Automation NOTEBOOK®

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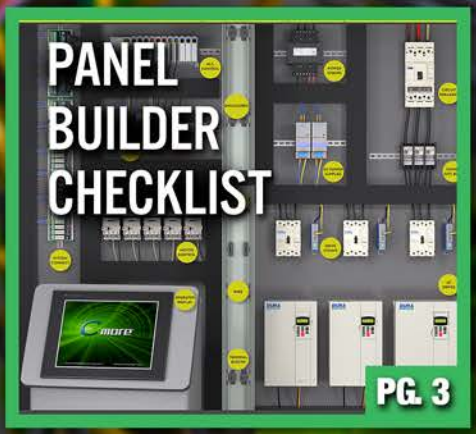
AVOID WIRING ERRORS PG. 7



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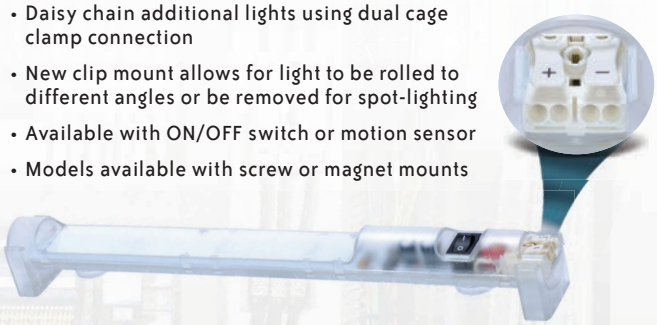

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PANEL BUILDER CHECKLIST

Building the Electrical Control Panel

There are many things to consider when building an automation control system. Some control systems are extremely simple, like a pump control system that consists of a pump, level controller, and a contactor, or they can be complicated and control a full production line with a series of sub control systems. No matter the complexity, control systems consist of sensitive electrical instrumentation, connections and devices that need protection from environmental factors.

Most often, an electrical enclosure or panel is used to shield the control devices from natural elements like rain, snow, heat or cold, as well as chemical, water or corrosive liquids. Enclosures also ensure the system is safe from accidental contact with personnel, and from being affected by hazardous conditions in the area where they are used.

Enclosures come in many sizes, shapes, materials, and specifications that allow a system designer to select the safest and most cost-efficient enclosure for their specific application. Once the enclosure is selected, a panel builder installs the components, devices, and wiring according to the specifications provided by an engineer and/or current electrical code(s) (NFPA 79 for instance).

A Panel Builder's Component Checklist

To give an idea of the many components, equipment, accessories, and devices available to complete an automation control system and that may require installation in an enclosure, we are providing a list of possibilities as a reference. This list is a starting point and can grow depending on your specific project.

Also, the graphic below is available online and has links to more information for each of the panel components shown.

To view, visit:

www.automationdirect.com/panels

Panel Builder / Designer Checklist:

☐ **Enclosures:** Safely enclose components/devices. Available in a wide range of materials, mounts, dimensions, styles, and NEMA ratings (see more about NEMA ratings on Page 4).

☐ **Thermal Management:** Provides ideal conditions inside enclosures to prevent component overheating and/or condensation.

☐ **Wiring/Accessories:** These include wires, terminal blocks, connectors, glands, conduit, wire ducts, and cable ties.

☐ **Electrical Power Devices:** Such as transformers, power monitors, panel meters, power distribution blocks, power supplies, surge protectors, and power line filters.

☐ **Cables:** Facilitate communication and control signals (i.e., cables for encoders, sensors, monitors, drives, solenoid valves, motion control, PLCs, HMI, PCs and more).

☐ **Circuit Protection:** Protect electrical components and/or devices via ON/OFF controllers, disconnects, circuit breakers, and fuses.

☐ **Control and I/O Devices:** Provide automation functions as needed for an application. Examples include PLCs, Field I/O, and PC-based Control.

☐ **Process Control and Measurement:** Controllers or sensors that continuously monitor changing variable data and may use it to control devices in a system. For example, a temperature controller.

☐ **Motor Control:** Provide electrical control for motors via a soft starter, variable frequency drive, motor starter, motor disconnects, or contactors.

☐ **Communication Devices:** Ethernet switches, gateways, VPN routers, and serial communication devices that provide communication between components and devices.

