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ANSI Z10 and Advancements in Electrical Safety Management

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Abstract

Electrocution is a leading cause of occupational fatalities in the US. Electrical injuries tend to have a high severity index, or ratio of non-fatal injuries to fatalities. This paper discusses applying advanced methods in safety management that focus on fatality prevention in addition to total recordable injury reduction. A case history of a global Fortune 100 company is used to illustrate practical results from application of advancements in safety management. This paper discusses a subtle but far reaching addition to the 2009 edition of NFPA70E, the prominent industry consensus standard for workplace electrical safety in the US. This standard primarily addresses administrative controls, safe work practices, and personal protective equipment. It does not address comprehensive hazard-control measures, program sustainability, and integration with business management systems. The 2009 edition acknowledged this limitation and referenced ANSI Z10, *Occupational Health and Safety Management Systems*, as a framework for designing and implementing an effective and sustainable electrical safety program.

Introduction

The accident triangle, developed by Heinrich in the 1930s has served as a model for safety management for nearly 80 years. This model implies a fixed ratio of near miss incidents to minor injuries to major injuries. As early as 1980, Peterson and Roos began questioning aspects of this model, in particular the application of the ratios to all hazards.(1) More recent work by Krause and Manuele has proposed that hazards having high potential for severe injuries are not accurately described with this model need to be addressed differently than those with low potential for serious injury.(2, 3) Figure 1 is adapted from Anderson and Denkl.(4) This figure shows the ratio of lost time injuries to fatalities by type of incident for the year 2007. Their analysis included contact with electricity in the category of exposure to harmful substances or environments. The separate category for contact with electricity was derived from analysis by Cawley and Brenner for the years 2003-2009.(5) The severity index ranges from 12 for Fires and Explosions to 14033 for Overexertion in Lifting. This chart clearly shows that assuming a fixed ratio of minor injuries to fatalities can be misleading in how an organization perceives risk of injury. Krause and Manuele have also noted that focusing on reducing frequency of injuries may show successful results without a corresponding reduction in severe injuries.

Exposure to electrical hazards remains a leading cause of occupational fatalities. In their study spanning 2003-2009, Cawley and Brenner reported it was the 7th highest cause of U.S. workplace fatality.(5) During this period 1,573 workers died from contact with electricity and 18,460 suffered non-fatal injuries. BLS criteria for non-fatal injuries include injuries involving one or more of these characteristics: loss of consciousness, days away from work, restricted work activity or job transfer, or medical treatment beyond first aid. Injury severity potential can be expressed as the ratio of Lost Time Injuries to Fatalities for specific hazards. Based on Cawley and Brenner's data, the injury severity index for electrical hazards is (1573 fatal injuries + 18,460 non-fatal injuries)/1573 fatal injuries = 12.74.

The evolution in advanced safety management has brought new thinking in how to manage both severity and frequency of injuries from workplace hazards.

Event or Exposure	**Severity Index** (Lost time Injuries/fatalities)
Fires & Explosions	12
Contact with electricity	13
Transportation accidents	23
Assaults & violent acts	28
Fall to lower level	104
Exposure to harmful substance or environment	107
Caught in, compressed or crushed	134
Total of all events or exposures	**205**
Struck by object	323
Falls on same level	2056
Struck against object	8414
Slips or trips without fall	12593
Overexertion in lifting	14033

Narrow base triangle

Broad base triangle

Figure 1. Data from US Bureau of Labor Statistics showing ratio of Lost Time Injuries to Fatalities. Adapted from Anderson and Dnkl (4) with electrical injury data from Cawley and Brenner. (5) Anderson and Dnkl data is from 2007. Cawley and Brenner data is from 2003-2009.

A Case History

The company described in this case history is the oldest of the Fortune 100, having been incorporated in 1802. For the first 100 years the company produced explosives used in farming, construction, hunting and warfare. The manufacture and distribution of these products were inherently hazardous and fostered a robust and disciplined culture for managing safety for highly hazardous processes. At the end of the 19th century, electricity was introduced in the company's facilities, and the experience in managing safety was applied to this new technology. As shown in Figure 2, by the 1940s, the company averaged one electrocution fatality per year. 1953 marked a shift from the common industry practice that allowed working on live energized circuits.(6) By the early 1980s, the company averaged one electrocution fatality every 33 months. Over a thirtythree year period 1968-2001, employees and contractors in its global operations incurred 12 fatalities from electrical hazards. Combined employee and contractor workforce during this period ranged from ~80,000 to ~120,000. The "workplace" included more than 200 industrial facilities, refineries, construction sites, laboratories, research centers, retail outlets, farming operations, and office complexes throughout the Americas, Asia and Europe.

