White Paper

November 2014

Neutralizing Control Panel Hazards

Energizing Employee Safety

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Introduction

Safety in the workplace is essential in everyday business. As automation and control systems continue to expand and become increasingly complex, the more crucial it is to take the necessary safety precautions. Facility managers, electricians, and control panel engineers have the responsibility to ensure a safe workplace environment to protect employees and businesses from harm.

Along with the expanding automation and control systems, the number of electrical accident incidents is also growing, further increasing the need to provide a safe environment. When environmental hazards are ignored, injuries to personnel can expand to unnecessary fines and increased operating costs. Balancing workers' safety, productivity and equipment optimization requires a disciplined approach that starts with a strong safety infrastructure.

This white paper is the fifth in a series of six papers on the topic of Control Panel Optimization. This paper highlights the standards that require compliance updates, the risks associated with arc flash hazards, protection against mechanical hazard, electrical hazard and hazardous location, and explosion situations. It identifies solutions available to help prevent arc flash incidents and optimize worker safety. Additional information can be found in the "Environmental Protection of Control Panels – Overview and Standards Compliance" white paper.

Standards for Personnel Protection

Coupled with business mandates to reduce costs, increase efficiency and provide additional capacity with dwindling resources to meet business needs, environmental health and safety professionals face the task of supporting the bottom line by maintaining effective programs that address time-consuming regulatory compliance issues and keep the workforce safe.

A report from the State of Washington indicated that from September 2000 - December 2005, 350 workers were hospitalized for serious burn injuries that occurred at work. Thirty (9%) of these injuries were due to arc flash/blast explosions. Total Workers' Compensation costs associated with these 30 claims exceeded $1.3 million, including reimbursement for almost 1,800 days of lost work time.

To protect operators, the Occupational Safety and Health Administration (OSHA) and National Fire Protection Association (NFPA) 70E standards require a "flash protection boundary." OSHA has adopted the NFPA's 70E, Standards for Electric Safety in the Workplace® as an acceptable means of compliance to meet this requirement and maintains that electrical work should only take place on de-energized equipment. Access to potentially energized equipment capable of generating an arc flash must be limited to qualified personnel with extensive protective clothing and equipment, including fire-resistant suits and hoods along with non-conductive wands.

NFPA 70E provides multiple methods by which the employer can calculate or estimate the hazard or risk. It covers electrical safety issues such as safety-related work practices, maintenance of electrical equipment/installations, and the requirement of special equipment for electrical installation. The Appendix lists arc flash solutions provided by both Panduit and Pentair/Hoffman.

The National Electric Code (NEC) is a United States standard for the safe installation of electrical wiring and equipment and is in effect to standardize the enforcement of safe electrical practices. It is part of the National Fire Codes series published by the NFPA and codifies the requirements for safe electrical installations into a single standard source.

Even the best-designed safety program will not guarantee that it will be consistently implemented and adopted across all workplaces. Implementation of a safety compliance program requires the support of management and the marshaling of many resources. Without this support, many safety programs often fail due to urgent priorities, inconsistent training of the workforce and delayed implementation.

The right project management and training support can help you:

- increase time to compliance
- limit exposure to regulatory fines
- improve workplace safety

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- ensure compliance with relevant hazardous energy standards
- provide high-quality, cost-effective implementation and training services that guarantee your compliance program execution and training goes smoothly and achieves the desired results

Preventive Measures for Arc Flash Risk

A growing concern in the electrical industry is the increased incidents of arc flash. An arc flash explosion is a very dangerous and often costly electrical system malfunction that occurs as a short circuit between electrified conductors. When the isolation between the conductors is breached or cannot contain the applied voltage, the air immediately surrounding the short can ionize, creating an intense energy flash of 5,000°F or more. Often, an arc flash event is triggered by operator movement or contact with the energized equipment. This is a particular threat when faults occur within an enclosure. A phase-to-ground or phase-to-phase fault that results in an explosion can cause fatal injuries, severe burns and produce considerable property damage.