☐ **Drives:** Control motor speed, torque and direction.

☐ **Operator Displays:** Includes HMIs and industrial monitors used to display system conditions and can provide functions like turning a device ON or OFF.

☐ **Motion Control Devices:** Control systems with accurate position/velocity/torque capabilities operating in open or closed loop modes. Examples include gearboxes, servo and stepper systems.

☐ **Pilot Devices:** Provide ON/OFF controls, system selectable options, status indication, and more. These include switches, pushbuttons, indicators, stack lights and audible signaling.

☐ **Relays and Timers:** Provide simple control or power conversion for many automation systems.

☐ **Safety Devices:** Ensure personnel/equipment safety to protect lives and equipment damage. Some examples are Emergency Stop pushbuttons, enclosures with locking mechanisms or with Lockout/Tagout hardware, and grounding systems.

Learn more about designing an automation control system from the "**Automation Control System Specification, Design and Installation**" article in this publication on Page 6.

WHAT DOES A NEMA RATING MEAN?

By Jim Krebs, Engineer and Technical Marketer, AutomationDirect

NEMA rating is one of those standards that is at times misunderstood or even ignored. However, it is an important specification that must be considered when buying a NEMA rated product to ensure the safety of personnel and equipment. For this post, let's use enclosures as an example of a NEMA rated product.

NEMA rated enclosures are designed to house all kinds of electrical components from simple terminal blocks, to industrial automation systems, to high voltage switchgear. Other uses include industrial applications to house motor controls, drives, PLC/PC control systems, pushbuttons, and termination systems. These enclosures are specifically designed to meet the National Electrical Manufacturers Association (NEMA) standards for performance and protection of the electrical equipment installed within them. All NEMA enclosures are given a NEMA rating according to the types of applications the enclosure serves. These ratings are based mainly on the conditions to which the enclosure will be exposed.

In my experience with industrial facilities and suppliers, I have seen a number of installations where enclosures were not properly selected for the service they're supposed to provide. I have heard people say, "I don't care about the NEMA rating, I just need an enclosure to put some equipment in". If this statement is true, then you could actually just get a cardboard box or a plastic sheet and cover the equipment, instruments or wiring. But of course, that wouldn't be good enough, it would be dangerous, and whatever it is you're trying to protect will probably not last very long.

Now, let's think about the real reason you might shop for an enclosure. Maybe you just have a small number of electrical connections with a few breakers, perhaps some type of meter. My guess would be that the first thing you would try to protect is facility personnel from serious or fatal injury by accidentally touching the electrical wires and/or connections. Well, if you take a peek at the table for NEMA classifications included on the following page, NEMA 1 reads, "provides a degree of protection against incidental contact with the enclosed equipment". Congratulations! Now you know you need at least a NEMA 1 rated enclosure.

If you noticed, I said at least. This is because you need to determine if all requirements to safely and properly protect your equipment and personnel have been met. So, let's assume that the other conditions to consider are that the enclosure will be located outdoors and because of this, it will be subject to rain, windblown dust, maybe sleet and possibly some ice formation. If you look at the table, you just upgraded your enclosure from NEMA 1 to at least a NEMA 3. However, maybe the conditions are hazardous or corrosive, there

NEMA Type	Provides a degree of protection against...
1	Incidental contact with the enclosed equipment
2	Small amounts of falling water and dirt
3	Windblown dust, rain, sleet, and external ice formation. Intended primarily for outdoor use.
3R	Falling rain, sleet, snow, and external ice formation when used outdoors, and for dripping water when used indoors. Typically used for wiring and junction boxes.
3S	Windblown dust, rain, sleet, and provides operation of external mechanisms when ice laden. Intended primarily for outdoor use.
4	A pressurized stream of water where an occasional washdown or where machine tool cutter coolant is used.
4X	Corrosive materials and caustic cleaners. These enclosures are made of stainless steel, aluminum, fiberglass, or polycarbonate and used for food, beverage, and applications where total washdowns with disinfectants occur repeatedly.
5	Settling airborne dust, falling dirt, and dripping non-corrosive liquids. Intended primarily for indoor use.
6	Water entry during a temporary submersion at a limited depth. Intended for indoor and outdoor.
6P	Water entry during a prolonged submersion at a limited depth. Intended for indoor and outdoor.
11	Temporary oil submersion and the corrosive effects of liquids and gases. Intended primarily for indoor use.
12	Falling dirt, dripping non-corrosive liquids, airborne contaminants and non-pressurized water and oil. Commonly used for indoor applications such as automation control, drives systems, packaging, material handling and manufacturing applications.
12K	Dust, falling dirt, dripping non-corrosive liquids (except at knockouts). These are enclosures with knockouts intended for indoor use.
13	Dust, spraying of water, oil, and non-corrosive coolant. Intended primarily for indoor use.

