lines is totally outside your author's experience, but most telephone systems are migrating to voice over IP (VOIP), using the data system rather than dedicated wiring.

Surge protection devices are required at all voltage levels, including incoming and outgoing data and communications. This is becoming almost standard in commercial design, so is not a change, but is a check-off item before plans submission.

Article 725, Class 1, 2 and 3 Circuits

Article 725, Class 1, 2 and 3 Circuits. Class 1 circuits look and smell like power circuits except that 16AWG and 18AWG are permitted. Application is line-voltage remote control devices, such as pushbutton stations, limit switches and light curtains.

Typically, Class 2 and 3 circuits are usually part of a vendor-supplied system, as doorbell, annunciation, HVAC control or public address, but special mention is made of thermocouple and process instrumentation. The examples in the 2008 National Electrical Code handbook include data and telephone in section 725, but Chapter is dedicated to communications, with a lot of telephone and a fair amount of data cabling.

Class 1, 2 and 3 circuits must be identified as such at terminal and junction boxes.

Sidebar Discussion of Labeling Voltage Levels.
I take NEC requirements seriously. This section requires labeling low-voltage circuits. Previous sections require labeling each voltage level present in a facility. It is easy to buy 480V, 240V, 208/120V and 120V labels. It is near-impossible to buy 50V or 24V labels. Usually the low-voltage labeling requirement is met by indelible felt pen.

Article 760, Fire Alarms

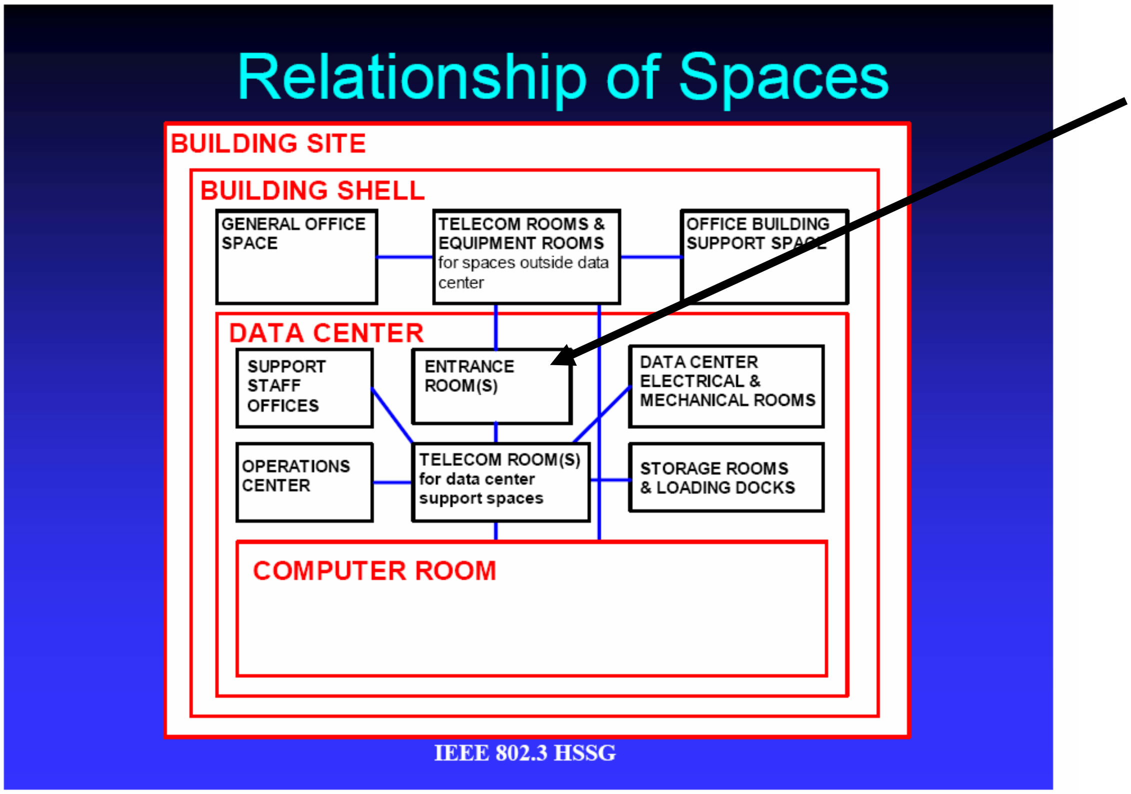
Article 760 refers to Fire Alarms. PDHonline offers a separate course exclusively dedicated to Fire Alarms (E207, NFPA 72). Because that topic is too important for a superficial review, your attention is drawn to the specialized course and it will not be addressed here.

