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BASICS

The Basics of Industrial Control Panels

A closer look at NEC Art. 409, which provides the minimum safety requirements for industrial control panels

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Article 409 provides the minimum safety requirements for industrial control panels (**What's an Industrial Control Panel?** below). Because this section of the Code is only a couple of pages long, it isn't that comprehensive. However, Table 409.3 lists more than two dozen other Articles that may apply to a given control panel, which definitely broadens its scope.

The NEC is primarily concerned with the hazards arising from the use of electricity, not the myriad of other issues that arise with industrial control panels. Thus, some things allowed by Art. 409 aren't optimal (**What Purpose Does it Serve?**). When there's a controls malfunction, the cause is unlikely to be an Art. 409 violation, unless the problem is of the "where's that smoke coming from?" variety.

Standards other than the NEC also apply to industrial control panels. Two that always apply are UL 508A, "Standard for Industrial Control Panels, and NFPA 79, "Electrical Standard for Industrial Machinery." NECA, NETA, and IEEE also have produced applicable standards for design, installation, testing, and/or maintenance. One more reference is critical. When industrial controls exhibit intermittent operation, a common cause is non-compliance with Art. 250 Part V (bonding). So make sure to build that compliance into your design and installation specs. Let's take a look at some specific guidelines.

Typing, sizing, and siting

Using Table 110.20, select the type of enclosure based on the intended environment. To determine the enclosure size, rough out its back planes, termination strips, and major component locations. Allow for enough space to install and wire these items with proper routing and bend radii.

An overlooked issue with larger control panels is the need to power test equipment and appliances, such as vacuums used for maintenance. Rather than ensure the need for extension cords, add sufficient receptacles at convenient locations, and allow for these in your rough layout. But don't place the order just yet. Work with your electrical distributor to see what standard offerings are closest to what you need. This collaboration can produce significant savings in cost and delivery.

If your panel is moderately complex, then you may have the option of “supplier engineering.” Don't try to save money by not purchasing this. Have the supplier engineer the panel once rather than redoing it in the field while under pressure from management to “get this thing going.”

Once you have the panel designed, you must figure out where to put it. Determine the outside dimensions and the swing requirements of cabinet doors. To reduce maintenance inefficiencies and other hidden costs during operation, allow enough room for a test cart to roll across the area with those doors open.

Control panels often are near the process area. A high ambient temperature may require a ventilation fan or even air conditioning on the cabinet, both of which will have filters that require maintenance. Other circumstances may dictate adding a heater or dehumidifier. Locate the air intakes and exhaust vents for easy filter replacement and ensure there is no process interference; having a cabinet vent suck in air off an aluminum melting pot is generally not helpful.

Supply conductors

Figuring out the ampacity for the supply conductors can be confusing unless you break down the requirements into the following discrete steps:

1. Calculate the full load current (FLC) rating of all resistive loads.

2. Add to this 125% of the FLC of the highest rated motor.

3. Add to this the sum of the FLC of all other connected motors and apparatus, based on their duty cycles and based on what will be operating simultaneously.

On the third step, the process might make the operation of various apparatus mutually exclusive for any number of reasons (e.g., Operation A must occur before Operation B). Allow for the highest load that would occur.

Overcurrent protection

You can either put overcurrent protection ahead of the panel or put a single main overcurrent protective device (OCPD) in the panel [409.21]. Which way is better? The answer depends on many factors. One reason not to locate OCPDs in the panel is that you want to minimize the opening of the panel because of the process environment. Don't confuse OCPD functionality with disconnect functionality. You don't have to co-locate these. For the disconnect, just apply the requirements of Part IX of Art. 430.

The rating of the OCPD for the panel must not be greater than the sum of:

- 125% of the FLC of all resistance heating loads.

- The sum of the FLCs of all other equipment that could be in operation at the same time.

- The largest rating (or setting) of the branch circuit and ground-fault protective device provided with the panel.

If the panel doesn't come with a branch circuit and ground-fault protective device, use 430.52 and 430.53 as applicable.