are chemical fumes, or the atmosphere is humid, and you want to ensure none of these affect the components in the enclosure. Now you need a higher rated NEMA enclosure.

We can keep going but hopefully you can see the importance of selecting the appropriate NEMA rated enclosure for your specific use and conditions. It is critical that you read the description of the NEMA ratings and select the best one that applies to your requirements.

Your enclosure's primary function is to protect the equipment enclosed inside from the surrounding environment and personnel from the hazards within the enclosure. Therefore, you need to understand the environment where the enclosure will be located and select the appropriate level of protection. Keep in mind that it is just as important not to over-specify the protection level of your enclosure as it is to under-specify, as increasing the protection level typically increases the cost of the enclosure.

Also, remember that there are other factors to consider when selecting an enclosure; you can find more information about enclosures and accessories in our website's "**Enclosures**" category and at our library in the "**What to Know When Selecting an Enclosure**" post.

AUTOMATION CONTROL SYSTEM SPECIFICATION, DESIGN AND INSTALLATION

Electrical control systems are used on everything from simple pump controls to car washes, to complex chemical processing plants. Automation of industrial machinery, tools and more has increased productivity and reliability in all areas of manufacturing, utilities and material processing. When an operation or process used to produce an end product is very laborious, time consuming, and produces inconsistent results, automating the process reduces manual labor, improves throughput and produces consistent results.

Whether you have the skills to develop the system or use a qualified System Integrator, it is always beneficial to understand automation control system devices and their terminology to ensure development of a system that will run efficiently and prevents any injury or damage to equipment. The most important topics to understand include:

- **Safety**
- **Identifying an operation or process that could benefit from automation**
- **Control device specification**
- **Control system design and construction**
- **Control system installation**
- **Control system maintenance**

The most important item to consider before attempting an automated control system, or even a simple on/off control for a pump, is safety, both for personnel who may be working with or near the automated equipment, as well as to prevent damage to the equipment. To minimize the risk of potential safety problems, you should follow all applicable local, state and national codes that regulate the installation and operation of your control system, along with the equipment or process it is designed to control. You should also consider lockout/tagout procedures as specified by Occupational Safety and Health Administration (OSHA). Safety should always be the most important consideration with every step of the automation control system design.

The first step to configure an automated control system is to identify what machines, procedures and processes can be automated. A good understanding of basic electricity, safety, hydraulics, pneumatics, mechanical operating mechanisms, electronics, control sequences, etc. is extremely important. It is also important to have a solid knowledge of the operation or process that you are going to automate.

The next step is to specify the various devices required for controlling the equipment in an automated system. Your specifications need to include not only the "controlling" devices for your application, but also items such as the housing or enclosure for the devices, the type of wire required to meet the various codes, agency approvals required for safety and insurance purposes, environmental conditions, etc. The first skill we need to develop in this effort will be the gathering of all the equipment parameters and specifications needed to specify the devices required to control the equipment.

Then you may proceed to the design of the automated control system, which includes planning by defining our sequence of operation, creating a schematic with the devices shown in a high-voltage to low-voltage order, input to output design layout, panel layout, wiring diagrams, bill of materials, software tools to document our design, choices between using hard-wired relays versus a PLC with programming, etc.