In 1989 company management made a highly visible commitment to reduce the risk of injuries to employees and contractors from electrical hazards. Goals for sustainable improvement were established, financial support provided, and dedicated people empowered to reduce the probability of electrical incidents, injuries and fatalities. After more than 20 years, we can look back and see positive and dramatic results. Figure 2 shows the impact on fatality prevention.

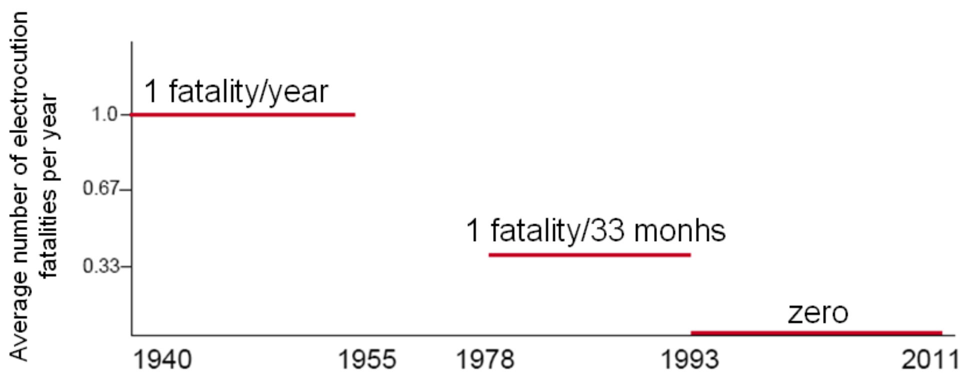

Figure 2. Trends in employee and contractor electrocution fatalities in example company's facilities and operations worldwide.

- Understand the business consequences of electrical incidents
- Engage all employees
- Stimulate near miss reporting
- Apply quality improvement model – Plan Do Check Act
- Build networks
- Challenge accepted practices
- Improve collaboration among management, electrical experts and safety professionals
- Use standards as tools
- Promote prevention by design
- Address life cycle: design, construct, operate, maintain, dismantle

Figure 3. Elements of the strategy described in the paper, "Creating a Continuous Improvement Environment for Electrical Safety."(7)

In 1991, leaders of the electrical safety improvement initiative formulated a long-term strategy to enable continuous improvement in electrical safety. This strategy was presented and published at an IEEE conference in 1992.(7) Fundamental to this strategy was that effective electrical safety management required a different understanding of the traditional Heinrich accident triangle. Electrical injuries were not a significant component of total recordable injuries, but fatalities from electrical hazards was a significant portion of fatal injuries. The strategy summarized in Figure 3 is closely aligned with concepts in ANSI Z10 and with techniques discussed by contemporary thought leaders addressing the challenges of serious injury and fatality prevention. (1, 2, 3) The following is a discussion of how these elements applied to electrical safety improvement efforts. In general they can be applied to other low frequency/high consequence events and exposures.

Understand the business consequences of electrical incidents

Incidents in electrical energy control, data and communication systems can have significant impact and costs to an organization even if there are no injuries involved. When injury is involved, medical and rehabilitation costs can be significantly higher than those of other injuries. Liberty Mutual reported in 2010 that serious electrical injuries were the most costly workers compensation claims.(8) Understanding the full range of business implications helped the build credibility for the electrical safety initiative. This was crucial when discussing issues with management.

Engage all employees

This had vertical and horizontal implication to the line organization. Vertically, this effort sought to engage line supervision and management to strengthen their role and involvement in electrical safety. Horizontally, this meant all workers, regardless of their previously perceived exposure to electrical hazards, were considered to have some risk and exposure to electrical hazards. The latter involved a paradigm shift in who was perceived to be at risk for electrical injury. Historically, the company electrical safety program was focused on workers whose job responsibilities specifically included working on or near potentially energized electrical circuits and equipment. An analysis of injury and fatality data showed this work group accounted for less than half of fatalities from contact with electricity.(9)

Stimulate near miss reporting

Initially, the database of electrical incidents in the company operations only included those having injuries. This was a very small data set and was not useful in understanding how best to focus improvement efforts. To stimulate near miss reporting, this definition for an electrical incident was developed to help educate workers and management on how to better recognize opportunities to correct underlying contributing causes to electrical injuries: “an event resulting from personnel action or equipment failure involving electrical installation, portable electrical equipment, or electrical test equipment that has the potential to result in an injury due to: 1) electrical flash or bum, 2) electrical shock from a source greater than 50 volts AC or 100s volt DC, or 3) reflex action to an electrical shock.” Within 5 years, electrical incident reports had increased by more than 10X, providing valuable insight on where to focus intervention strategies.