Arc flash is a dangerous condition associated with the release of energy caused by an electric arc, a very common workplace hazard. Due to the significant number of electricians that have been seriously burned or killed by accidental electrical arc flash while working on energized equipment, NFPA 70 requires the labeling of switchboards, panel boards, and control panels to warn the qualified person of the potential for arc flash.

According to NFPA 70E, typically, as much as 80% of hospital admissions from electrical incidents are a result of burns resulting from an arc flash and ignition of flammable clothing, rather than electrical shock. The amount of energy released from an arc flash can be fatal at distances of 10 ft. (3m).

Furthermore, over 2,000 people each year are admitted to burn centers for severe arc flash burns. Estimates also indicate that more than 30,000 non-fatal electrical shock accidents occur each year.

Best practices in meeting the OSHA, NFPA, and Canadian Standards Association (CSA) safety standards requirements to establish a workplace free of unknown hazards in relation to the electrical system include training programs, lockout/tagout procedures and identification systems.

Training Programs

Training is critical for all workers who are exposed to safety hazards. These workers must thoroughly understand the requirements of the electrical safety program, which is required by NFPA 70E and OSHA 29 CFR 1910.147 for all industrial locations and must include safety principles, controls used to measure and monitor, and specific procedures regarding how to work within the safety boundaries.

- NFPA 70 requires training which is divided into two groups: Qualified and Unqualified employees. A qualified person has skills and knowledge relating to the construction and operation of electrical equipment and installations. This person is typically the electrician who is working on energized conductors. Unqualified personnel are neither trained nor familiar with determining exposed energized conductors or how to determine nominal system voltage and the apparent hazard.
- The content of the qualified personnel training includes the identification of specific electrical hazards and the potential risk for injury. It also discusses emergency procedures needed in the event of an incident and first aid care, including resuscitation.
- Unqualified employee training only includes training on electrical safety practices necessary to avoid injury. Retraining or additional training is required when new technology or job roles change or on an interval NOT to exceed three years. It is important that the employer documents employee training, which should include the content of the training, employee's name and dates of training.

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Lockout/Tagout Procedures

Lockout/Tagout procedures are established to protect employees from accidental start-up of equipment or accidental release of hazardous energy.

NFPA 70E specifies that LOTO procedures be implemented as part of establishing a safe working condition – see related specification OSHA 29 CFR 1910.147, *The Control of Hazardous Energy*. Annex G of NFPA 70E, which has a sample LOTO program that may be used as a template. A key principle of the LOTO procedure is that a circuit or panel is considered to be "live" until a voltage tester is used to verify the source(s) of energy is removed. See Figure 1 for a de-energize signage example. Other key principles of a robust LOTO program include:

- *Employee Involvement* – each person who could be exposed to hazardous energy on a specific job is included in the LOTO process – otherwise referred to as Group Lockout. Personnel shift changes should also be monitored.
- *Training* – employees are trained on the site specific LOTO/Energy Control Procedure.
- *Procedures* – specific procedures are required for "complex" LOTO instances where there are multiple energy sources and/or multiple crews, locations, employers, specific sequences, etc. (see NFPA 70E Article 120 (D) (2) for more information). OSHA 29 CFR 1910.147 (c) (4) (i) requires machine-specific procedures in complex lockout conditions including equipment with more than one energy source.

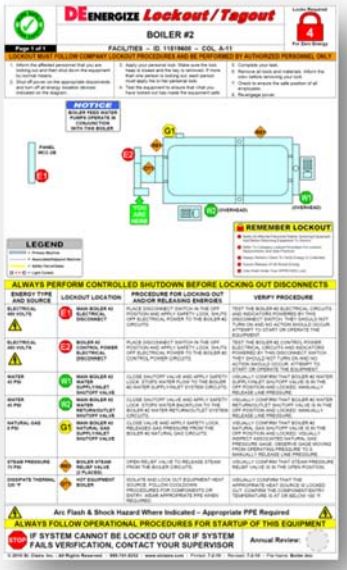

Figure 1. For industrial equipment with multiple energy sources: Audit equipment documenting layout and energy sources; Create de-energize procedure; Install placards; Train end user personnel.

