Promoting Electrical Safety through NFPA 70E Standards Adherence

October 2018

Kim Cavaliero-Keller, MELTRIC

INTRODUCTION

Electrical injuries claim hundreds of lives each year and are the root cause of thousands of non-fatal injuries across the country. In 2016, the U.S. Bureau of Labor Statistics (BLS) reported 154 electrical fatalities, a 15 percent increase compared to 2015. Additionally, exposure to electric current moved up one spot to number six on the list of occupational exposures that lead to on-the-job fatalities.[1] Construction, mining, and utility industries reported the greatest rates of injury, including burns and electrical shock.

The U.S. Occupational Safety and Health Administration (OSHA) is a government agency tasked with establishing and enforcing workplace health and safety laws by which companies must abide.

The National Fire Protection Association (NFPA) is the leading global advocate for the elimination of death, injury, property, and economic loss due to fire, electrical and related hazards. They deliver information and knowledge through the creation and distribution of more than 300 consensus codes and standards, research, training, education, outreach, and advocacy.[2]

OSHA and the NFPA work together as an alliance to provide information, guidance, and training resources to recognize, reduce, and prevent electrical hazards and injuries in the workplace.

First published by the NFPA in 1979 and updated every three years, the *NFPA 70E Standard for Electrical Safety in the Workplace* is the authoritative "how-to" guide for establishing electrical safety-related work practices, maintenance requirements, and the administrative controls necessary to keep employees safe from electrical hazards in the workplace. The standard focuses on electrical safety for installation, inspection, operation, maintenance, and demolition of electric conductors, electric equipment, signaling, communications conductors and equipment, and raceways. It also details interaction and electrical hazard exposure to workers not in the electrical trades; including unintentional contact with overhead power lines and electric shock from machines, tools, and appliances.

OSHA and the judicial system use NFPA 70E Standards as the measuring stick for electrical safety compliance in the workplace. Businesses that don't adhere to OSHA laws or align their electrical safety practices with NFPA 70E Standards open themselves up to a myriad of negative consequences. From injuries and fatalities, to huge fines and lawsuits, business owners and managers need to understand the importance of electrical safety compliance in protecting their employees and keeping their bottom line in the black.

In this paper, we will review NFPA 70E as it relates to workplace safety, explore statistics relevant to electrical hazards, injuries, and fatalities, and address the ways in which code adherence can assist in creating safer work environments.

Common Electrical Hazards

The most common electrical injuries suffered by workers are electrical shock, burns, arc flash, and arc blast.

Electrical Shock—this is the most prevalent injury related to electric current exposure; effects of electrical shock vary depending upon amperage and can range from a slight tingling sensation to severe burns, full-blown cardiac arrest, or death.

Burns—they are the most common electrical shock-related injury; because the body is such an effective electricity conductor, it doesn't take long for severe burns to result from even a mild electrical shock.[3]

Arc Flash—arc flash happens without warning and can occur anytime a flashover of electric current leaves its intended path and travels through the air from one conductor to another, or to ground. Arc flash can result in serious and even fatal burns, depending upon the worker's distance from the initial flash. This flash can cause a violent explosion known as an arc blast.

Arc Blast—during an arc blast, conductive material can be vaporized by arc temperatures reaching upward to 35,000 degrees Fahrenheit; high energy arcs can melt metal fragments which then become molten flying particles. Even low energy arcs can cause explosions in areas where explosive gas, vapor, or dust is present.[4] Arc blasts are responsible for serious injuries and fatalities, ranging from eye and ear damage, to workers being thrown, their clothing, skin, or hair catching fire, falling off of equipment, or breathing in hot vaporized particles.

Statistics from the National Institute for Occupational Safety and Health (NIOSH) indicate that five to ten arc flash explosions occur in electrical equipment every day in the United States. These accidents send more than 2,000 workers to burn centers with severe injuries each year.