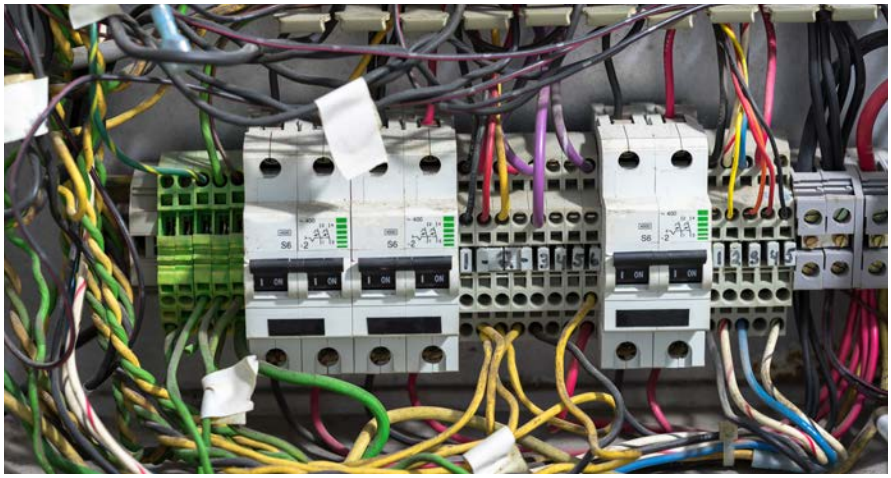
With the design portion ready, we can jump to the steps needed to build, start up, and maintain the automated control system. To build the system you will need tips on the use of a subpanel, terminal blocks, grounding, shielded cable, etc. You will also need to know steps to start up the system so that it is brought online in a safe and logical manner, and you will also need some suggestions for developing a plan to maintain the control system.

To properly design an automation control system, it is important to be familiar with all the items mentioned above. Be sure to have the knowledge of every facet of an automation system or to hire a System Integrator that will help you design a safe and efficient system. For more information on how to specify, design, install and maintain an automation control system, check out our **Condensed Guide to Automation Control System Specification, Design and Installation** whitepaper at **library.automationdirect.com/white-papers/**

AVOID WIRING ERRORS

By Peter Welander, Industry Consultant

Following a few basic standards and using the right terminal block systems when connecting and terminating wiring in the field and in control enclosures will ensure proper operation and simplify troubleshooting.



In a Control Design September 2018 Automation Basics column titled "Terminate the Rat's Nest", author Dave Perkon gets right to the point when he writes, "For those who think it's okay to open a control enclosure and see a monochromatic rat's nest of wires without any wire labels, you should be aware, that's worst-case practice."

To make sure this doesn't happen, there are many standards to follow, but for some reason, many panel designers and builders go their own way. As Perkon writes in his column, "Whether it's the lack of experience of the designer and builder, or the OEM thinks it's OK to do it that way to save money or someone is just being lazy, messy control-enclosure wiring and lack of wire labels are just a job done poorly in the world of industrial control systems. When it comes to terminating I/O and power wiring in a control enclosure, there are basic standards that must be followed." Just about any industrial-equipment user should require suppliers of control systems and control panels to follow some control-panel-wiring best practices. A good source for these wiring practices and much more can be found in NFPA 79: Electrical Standard for Industrial Machinery, 2018 edition.

While it's just one of many standards automation engineers should use, NFPA 79 is a must-have for any machine builder, OEM, system integrator or any end user with automated machines. It provides control-design standards and how to install electrical equipment properly to protect operators, equipment and facilities from electrical hazards and fire.

Field Cable Routing

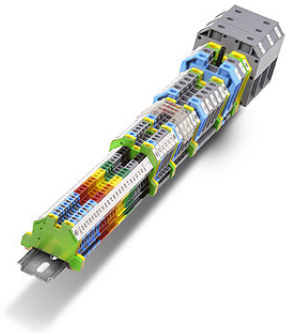
The column points out that proper I/O termination does not just include where the wire is connected to the terminal in the control enclosure, it starts in the field where the cable must be properly routed and supported. The field cables, external to the enclosure, should be attached to the machine frame. These field cables combine into large cable bundles, and both individual cables and cable bundles should be supported or attached to the frame every 12 inches.

The machine, equipment or its operation may damage cable, so wiring and cables need to be protected. "Cable routing provides long-term protection, so don't attach the cables to machine guarding that may be removed," says Perkon in the column. "Also, if a damaged sensor cable must be replaced, as part of a bundle of cables, cut all the cable support ties, remove the faulty cable, replace the sensor cable and then reinstall the cable ties while keeping the cables parallel in the bundle, not woven-like."