LOTO procedures need to contain instructions to include:

- *De-Energize Equipment* - where and how to de-energize the energy load on the equipment
- *Stored Energy* – how to release hazardous electrical, mechanical, or other stored energy (for example capacitors are discharged, springs unloaded, pneumatic/hydraulic pressure released, etc.)
- *Verification* – how to verify the equipment is de-energized and cannot restart in the locked out condition
- *Easy to understand procedures* - for securing equipment and electrical access points start with a floor plan layout that provides a bird's eye view or easy-to-understand photographs of equipment.

Identification Systems

Signage, labeling and identification systems form the backbone for life safety information such as exit signs, arc flash potential, high voltage, and sheltered areas. It also helps with routine tasks that mark, for example, the location for parking a fork lift truck. Safety identification systems can include:

- Signs and labels that indicate hazardous conditions
- Voltage markers, pipe markers, tapes and letters / numbers
- Custom markers

It is important to understand that whether performing energized or de-energized work, mitigating the risk of electrical hazards begins with an analysis of mechanical, electrical and hazardous location explosion situations to determine the incident energy available at the specific area of work on the electrical power system.

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Mechanical Hazard Protection

The arc flash protection boundary is the distance where the incident energy is equal to 5 J/cm² (1.2 cal/cm²), which is the energy level that unprotected skin will sustain a second degree burn. Therefore, unqualified personnel must be continuously escorted by qualified workers and Personal Protective Equipment (PPE) is required within the arc flash boundary. Arc flash PPE is selected from either the incident energy calculation or the hazard risk category determined from NFPA 70E Table 130.7(15).

Observing the arc flash protection boundary can help mitigate the arc flash hazard. This boundary is relevant to systems 50 volts and greater and should be updated when a significant modification or renovation involving the electrical distribution system occurs or it should be reviewed at least every five years. Figure 2 is a diagram of the arc flash protection boundary and illustrates the type of personnel (qualified or unqualified) authorized for each specific area.

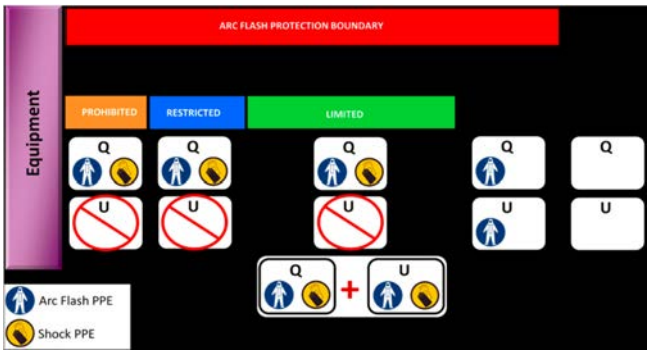

Figure 2. Prohibited, Restricted and Limited Shock Hazard boundaries and Arc Flash Protection boundaries
Q = Qualified Personnel U = Unqualified Personnel

Visual Signs – Labeling enclosures with safety signs and labels play a critical role to warn, remind, and alert people of possible harm. There are several mechanical hazards and dangerous situations where the risk can be mitigated using appropriate signage.

Other alerting techniques such as safety signs, symbols, or prevention tags are recommended to warn employees of potential workplace hazards. As an example of facility signage specified by the National Electric Code - according to 490.53, for equipment operating over 600V, all energized switching and control equipment shall be enclosed in grounded metal cabinets and marked "DANGER - HIGH VOLTAGE - KEEP OUT."

Physical Barriers – Physical barriers are important to protect against mechanical hazard. It is necessary to design equipment so untrained electrical personnel are free of risk sources.