Apply quality improvement model – Plan Do Check Act

This established the expectation that the electrical safety improvement initiative was not a short-term improvement project, but a long-term commitment to continuous improvement. The Plan-Do-Check-Act quality management model is an essential component of ANSI Z10 and other internationally recognized safety management systems standards. (10, 11, 12)

Build networks

Internal networks within the company were created to link all people who were involved or impacted the electrical work environment in the company. This enabled discovery of best practices and dispersion of these practices across all locations. External networks, those that reached outside the company, were essential in connecting with other centers of excellence and to engage other companies and organizations in advancing codes, standards, and inherently safer technologies. The most visible and successful of theses external networks is the IEEE IAS Electrical Safety Workshop.(13) This annual forum was launched in 1992 with 35 participants. In recent years attendance has exceed 400. It is the only international forum dedicated solely to advancing the prevention of occupational electrical injuries and fatalities.

Challenge accepted practices

Electrical fatalities were not on the company radar screen because electrical injuries were not significant when looking at total recordable injury data. One of the first realizations was a better understanding that efforts to manage safety in a broad and general way had little direct impact on the specific hazards of electrical energy. Recognizing the Heinrich safety triangle model did not accurately represent electrical incident and injury statistics was an important discovery. It set the stage for focusing an improvement initiative without being based on total injury statistics. Another example involved development of the concept "Test Before Touch,", created to help displace unsafe practices that had evolved in the early days of industrial electrification.(14)

Improve collaboration among management, electrical experts and safety professionals

Prior to 1990, the electrical safety program had been delegated to electrical experts. In retrospect, the knowledge base of this group was extensive in electrical technologies and work practices, but weak in hazard analysis, risk assessment, and safety management systems. Safety professionals typically did not get involved in the electrical safety program except during injury investigations. Efforts were taken to create and nurture collaboration among electrical experts, safety professionals, and management to strengthen all aspects of the electrical safety program. Management has the responsibility for managing priorities and resources and setting business objectives. Safety professionals bring a skill set in safety management systems, risk management, and rapport with all levels of the line organization. Electrical engineers, electricians, and technicians bring a skill set spanning design, construction, maintenance, and operation of electrical equipment and systems. Collectively, these skills, knowledge, and responsibilities helped create an extraordinary collaboration and synergy to assess and improve our electrical safety program.

Use standards as tools

An organization may choose compliance with codes, standards, and regulations as a goal. However, compliance may meet legal requirements without achieving world class performance. Industry consensus standards by definition imply compromise by members of the developing organization. Leading edge, state-of-the-art, or innovative methods may take decades to be incorporated into consensus standards. We took the approach that compliance was a step in the direction of where we wanted to be in electrical safety. We strengthened our commitment to seek collaboration with other companies and organizations to promote and stimulate innovation in safe work practices, tools and equipment, and training methods. One example was a collaborative effort in 1996 involving eight companies to create an awareness of arc flash hazards in industrial settings. (15)

Promote prevention by design

Initial reaction to increasing understanding of arc flash hazards in industrial power systems focused on use of protective clothing. Engineers began exploring techniques to reduce thermal energy exposure in arc flash events. An early success was realized by retrofitting fast acting current-limiting fuses in 480V feeder circuits. This paved the way for further development of engineering design solutions to eliminate or reduce severity of exposure. Recent developments, in particular the NIOSH Prevention through Design initiative, and the publication of ANSI Z590.3 *Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes* confirm that there is much room for improvement in the concepts of eliminating or reducing hazards in the design of facilities, equipment and processes. (16, 17)

Address life cycle: design, construct, operate, maintain, dismantle

This is about taking a long-term, comprehensive view of electrical safety, from the initial design concept all the way to demolition or replacement of the facility. All stages in an electrical system's life cycle affect the electrical work environment.