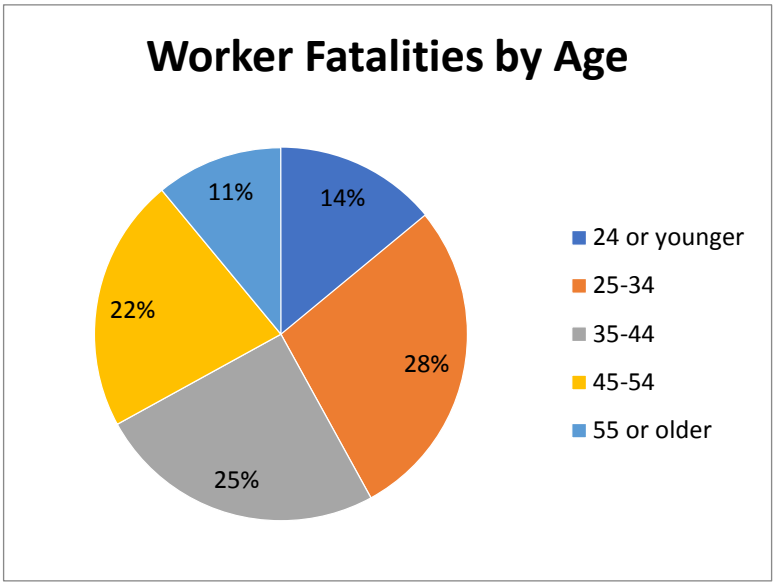
Due to the violent nature of arc flash exposure and arc blast injuries, it's not uncommon for an injured employee to never regain their past quality of life. It's estimated that the cost of extended medical care, which is often required, costs in excess $1 million dollars per injury.[5]

Electrical Fatalities and Injuries

Electrical fatalities and injuries happen every year. Statistics from the U.S. Department of Labor Statistics' Census of Fatal Occupational Injuries reports 1,962 electrical-related fatalities occurred between 2004-2013.

Industry	Number of Fatalities
Construction	923
Professional and Business Services	258
Trade, Transportation and Utilities	210
Natural Resources and Mining	197
Manufacturing	155

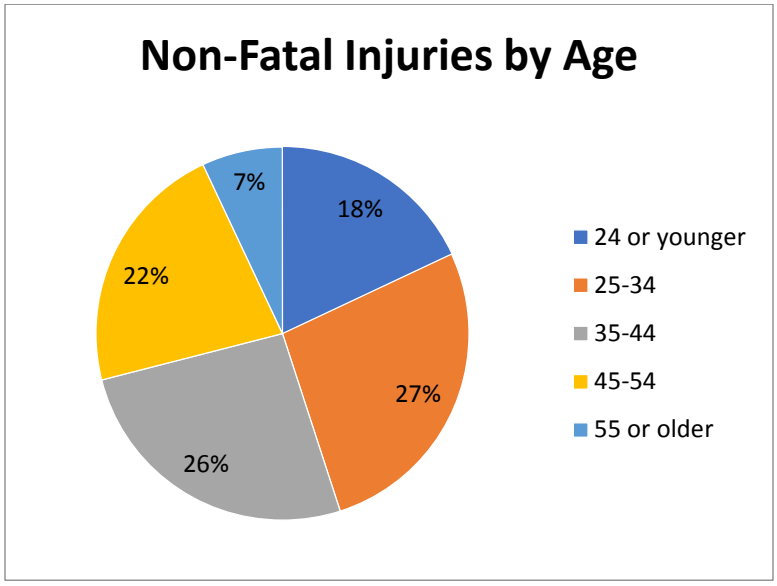
Data shows the construction industry had the largest number of electrical fatalities, with 923[6]; 99 percent of injuries were electrocutions, with the remaining 1 percent resulting from burns. Men suffered 99 percent of fatal electrical injuries, and men ages 25-34 suffered the greatest number of fatalities. See the chart below for additional information.



Non-Fatal Injuries

The U.S. Bureau of Labor Statistics reports more than 20,000 non-fatal injuries occurred between 2003-2010 due to contact with electric current.