The author also points out that field wiring should be neat and well maintained. "The rat's nest may be outside the control enclosure. By not reinstalling the cable ties and just strapping the new cable to the outside of the existing cable bundle or leaving the faulty cable in the bundle, the technician is just creating a mess that only gets worse over time. A poorly done repair, with the excuse that it was quicker, is a worst-case practice."

The Landing Strip

Once the field cable enters the enclosure through a suitable cable gland or conduit fitting, it cannot just be terminated to an internal device such as a power supply or motor starter. Instead, it must pass through a terminal strip. Just as breakers and fuses must be properly sized for the expected ampacity, terminals must be properly sized.



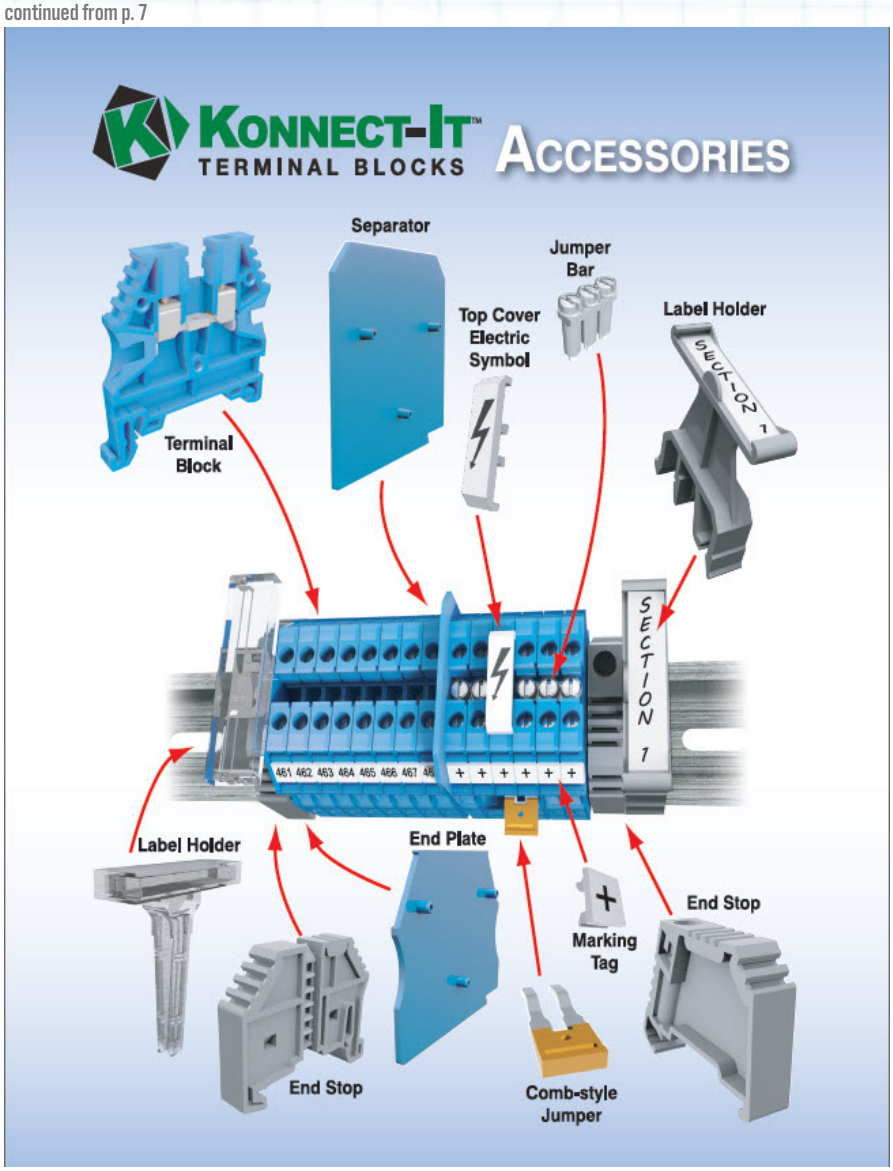
The DINnectors DIN rail mounted terminal blocks shown above are available in single-level, double-level, triple-level, sensor, mini, grounding, fuse holder, disconnect, plug-in, thermocouple, test plug and direct mount configurations to meet various wire termination needs.