Advancements in NFPA 70E

Widely considered one of the most prominent standards regarding workplace electrical safety in the US, NFPA 70E *Standard for Electrical Safety in the Workplace*, has helped raise the visibility improvement opportunities for electrical safety in the workplace. Due to scope limitations established by the National Fire Protection Association, NFPA70E focuses on the three bottom control measures in Figure 3, and does not directly address the top three. Previous editions of NFPA 70E have acknowledged this limitation with a Fine Print Note in Section 110.7 Electrical Safety Program, which stated that, *"Safety-related work practices are just one component of an overall electrical safety program."*

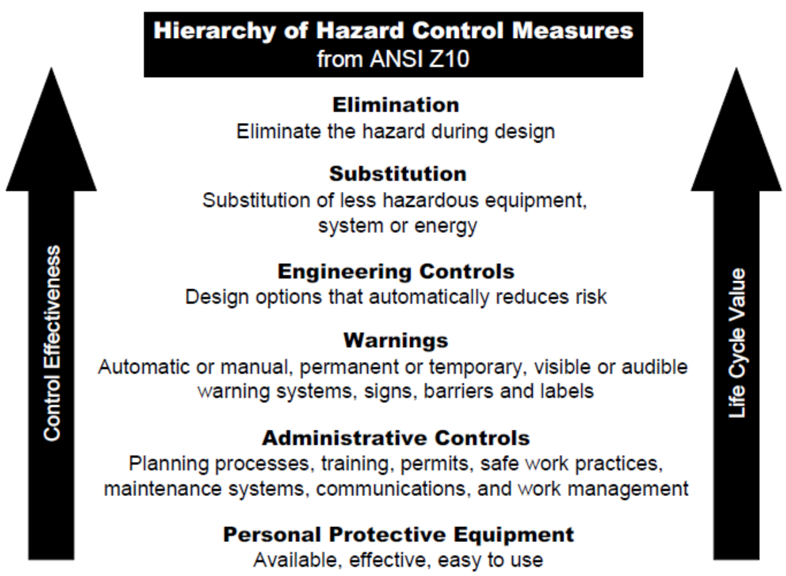

Figure 4. Hierarchy of Hazard Control Measures (18)

The 2009 edition added a reference to ANSI Z10, and states *"ANSI/AIHA Z10-2005, American National Standard for Occupational Health and Safety Management Systems, provides* *a framework for establishing a comprehensive electrical safety program as a component of an employer's occupational safety and health program."*[(19)

NFPA 70E-2009 also added Annex O, Safety-Related Design Requirements. This annex describes how the hazard risk assessments methods in the standard, commonly used for the selection of personal protective equipment, can also be used to *"…compare design options and choices to facilitate design decisions that serve to eliminate risk, reduce frequency of exposure, reduce magnitude or severity of exposure, enable the ability to achieve an electrically safe work condition, and otherwise serve to enhance the effectiveness of the safety-related work practices contained in this standard."*(19)

The scope limitation of NFPA70E is set by its historic relationship with NFPA70 National Electrical Code. The NEC® is managed by the NFPA as an installation document and not a design document. An organization intent on using NFPA70E as a basis for its electrical safety program needs to understand this limitation and plan a comprehensive program using the framework of ANSI Z10 or other recognized safety management system, as implied by section 110.7 noted above.

Assessment Tools

Auditing and assessment of program performance is an essential aspect of safety management systems. An innovative new development in electrical safety program assessment was launched by the Electrical Safety Foundation International (ESFI) in early 2012.(20) ESFI is a 501(c)(3) non-profit organization dedicated to reducing the number of workplace electrical injuries and fatalities through education, awareness, and advocacy. ESFI has created an online assessment tool, available free of charge. Called ***How Do You Know***, the program provides a tool for managers and employees to develop a proactive approach to electrical safety by determining the effectiveness of the current safety practices they have in place. The program features high-quality video modules to reinforce the importance of electrical safety programs and compliance with standards and regulations, while demonstrating the importance of safe electrical practices. It features a web interactive self assessment to help review and analyze a company's electrical safety practices related to facilities, personnel, and procedures. This online tool guides users through a series of questions that will help identify areas of the electrical safety program that may require further examination. This includes both minor and significant changes that can lead to a safer work environment. Once the assessment is complete, respondents can visit ESFI's website for a library of safety resources and links to help find the information required to take the next step.

Conclusion

Electrical hazards are a leading cause of occupational fatalities and have one of the highest severity indexes of all hazards in the workplace. While having high potential for severe injury and fatality, electrical incidents are relatively low frequency events in the spectrum of total recordable injuries. Thought leaders in safety management have proposed advancements in how safety professionals think about the traditional Heinrich accident triangle, with additional attention given to hazards that are characterized as low frequency but high potential for serious injury or fatality. An example case history validates this approach in significantly reducing fatalities from electrical hazards. Consensus standards relevant to electrical safety have evolved in content and application to more effectively reduce risks from electrical injury. An easily accessible innovative tool for assessing electrical safety program effectiveness is now available as an additional feature in a safety professional's toolbox.

While centered on the electrical hazards in the workplace, this paper provides insight in applying advancements in serious injury and fatality prevention to other high-risk hazards in the workplace.

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