Men were more likely to be injured (81 percent) compared to women (19 percent). Workers in the construction and extraction occupations experienced the largest share of electrical injuries with 30 percent of the total. The leading non-fatal injury event (37 percent) was identified as contact with electric current from a machine, tool, appliance, or light fixture. Men in the 25-34 age group suffered the greatest number of non-fatal injuries. See the chart below for additional information.



Economic Effects on Business: the Cost of Fatalities and Injuries

The physical and emotional toll of electrical fatalities and injuries is in itself devastating to workers, but when these unfortunate events occur, businesses also feel severe economic repercussions.

As a Federal enforcement agency, OSHA conducts inspections and assesses fines on businesses that are non-compliant with workplace health and safety laws and regulations. OSHA conducts these inspections based on a number of criteria, including referral from a local or state agency, employee complaints, if it's a high-hazard industry or business, inspections at random, or follow-up inspections.

OSHA fines are expensive and are meant to penalize businesses who don't take seriously the health and safety of their workers. Law requires businesses to report all work-related fatalities to OSHA within eight hours and all work-related inpatient hospitalizations, amputations, or losses of an eye within 24 hours.

OSHA fines start at $12,934 per serious violation and can increase to $129,336 per violation if found to be willful or repeated. In addition, violations occurring beyond a set abatement date can be charged on a per-day, per-violation basis.

OSHA figures from 2016-2017 show that all companies who made the list of top 10 largest fines during this time frame paid at minimum, more than $500,000 in OSHA fines. The largest fine issued was $2.6 million to a company where a worker was crushed to death inside a machine. Failure to use energy control procedures to prevent machinery from starting during maintenance and servicing was one of the 23 willful, serious, and other-than-serious violations, including 19 egregious instance-by-instance willful violations, for which the company was cited.

The list of *OSHA's Most Frequently Cited Violations* sadly includes *Lockout/Tagout* at number 5 and *Electrical–Wiring Methods*, at number 10.

OSHA's 'Top 10' List of Most Frequently Cited Violations (2016-2017)	
Ranking	**Number of Violations**
1. Fall Protection – General Requirements (1926.501)	6,072
2. Hazard Communication (1910.1200)	4,176
3. Scaffolding (1926.451)	3,288
4. Respiratory Protection (1910.134)	3,097
5. Lockout/Tagout (1910.147)	2,877
6. Ladders (1926.1053)	2,241
7. Powered Industrial Trucks (1910.178)	2,162
8. Machine Guarding (1910.212)	1,933
9. Fall Protection – Training Requirements	1,523
10. Electrical – Wiring Methods (1910.305)	1,405

Source: National Safety Council Safety and Health Magazine

In addition to OSHA fines and lost productivity, in the case of an injury or fatality, companies often face lawsuits; they pay medical and legal expenses and worker's compensation. They pay to repair or replace damaged property or equipment. There are administrative costs, plus training and compensation for replacement workers. These businesses also experience higher employee absenteeism and turnover due to decreased morale and concern that the employer doesn't value worker safety.

Avoiding Electrical Injuries
A good look at harsh statistics proves the importance of adhering to electrical safety standards and abiding by the law. No one wants an OSHA inspector conducting an injury or death investigation at their business.

Working on or near energized equipment obviously brings a level of risk to the worker, but risk mitigation processes and practices can make situations safer and allow work to be completed without electrical injury. The NFPA 70E Standard is the primary resource for helping employers establish and follow the safe work practices needed to minimize the probability of incident or injury.

Injuries, fatalities, arc flash, and arc blast incidents, including electrocution and burns, could all be mitigated by following the standards laid out in the guide. NFPA 70E should be used to address and establish safety processes and practices, procedures, and program controls to mitigate electrical risks and hazards.[7]

Key Elements of the Standard
The NFPA 70E Standard includes the following elements. To read the full NFPA 70E Standard text, including all requirements, visit the NFPA website at www.nfpa.org.