These terminal strip devices are mounted on a DIN rail. It is good design practice to surround the terminal strip with wire duct to help manage the wires and cables, so the DIN rail is often raised. Not using wire duct around a terminal strip can cause a sagging tangle of wires. Not raising the DIN rail will make it difficult to connect wires to the terminals as the wire duct can block access, depending on its height.

continued p.8 >>

AVOID WIRING ERRORS CONTINUED

continued from p. 7



"There are very few instances where a terminal, as part of a terminal strip, is not used to connect all field wiring, stresses Perkon in the Control Design column. "Field wiring does not attach directly to relays, input/output modules, safety devices and drives; it typically passes through some kind of terminal first."

Different types of terminals have different applications. In his column, the author suggests that "Single-level terminals work well for miscellaneous terminations within the enclosure and some power distribution. Double-level terminals work well to terminate discrete output signals with one level for the output and one level for a bussed common. It's also a good way to distribute 24 Vdc power. Triple-level terminals work well to terminate discrete input signals, providing an input terminal and terminals for +24 Vdc and 24 Vdc common, often needed for sensors."

Perkon also notes that analog I/O terminations benefit from multi-level terminals to address needs for loop-powered or self-powered transmitters and cable shields, which must also be terminated.

Wiring Terminations

Some of the author's final notes on eliminating the rat's nest include the following. "Wires do not pass over the top of terminal strips; they go around, using the wireway. And in no cases are splices, wire nuts or solder connections allowed to stretch a wire in the duct—add a connector." Accessories should be used as required including separators, end plates, jumper bars, comb-style jumper, label holders, marking tabs and end stops.

The Control Design column also included wiring basics. "Each cable or wire connected to the terminal strip must be labeled to match the electrical schematic. The terminal strip should also have a label on the back panel, such as TS1 (terminal strip 1).

Along with labeling that matches the schematics, it is important to use the correct color wire. Field wiring often uses multi-conductor and multi-color wiring. Discrete wiring inside the control enclosure and field cables, such as 3-wire sensor cables, should follow NFPA 79, NEC 70 and UL 508A standards. These North American Codes are harmonized where they overlap among the field, machine and cabinet levels.

Multi-conductor cables often have black conductor insulation with white printed numbers, although some are multi-colored, and there is often a green/yellow insulated ground conductor, all inside a gray jacket. Two- and three-wire sensor cables are moving to an international color code. Pair cable often includes a black and white wire, while 3-wire sensor cables include a brown, black and blue wire. It depends on the sensor, but the brown wire is typically 24 Vdc, the blue is 24 V common and the black is the signal. Four-wire cables add a white wire, often a signal wire as well. The cable shield is often a braid or foil and includes a tinned copper wire.

Each of these cable conductors from the field should be terminated at the cabinet terminal strip. This includes the shield, which may be grounded at the terminal connection or isolated from ground as it passes through the terminal to a control panel device. If some of the cable conductors are not terminated at the terminal, they should be tied back and treated with a heat shrink—as clearly stated on the electrical schematic that details the connections.

HOW TO SELECT AND SIZE ENCLOSURE THERMAL MANAGEMENT SYSTEMS

Housing electrical components inside an enclosure in industrial applications facilitates the protection of controllers, power distribution components, power supplies and other electronics from harsh factory floor environments. Factories, plants and facilities often experience considerably warm ambient temperatures, and many of the electrical components housed in the control enclosure generate heat, so many enclosures require cooling. In some instances, such as for outdoor installations, enclosures may require heating. When fluctuating ambient temperatures exist, cooling and/or heating are often required to maintain optimal operating temperatures, keep condensation from forming, and prevent components from overheating or freezing.

There are many products available to keep enclosures and components housed inside within an acceptable temperature range. Enclosure thermal management controlling internal temperature is done by transferring heat into or out of an enclosure. The three heat transfer mechanisms used are convection, conduction and radiation

- **Convection:** Moves heat through a moving fluid, a gas or a liquid.
- **Conduction:** Provided through the flow of heat through solid material, such as the enclosure itself, or between two solids.
- **Radiation:** Transfers thermal energy via conversion to and from electrical energy (i.e., electric strip heater).