Short circuit current rating

The NEC requires marking every panel with its short circuit current rating (SCCR) [409.110)]. Listed components and assemblies have the SCCR marked on them. Unless you're buying a listed control panel assembly — and that's unlikely — you must determine the SCCR of the panel and mark it accordingly. But how?

UL 508A contains an example of an approved method of SCCR determination [409.110 FPN], but you can use a simpler method. The SCCR is really the withstand rating of the device or assembly [110.10]. This means that, like the weakest link in the chain, the device with the lowest rating limits the entire assembly to that rating. The control panel SCCR is the SCCR of the lowest-rated device in the enclosure. *Caution*: Make sure the SCCR is adequate for the available fault current.

Grounding

Don't ground this panel. Although its title is “grounding,” Sec. 409.60 provides the requirements for bonding (see Art. 100 definitions). Make sure there's no difference of potential between enclosure parts and any nearby metallic objects. Install an equipment grounding (bonding) conductor or grounding (bonding) bus sized per Table 250.122.

If the panel is part of a manufactured system, the manufacturer may require an “isolated ground” as a condition of warranty. The intended meaning of this often isn't the same as that defined by the NEC or IEEE-142. If the manufacturer requires driving an “isolated” ground rod, that's an unenforceable condition of warranty because of its underlying illegality. Nobody can require a code violation as a condition of warranty. This “isolated” ground rod idea is based on the misperception that electricity seeks the path of least resistance, instead of being subject to Kirchoff's Law of Parallel Circuits. In fact, such an installation ensures the very failures it allegedly prevents. Follow accepted engineering practices, not arbitrary requirements based on voodoo physics. See Art. 250, Part V for how those practices apply to equipment bonding.

Workmanship

In a cabinet installed with good workmanship, the wires are neatly bundled, run in gutters or similar supports, and routed with smooth radius bends — and all terminals, wires, and components have identification labels.

A good labeling strategy saves time and reduces errors in terminating, testing, maintenance, and repair. Don't use handwritten labels. You can choose from many available labeling solutions to produce legible, durable labels in an efficient, cost-effective manner.

To the extent possible, run power, control, and signal wiring in separate bundles/gutters, even if that means using more wire. This will improve noise immunity, reduce troubleshooting time, and make future changes easier.

Maintenance

Article 409 doesn't address control panel maintenance, but common sense says a small amount of maintenance provides huge gains in reliability. Some basic things that need to be in the preventive maintenance procedures include:

- **Pest control**

  This may consist of a rodent trap in one corner. Whatever method, ensure it's inspected periodically.

- **Dust control**

  Vacuum the accumulated dust off the cabinet floors. If conditions require vacuuming anything else, remember it's an energized cabinet — follow the applicable procedures. Don't vacuum near circuit boards without following electrostatic discharge (ESD) rules.

- **Connection control**

  It seems counterintuitive, but re-tightening terminal screws causes loose connections. Instead of inadvertently over-tightening terminal screws (consequently diminishing their clamping power), use an infrared gun to see which terminals are high resistance. Disassemble, clean, and reassemble.

- **Insulation**

  An insulation resistance testing program is the best way to prevent wiring failures.

By taking a few extra steps in the selection, design, and installation of an industrial control panel, you can ensure it will have no failure time bombs ticking away. With a modest maintenance program, it will be nearly problem-free for its entire life.

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Sidebar: What's An Industrial Control Panel?

For NEC purposes, an industrial control panel operates at less than 600V and consists of power circuits and/or control circuits. A control circuit provides the signals directing the performance of the controlled equipment but doesn't carry the main power or include the controlled equipment. The “panel” part means the control system is mounted on (or in) an enclosure or subpanel [409.2].

Sidebar: What Purpose Does it Serve?

The NEC allows you to use the control panel as a junction box for other wiring or systems [409.104(A)], if you provide ample space for this purpose. However, such a design sacrifices modularity, complicating maintenance and making inductive noise and other problems more likely. Double duty seldom saves much money up-front and may create huge costs later.