- *Latching mechanisms* on enclosures to safe guard the power source from within the enclosure prevents personnel from accessing inside the enclosure with the power source on. These mechanisms assure that power is physically turned off to allow the enclosure door to open. Once the enclosure door is closed, power can then be restored. (Appendix solution #1)
- *Data Ports* are used to allow programming access, as well as conduct diagnostics to devices inside an enclosure without opening the enclosure door. These ports can be mounted on the outside of the enclosure door or enclosure wall, allowing personnel to program the device inside the enclosure without exposing hazard risk by opening the enclosure. (Appendix solution #7)
- *Lockouts* are another method to protect against mechanical hazard. Lockouts are used when more than one person is servicing an enclosure and need to secure the power source. Safety lockouts ensure that before any work on a machine or equipment is started, all applicable energy sources have been rendered safe. (Appendix , solution #10)

Personnel can apply individual padlocks to secure the power source when servicing the enclosure and remove their own lock once completed. This ensures that the power source cannot be turned on by one person when another person is servicing the enclosure. The last person to complete the project removes the lock and restores the equipment to operation.

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Electrical Hazard Protection

One of the most common causes of arc flash injuries happens when switching on electrical circuits and tripped circuit breakers. A tripped circuit breaker often indicates a fault has occurred somewhere down the line from the panel, therefore the fault must usually be isolated before switching the power on, or an arc flash can easily be generated. There are many methods of protecting personnel from arc flash hazards.

Visual Signs – All power sources for machines are potential sources of danger, therefore safety signs should be used to create awareness to the hazard and potential danger to employees. See Figure 3.

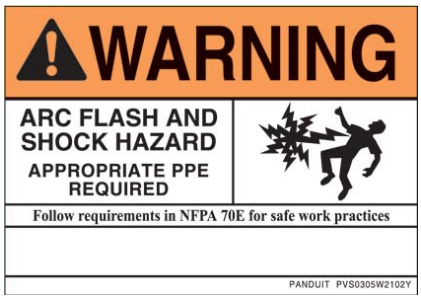

Figure 3. Hazard warning label.

Personal Protective Equipment (PPE) –The purpose of personal protective equipment is to reduce employee exposure to hazard when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPE includes specialized clothing or equipment worn by employees to protect the body including the head, face, eyes, and hands. The level of PPE is determined by the degree of the shock and arc flash hazard. The Hazard Risk Category determined by the NFPA 70E 130.7(C) (15) or the incident energy calculation is then used to decide the required PPE for the task. For example, the Hazard Risk Category for toggling a circuit breaker with the enclosure doors open for a 600V class motor control center (MCCs) is a Hazard/Risk Category (HRC) 1 according to Table 130.7 (C) (15) (a). According to Table 130.7 (C) (16), for HRC 1, the PPE required is a hard hat, safety glasses or goggles, hearing protection, heavy duty leather gloves, and leather work shoes. Additionally, insulated tools and equipment (and/or handling equipment) are used when working within the limited approach boundary.

The PPE is listed in Table 130.7 (C) (16) by Hazard Risk Categories 0 through 4. Above 40 cal/cm² is considered HRC DANGEROUS because PPE is not able to sufficiently protect employees, which means energized work is prohibited. NFPA 70E Table 130.7 (C) (14) lists the standards relevant to protective equipment.

It Is All About Protection

An engineer is assigned to perform troubleshooting and replacement of fuses on a power system, in which an overvoltage condition occurred as the result of an undetected ground fault on an ungrounded system.

The engineer was in the process of restoring electrical power to the power supplies, when an arcing ground fault occurred. The engineer was not wearing the appropriate personal protective equipment and received first and second degree burns.

Conclusion: The root cause was failure to ensure that good industrial practices, as well as NFPA 70E requirements for the design, test, operation and maintenance of unground delta electrical power distribution systems were used. If these management processes and quality assurance requirements had been implemented, the engineer would have been better protected and the accident could have been prevented.