Heating a Control Enclosure

In most cases enclosure heating is not used to keep internal components warm. In fact, most electric and electronic components perform better at colder temperatures with the exception of enclosures installed outside in an area where ambient temperatures dip well below freezing. In these situations, heating is required to keep internal temperatures within the operating range of electrical components. More typically, heating is needed to reduce moisture and related corrosion.

The goal of enclosure heating is to keep the relative humidity inside the enclosure below 65%. A consistent temperature inside a control enclosure helps guarantee optimal operating conditions and prevent condensation. In some applications, an enclosure may need to be cooled during the day and heated at night. When using a heater, there are many things to consider such as placement, enclosure size and others.

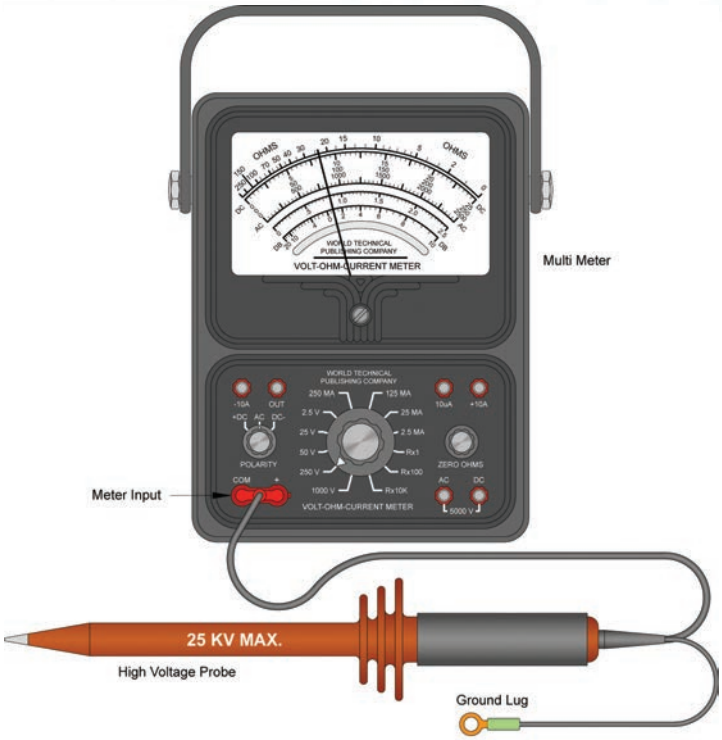
Cooling a Control Enclosure

Reasons to cool a control enclosure may be due to heat added from internal components such as drives and power supplies, or from external sources such as ovens, furnaces, foundry equipment, etc. Excess heat decreases life expectancy of critical control components and can also cause electrical/ electronic component problems. The cooling method used depends on the combined internal and external enclosure heat load.

Properly sizing air conditioners, Vortex coolers, fans or heaters is extremely important to ensure the best and more efficient operating conditions for all the equipment and components housed in an enclosure. Be sure to understand whether you need to keep your enclosure cool, or warm and dry, or both. Once your cooling or heating needs are defined, select a solution and properly size it for the application. For more information on selecting and sizing enclosure thermal devices, check out our Enclosure Thermal Management whitepaper at

library.automationdirect.com/white-papers/

ARC SUPPRESSION – THE AFTERTHOUGHT THAT COULD SAVE YOUR LIFE



Those of us who have worked with, or around, electrical equipment have witnessed electrical arcs. At the very least, we've seen the sparks produced when a relay or contactor switches off. This is easily observed by watching a motor starter with open contacts. When the motor turns on, the contacts close in a fairly uneventful fashion. However, when the contacts open, there is a bright, momentary arc produced which is visible to the naked eye. You may think that electrical arcs are just a common occurrence and nothing to worry about. But repetitive arcing can be very damaging to contacts over the long term, requiring periodic replacement of relays or their contacts. Electrical arcs can also pose a serious danger to personnel if they are not taken seriously and precautions are not put in place.

The Cause

The principal reason for arcing is the inductive kickback produced by a coil when it is de-energized. When power is disconnected, a coil naturally tries to preserve the current. It does this by increasing the voltage. In some cases, this increase reaches several thousand volts, which easily promotes arcing across contacts and through the coil itself. During this discharge, localized temperatures often become high enough to promote rapid erosion of the control contacts.