Article 770, Fiber Optic Cable

Article 770 presents requirements and prohibitions regarding fiber optic cable. This is important because the standards usually followed in fiber optic installation, BICSI and TIA are enforceable only through the construction contract. The National Electrical Code is externally enforced by a public Electrical Inspector who has authority to stop work on the project and introduce substantial delays and associated costs.

Another very interesting aspect of the rules for fiber optic installation is that it reflects the transition of the National Electrical Code from concern over electricity starting the fire to cable insulation communicating the fire to previously uninvolved areas. The rules in article 770 relate to non-combustible cable jackets, removing abandoned cables and acceptable mounting to permit access for maintenance and fire fighting.

The only close relation of fiber optic cables to electric cables is the metallic external sheath or internal metallic strength member, which may be present. When present, it must be grounded to avoid transmission of lightning surges and maintain an equipotential environment for personnel safety. Grounding of fiber optic cable comes under the intersystem ground bus introduced by the 2008 National Electrical Code in section 250.94. Typically a #6AWG conductor from the fiber break-out point back to the ground bus is acceptable. There is wording requiring the ground be applied where the cable first enters the building, but exceptions permitting completing the run to the data entrance room in the data center. The TIA-942 recommends keeping access provider technicians out of the working data center – the entrance room is walled-off. The service areas are illustrated in the following slide put on the internet by cdiminico@ieee.org:



Sidebar Discussion of TIA-942
Several articles in trade publications have referenced the 2005 TIA-942 document. All favorable comments are endorsed here. It is a comprehensive, understandable, detailed standard for good data center installation. Mr. DiMinico's powerpoint presentation came back as an early hit on a Google search for "TIA-942". There are 36 slides which eloquently introduce the topic without watering it down. The entire document is 148 pages, available from tiaonline.org. An extremely valuable component is the extended table in the back which relates uptime qualification (Tier 1-4) to specific facility features. The content is fully understandable but not fully intuitive until you study the standard

The National Electrical Code Handbook includes a discussion of corrugated plastic fiber optic innerduct. A superior product I just discovered is MaxCell™ cloth data space separator. It permits use of up to 85% of a conduit cross-section. It is not used "loose" in plenums or cable tray. Following is a photo of conventional innerduct showing how it protects fiber optic cable and enforces acceptable bend radius:

Article 800, Communications Circuits

Article 800 presents requirements and prohibitions for communications circuits, meaning voice and data. The NEC carefully distinguishes between special permissions for information technology equipment and equipment rooms, covered by article 645 and the requirements of article 800. With the exception of underfloor flexible cables and flexible conduits, the requirements of article 800 generally apply. Remember, please, that many IT professionals choose not to use the special permissions of article 645 because they require shutdown of power and hvac. In addition the NEC specifically excludes telephone switching rooms operated by the utility.

The rules of article 725 for low-voltage control wiring are almost identical to the communications wiring rules in article 800. A special case, worthy of your attention is POE, power-over-ethernet. This is a relatively new IEEE standard, accompanied by products in the marketplace and rapid adoption. The data switch in the data center or remote network closet provides 48 VDC over existing or new 4-pair twisted pair data cable. It is severely power limited, but capable of powering several remote data switches or IP TV cameras with infrared illuminators. None of the NEC or TIA rules change for POE, but it should change the way we view data cabling.

Data and telephone grounding follow the preceding discussion of grounding for fiber optic cables. Ground the metallic sheath and provide surge suppressors where the cables enter the building.

This course will not address the remainder of Chapter 8, radio and television equipment, CATV distribution and network-powered broadband communications systems.

The 2008 National Electrical Code also contains tables, product standards, sample calculations, conduit fill tables, types of construction, supplementary information on COPS and SCADA and a section with sample forms for administration and enforcement. These topics are not addressed here.

[eof]