Electrical Equipment Design – Another method to protecting against arc flash is modifying the design and configuration of electrical equipment. External disconnects can help mitigate arc flash occurrences when working on interior components by isolating incoming power from the main enclosure. The disconnect switch and fuse block/circuit breaker are mounted in the external enclosure with terminal connections to bring power to the main enclosure.

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Hazardous Location Explosion Protection

A hazardous location is a place where concentrations of flammable gases, vapors, or dusts occur. Equipment installed into such environments is designed to protect against these elements. For example, a purge and pressurization device is installed in a hazardous location to allow lesser rated equipment to be used within the hazardous area.

Purge and pressurization is a two-step process prior to energizing electrical equipment inside an enclosure (see Figure 4). The goal is to insure that once the enclosure is purged and pressurized with a protective gas supply, only then can the enclosure be energized or powered up. The protective gas supply needs to be free of any hazardous or explosive gas and of the capacity to sustain the purge and pressurization process.

Purge and Pressurization Systems (Appendix, solution #4) supply one or more enclosures with instrument quality air or an inert gas to keep hazardous gas out of the system so installed equipment can be safely used. The system removes hazardous gases out of the enclosure and maintains a positive pressure to the system to keep the hazardous gas out.

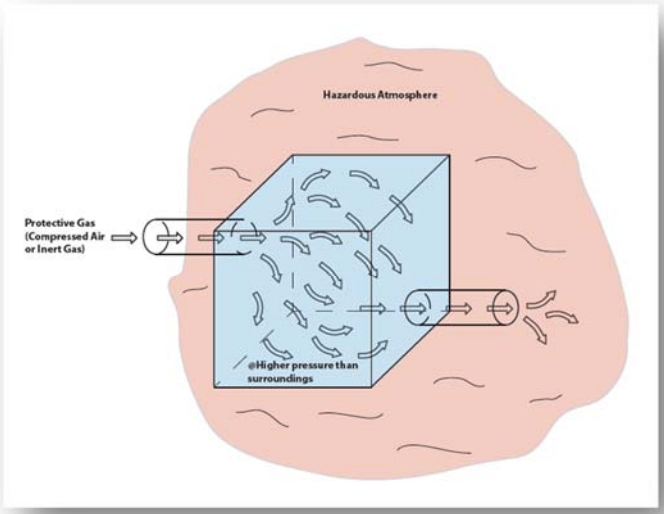

Figure 4. Pressurization system.

Conclusion

It is crucial that facility managers, electricians, and control panel engineers take all recommended precautions to ensure a safe work environment for their employees. A safe work environment protects employees and impacts various levels of day-to-day business, including the bottom line, both directly and indirectly. There can be significant costs associated with incidents such as worker's compensation, insurance costs, and legal fees. Indirect costs such as lost productivity that occurs when workers must turn their attention to dealing with a safety incident, are also impacted.

By evaluating and understanding current safety programs, potential gaps in compliance, analyzing workplace injury statistics and managing compliance programs it is possible to avoid choosing between the bottom line and safety. Facility managers, electricians and control panel engineers can also participate in the Panduit Safety Services program highlighted in the Appendix.

Together, Pentair and Panduit leverage their solutions to protect against mechanical, electrical, and hazardous situations to protect human life in everyday business.