There are several factors that can promote electrical arcs including misapplication of components and dirt buildup. Over time, dirt builds up on electrical components, causing standoff voltages to decrease until an arc initiates. Then, either the arc energy blows the built-up dirt away and the component returns to normal operation, or the dirt burns, creating a carbon path on the insulating surfaces of the component(s), thereby permanently reducing the stand-off voltage. This reduction in stand-off voltage promotes more arcing, which causes more damage, rapidly forming a run-away situation.

The Cure

There are three basic methods which can mitigate inductive kickback: shorting, arc lengthening and switching management. Shorting employs devices such as metal oxide varistors (MOVs) which provide an open circuit below a specified voltage rating and become conductive above that rating. Once the MOV is conductive, it can be used to short out the circuit, eliminating the kickback voltage before it ever becomes large enough to initiate the arc in the first place.

With arc lengthening, the arc itself is stretched to a point that the inductive energies can no longer sustain the reaction. Arc dividers are an example of these devices and are used to alter the physical characteristics of the arc over the sustaining threshold.

Switch management represents the cutting edge of arc suppression technologies and uses a high speed, solid-state switch element to counteract the arc. Usually a silicon-controlled rectifier (SCR) or a high-power transistor set makes up the switch element. Switching off at or near the zero crossing of the AC signal will substantially reduce inductive energies and the damaging effects of an arc can be principally negated.

Surge suppressors, crowbar circuits and effective grounding are additional methods to decrease the potential for injury to electrical components and personnel. For example, in a situation where an arc forms within a properly grounded panel, the hazard is safely contained and does little more than startle the technician. However, if the cabinet isn't grounded, an inadvertent arc may form through the person standing in front of the box, which can cause them significant harm or even death.

The potential for destructive and even deadly arcs is ever-present in electrical systems. Preventative measures that provide adequate protection should always be considered beforehand and never be relegated to an afterthought. For more information on electrical arcs and ways to reduce their damaging effects, check out our **Electrical Arcs** whitepaper at **library.automationdirect.com/white-papers/**

BRAINTEASERS

By Chip McDaniel

1.) Loopy Lapel

To setup this puzzle: drill a hole in a pencil and tie a loop of string through the hole (as shown in the picture). Make sure that the loop of string is short enough that it will NOT pass over the long end of the pencil (the pointy end).

Now, the trick: without untying the string, or sharpening/shortening the pencil – can you loop the pencil/string assembly through a button hole? Like this:

It's a neat trick to play on an unsuspecting friend – after you have discovered the secret, and have practiced it a few times…

Ask the friend to look away for a second and slip it into a button hole on their blazer. Then watch them scratch their head while trying to remove it ;-)

2.) Algebradabra

Find all real numbers x such that:

$$\sqrt{5-\sqrt{5-x}} = x$$

3) Alphametics

Each letter in an "alphametic" represents a single numeric digit. Each letter represents the same digit each time it occurs, and two different letters never represent the same digit.

The most famous of these is probably:

```
  SEND
+ MORE
 ------
 MONEY
```

The story goes that this was the text for the least expensive telegram that a destitute traveler could send back home – and it includes both the request for help AND provides the amount of MONEY needed. If you are too young to remember: telegrams were charged per character transmitted. (Maybe we should return to that model to cut down on spam!)

And if you haven't seen that one before – give it a try – it's a great puzzle.

But here is an interesting pair of alphametics for which a single solution will solve both:

```
  ONE
+ ONE
 -----
  TWO
```

```
  TWO
+ TWO
 -----
 FOUR
```

But here's the rub: a solution that holds for both equations is not possible with our standard "base 10" number system.

Can you determine the solution and the smallest positive integral base for that solution?

[*Credit: Mathematics Student Journal – circa 1965*]

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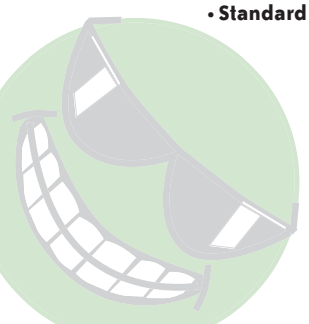

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