General Requirements for Electrical Safety-Related Work Practices
NFPA 70E establishes requirements for electrical safety-related work practices, which includes training employees to recognize and identify electrical hazards, and to know the safety-related work practices and procedures required to provide protection from these hazards. Employees are certified to the level of training provided, which also determines the tasks that employee is qualified to perform.

Electrical Safety Program
NFPA 70E requires employers to document and implement an electrical safety program that directs employee activities in a manner appropriate for the different voltage, energy level, and circuit conditions that may be encountered. Read full details in NFPA 70E section 110.0.

The safety program must include all electrical safety procedures, be documented, and made available to all employees. Highlights include:

- **Inspection**–verify that all electrical elements installed or modified have been inspected and meet code requirements.

- **Condition of Maintenance**–develop a plan to maintain electrical equipment and systems.

- **Awareness and Self-Discipline**–provide employees with awareness of potential electrical hazards; instill in employees safety principles and controls so they abide by safe electrical practices while working on or near electrical equipment.

- **Electrical Safety Program Procedures**–identify procedures which must be implemented prior to work being started by an employee exposed to electrical hazards.

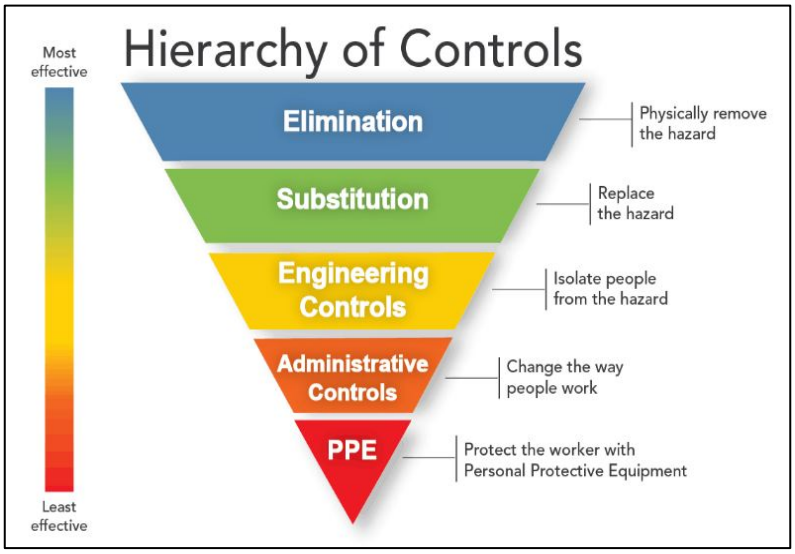
- **Risk Assessment Procedure**–this process should be used by an employee prior to starting work near electrical hazards:

    1. Identify hazards.
    2. Assess risks.
    3. Implement risk control according to the hierarchy of risk control methods.

- **Human Error**–account for potential human error and its negative consequences on people, processes, work environment, and equipment.

- **Hierarchy of Risk Control Methods**–detailed later in this document, this is an important element of a safety program; it establishes the most effective methods to reduce risk, injury, and death. This includes:

    1. Elimination
    2. Substitution
    3. Engineering controls
    4. Awareness
    5. Administrative controls
    6. PPE



National Institute for Occupational Safety and Health (NIOSH)

- **Job Safety Planning**–created by a qualified person, it is documentation that takes all aspects of the job into account. This includes a job and task description, identification of electrical hazards, conducting shock risk and arc flash risk assessments, listing work procedures involved, noting any special precautions and risk control methods.

- **Job Briefing**–conduct a job briefing that covers the safety plan and permit information (if applicable), prior to the start of any work.

- **Change in Scope**–conduct an additional briefing should changes occur during the course of the work that might affect employee safety.

- **Incident Investigations**–include elements within the program to investigate electrical incidents.

- **Electrical Safety and Field Work Audits**–audit both the electrical safety program and field work to ensure NFPA 70E compliance and that work is performed in accordance with the safety program principles and procedures.