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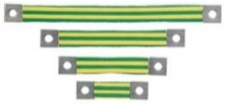
Appendix Solutions from Pentair Hoffman and Panduit to Help Neutralize Control Panel Hazards

#1		**Disconnect Enclosures** Pentair offers disconnect enclosures to safe guard the power source from within the enclosure.
#2		**Sequester External Disconnect Enclosure** This enclosure from Pentair helps mitigate arc flash occurrences when working on interior components by isolating incoming power from the main enclosure. The disconnect switch and fuse block/circuit breaker are mounted in the external enclosure with terminal connections to bring power to the main enclosure.
#3		**Hazardous Location Protection Systems** For protection where safety is critical, count on Pentair safety enclosures and purging/pressurization systems.
#4		**Purge and Pressurization Systems** Supplies one or more enclosures with instrument quality air or an inert gas to keep hazardous gas out of the system so installed equipment can be safely used. This system from Pentair removes hazardous gases out of the enclosure, then maintains a positive pressure to the system to keep the hazardous gas out.
#5		**StructuredGround™ Universal Ground Bar System** Panduit offers a variety of UL listed universal ground bars for multiple termination methods (bare wire, ferrule, ring terminal and compression connector). 1 – Bare Wire #14 to 4 AWG 2 – Ferrules to 6 AWG 3 – Ring Terminals 4 – Compression Connectors
#6		**StructuredGround™ Flat Braided Bonding Straps** Bonding straps, such as Panduit StructuredGround™ Flat Braided Bonding Straps, help reduce the effects of EMI by passing high frequency noise more effectively than round stranded type cables.
#7		**INTERSAFE Data Interface Ports** These ports from Pentair allow programming access, as well as conduct diagnostics to devices inside an enclosure without opening the enclosure door.
#8		**IndustrialNet™ Data Access Port** This data access port from Panduit provides a safe and secure means to maintain and monitor performance of PLCs, VFD, and industrial networks. Integrated security features prevent the intentional disruption of service by unauthorized personnel.
#9		**Physical Network Security** Network accessories from Panduit block unauthorized access to existing network infrastructure from the data center to the workstation.
#10		**Safety Lockouts** From Pentair, these safety lockouts provide a means of using multiple padlocks on a secured power source. Includes a 10.00-in. (254-mm) plated steel chain. Manufactured from 10 gauge steel with six station holes.
#11		**Facility Identification** Panduit has a broad array of identification products, including pre-printed, custom printed and print on-demand solutions. Our goal is to provide a facility identification solution to protect your employees and infrastructure from dangers present in the workplace.

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#12		**Lockout/Tagout Devices** Panduit has a line of versatile and innovative Lockout/Tagout devices to provide additional value to your safety program.
#13		**Safety Services** Service offerings from Panduit help customers establish compliance with the latest NFPA and OSHA safety standards.

Referenced Resources

- http://www.ishn.com/articles/98361-two-workers-at-nj-manufacturing-facilities-suffer-severe-hand-injuries
- http://lni.wa.gov/safety/research/files/arcflashhazardreport.pdf
- http://energy.gov/sites/prod/files/2014/04/f15/BNL_TypeB_041406.pdf
- NFPA 70E® , "Electrical Safety in the Workplace® , 2012"
- OSHA 29 CFR1910. 147, "The Control of Hazardous Energy"

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About Pentair Equipment Protection

Pentair Equipment Protection, a Pentair global business unit, is the leading provider of worldwide product and service solutions for enclosing, protecting and cooling electrical and electronic systems. Its industry-leading brand — Hoffman — provides a broad variety of standard, modified and engineered solutions to the commercial, communications, energy, general electronics, industrial and infrastructure markets.

About Panduit

Panduit is a world-class developer and provider of leading-edge solutions that help customers optimize the physical infrastructure through simplification, increased agility and operational efficiency. Panduit Unified Physical Infrastructure℠ (UPI)-based solutions give enterprises the capabilities to connect, manage and automate communications, computing, power, control and security systems for a smarter, unified business foundation. Panduit provides flexible, end-to-end solutions tailored by application and industry to drive performance, operational and financial advantages. Panduit global manufacturing, logistics, and e-commerce capabilities along with a global network of distribution partners help customers reduce supply chain risk. Strong technology relationships with industry leading systems vendors and an engaged partner ecosystem of consultants, integrators and contractors together with its global staff and unmatched service and support make Panduit a valuable and trusted partner.

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