- **Lockout/Tagout Program and Procedure Audit**–conduct the required annual audit of NFPA 70E-required lockout/tagout program and procedures to identify and correct deficiencies in lockout/tagout program and procedures, training, and worker execution. The audit must include at least one lockout/tagout in progress.

NFPA 70E also states that safe work practices consistent with the nature and extent of the associated electrical hazards shall be used to safeguard employees from injury while working on or near exposed electrical or circuit parts that are or can become energized. Two primary conditions are identified and addressed:

1. **Energized Electrical Conductors and Circuit Parts – Safe Work Condition:**
   Any electrical equipment or circuits greater than 50 volts must be de-energized—placed into an electrically safe work condition—before employees can work on or near them, unless work on energized components can be justified according to section 130.2—*Electrically Safe Work Conditions*.

2. **Energized Electrical Conductors and Circuit Parts – Unsafe Work Condition:**
   Only qualified persons may work on electrical conductors or circuit parts that have not been put into an electrically safe work condition. Working on energized equipment should always be the exception rather than the rule. When this occurs, an energized electrical work permit is required and should be documented.

Hierarchy of Risk Control Methods

Because the most effective method to prevent electrical injury is to completely remove the source of electrical energy—de-energize—and eliminate the possibility of its reappearance, workers must identify and disconnect all possible sources of electricity. NFPA 70E details this process in seven steps:

1. Identify and locate all possible electric supply sources. Care should be taken to identify the possible presence of secondary sources.

2. Properly interrupt the load current(s) and open the disconnecting device(s). Not all disconnecting devices are rated to interrupt load currents; this should only be done with a properly rated device.

3. Verify de-energization through visual inspection of the disconnect contacts. Disconnect may sometimes fail to open all phase conductors when the handle is operated, so it is necessary to verify physical contact separation. If this requires removing the disconnect door or cover, appropriate PPE must be used.

4. Release stored energy; release or block mechanical energy.

5. Apply lockout/tagout devices. This should be done in accordance with a formally established company policy.

6. Use an adequately rated portable test instrument to test each conductor to which the worker may be exposed in order to verify de-energization. The voltage detecting device must be functionally tested both before and after taking the measurements in order to ensure that it is working satisfactorily.

7. Circuit parts with induced voltages or stored electrical energy must be grounded. If the conductors being de-energized could contact other energized conductors or circuit parts, temporary grounding devices rated for the available fault duty should be applied.

Work Involving Electrical Hazards

NFPA 70E states that working on or near energized equipment should be a last resort when there is no other option available. Working on energized parts at 50V or more should only be performed if the employer can demonstrate that de-energizing will introduce additional hazards or is not feasible due to equipment design or operational limitations. When this situation arises, a detailed work permit must be obtained and approved by a responsible manager, safety officer, or owner. Further information about securing a work permit is contained in the NFPA 70E Standard.

Common Excuses for Unsafe Work on Energized Equipment

Research shows that many electrical injuries occur when equipment or fixtures are not de-energized prior to the start of work.[8]

The most common reasons for lack of de-energization are:

- Workers rushing to complete a job or feeling pressure to stay on schedule
- Worker doesn't believe there is a risk in making a repair to a low amperage fixture
- Building owners or managers don't want the power in the building or facility shut down
- Worker has macho attitude toward working live

Approach Boundaries and Arc Flash Assessments
NFPA 70E provides life-saving detailed information and tables to help establish approach boundaries that minimize the possibility of electrical shock, perform an arc flash assessment, and establish arc flash protection boundaries. See NFPA 70E Article 130 for details.

Personal Protective Equipment (PPE)
If the electrical hazard cannot be eliminated and the employee must work on or near energized electrical equipment, the employer must provide appropriate PPE.

The type of PPE required for electrical work depends upon the work being performed, the type and electrical characteristics of the equipment, and the distance to the equipment. PPE ranges from simple safety glasses and hard hat, to fully-insulated arc-rated gloves, headwear, clothing, and boots, depending upon the level of protection needed.

NFPA 70E provides tables with PPE requirements based on calculated arc-flash boundaries for both AC and DC electrical systems. Categories are based on a minimum arc rating calculation and range from Category 1 to 4 as the risk increases.

PPE requirements for each of the four categories are similar in that they all require suiting up in arc-rated clothing and other standard protective equipment, but vary significantly in the arc rating the clothing must provide, with Category 1 being 4 cal/cm^2 and Category 4 being 40 cal/cm^2.

A sample from one of the tables can be found below. Full, detailed tables are found in NFPA 70E.

Equipment	Arc-Flash PPE Category	Arc-Flash Boundary
Panelboards or other equipment rated 240 volts and below Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	1	485 mm (19 in.)
600-volt class motor control centers (MCCs) Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	4	4.3 m (14 ft.)

Sample from Table 130.7 (C) (15) (a)

Conclusion

Electrical injuries and fatalities are tragic, but made worse when after an investigation, we learn that the tragedy could have been prevented had proper safety procedures and protocols been followed; or if alternative equipment had been used to eliminate the hazard.

OSHA laws and NFPA 70E Standards exist to educate workers and managers about safety, hold businesses accountable for negligent practices, and provide hazard and risk remediation to protect lives.

Educate yourself, your co-workers, and managers about safe electrical practices. Study, understand, and stay up-to-date on the latest changes in NFPA 70E Standards. Join a professional organization, attend conferences and seminars, and keep up with the latest advancements in equipment and best practices in your profession.

Most importantly, always strive to eliminate the hazard. When that isn't possible, never take chances while working on or near electrical equipment; regardless of how inconvenient they may be, always follow safety protocols and procedures. A life depends upon it.

About MELTRIC

Franklin, Wis.-based MELTRIC manufactures a comprehensive line of industrial plugs and receptacles, including UL/CSA switch-rated plugs and receptacles that meet NFPA 70E requirements, enable fast and easy plug and play equipment changeouts, and easy lockout/tagout. Visit www.meltric.com to learn more about our industry-leading products.

References

1. U.S. Bureau of Labor Statistics. (2017). *Fatal occupational injuries for selected events or exposures, 2011-16, Table 2*. Retrieved from Internet 7-2018: https://www.bls.gov/news.release/cfoi.t02.htm.

2. National Fire Protection Association. (2018). *About Us*. Retrieved from Internet 7-2018: https://www.nfpa.org/About-NFPA.

3. Foris, L. A., & Huecker, M. R. (2017) *Electrical Injuries*. Retrieved from Internet 7-2018: www.ncbi.nlm.nih.gov/books/NBK448087.

4. EFCOG Electrical Safety Improvement Project. (2000). *Electrical Safety Hazards Awareness Study Guide.* Retrieved from Internet 7-2018: https://www.lanl.gov/safety/electrical/docs/elec_hazard_awareness_study_guide.pdf.

5. Train the Trainer's Guide to Electrical Safety for General Industry. Workplace Safety Awareness Council. 2011. https://www.osha.gov/dte/grant_materials/fy07/sh-16615-07/train-the-trainer_manual2.pdf.

6. Campbell, ScD, R. B. & Dini, P.E., D. A. Fire Protection Research Foundation. (2015). *Occupational Injuries from Electrical Shock and Arc Flash Events Final Report.* Retrieved from Internet 7-2018: https://www.nfpa.org/-/media/Files/News-and-Research/Resources/Research-Foundation/Research-Foundation-reports/Electrical/RFArcFlashOccData.ashx?la=en.

7. National Fire Protection Association. (2018). *NFPA 70E Standard for Electrical Safety in the Workplace.®*

8. McMann, M., Hunting, K. L., Murawski, J., Chowdhury, R., & Welch, L. (2003). *Causes of Electrical Deaths and Injuries among Construction Workers*. American Journal of Industrial Medicine 43:398-406. Retrieved from Internet 7-2018: https://onlinelibrary.wiley.com/doi/full/10.1002/ajim.10198.