

Electrophysics Resource Center: **Infrared Inspection**

White Paper: **Improved Safety During Infrared Inspections of Electrical Equipment**



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Improved Safety During Infrared Inspections of Electrical Equipment

Introduction

The risk of an arc flash occurring is real and statistics show that there are 5 to 10 serious arc flash incidents everyday in North America. These incidents result in approximately 2,000 workers being treated in burn centers annually.



Image from EWB Engineering, LLC

There are many risks associated with the infrared inspection of electrical equipment. Those risks include not only shock, but burn injuries from arc blasts. Arc flash accidents can cause serious burns and in some cases death. The risks associated with an arc flash were first introduced to the industry by Ralph Lee in the early 1980's with his publication of, "The Other Electrical Hazard: Electric Arc Blast Burns." The risk of an arc flash occurring is real and statistics show that there are 5 to 10 serious arc flash incidents everyday in North America. These incidents result in approximately 2,000 workers being treated in burn centers annually. Many more workers suffer less severe injuries resulting in only emergency room treatment. It is estimated that these incidents cost organizations hundreds of millions of dollars annually.

Safety standards adopted by the NFPA and OSHA provide workers with guidelines for reducing risk while inspecting electrical equipment. At the heart of these guidelines is the NFPA 70E, which is a standard that outlines electrical safety requirements that are necessary for safeguarding employees during various workplace activities, including not only safe practices, but proper protective equipment based on risk. The 2009 edition of this standard includes new information intended to further improve workplace safety.

The Hazards of Electrical Inspection

Electrical inspectors face many hazards. Hazards can occur from shock, electrocution, arc flash, arc blast, and more. These dangers are very real. In fact, every day in the US one person dies from shock, electrocution, arc flash, and arc blast. Additionally, some 8,000 workers are treated each year in emergency rooms for electrical contact injuries.



Image from Arc Flash Information Resource Center

Of these injuries, burns are the most common. Burns can result from a variety of reasons including electrical burn, arc burn, or thermal contact burn. Of these, electrical burns are the most serious in nature and require immediate medical attention.

Electrical burns result from the flow of electric current through tissue and/or bone. The flow generates heat that damages tissue. Arc flash burns result from the intense heat generated from the flash occurring near the victim's body. Thermal contact burns occur from contact with heated components.

What is an Arc Flash?

An arc flash is a release of electrical energy that can be hotter than the sun and more powerful than eight sticks of dynamite.

An arc flash is a release of electrical energy that can be hotter than the sun and more powerful than eight sticks of dynamite. An arc flash or fault is essentially a short circuit (a phase-to-phase or phase-to-ground fault) where the air becomes the conductor. Arc flashes can be triggered by a variety of conditions including:

- air movement
- dust,
- contact surface corrosion,
- racking of breakers,
- fuse replacement,
- loose connections,
- insulating material failure, and,
- conductor contact



An arc flash results from a rapid release of energy occurring when there is sufficient voltage in an electrical system and a path to either ground or a lower voltage is present. The arc flash has to be started manually by something either creating the path of conduction or a failure in a system such as a breakdown in insulation. Generally, arc faults occur in systems with a bus voltage in excess of 120 volts, as lower voltage levels are not powerful enough to sustain an arc.

During the initial flash, the cause of the fault normally burns away allowing for the sustainment of the arc fault by the establishing of highly conductive plasma. The resulting plasma arc will conduct as much energy as is available, limited only by the impedance of the arc itself. Arc flashes can vary in intensity and duration.

Because of the massive energy discharge, components can burn away vaporizing the copper and causing an explosive volumetric increase in the arc blast, which can be conservatively estimated as an expansion of 40,000 to 1. The resulting fiery explosion creates deadly shrapnel heated to extreme levels that can destroy everything in its path.

Who is the NFPA,
OSHA, and why
do they care about
worker safety?



NFPA

Founded in 1896, the National Fire Protection Association (NFPA) is an international nonprofit organization dedicated to reducing the worldwide population's burden on its quality of life resulting from fire and other hazards. The NFPA accomplishes this by developing and advocating standards and consensus codes, in addition to conducting research, training, and education.

The NFPA's membership includes more than 80,000 professionals from approximately 100 nations worldwide. The NFPA is responsible for as many as 300 codes and standards that establish criteria for building, processing, design, service, and installation of equipment in an effort to minimize the risk and effects of fire and other hazards worldwide.



OSHA

The Occupational Safety & Health Administration (OSHA) is a federal agency that was founded in 1970 to ensure that the safety and health concerns of all American workers are being met. Since the agency was established, workplace fatalities have dropped by 62 percent and injury rates have declined by 40 percent. OSHA has accomplished this by developing and enforcing workplace standards. Additionally, OSHA provides training and educational programs for organizations of all sizes.

The NFPA and OSHA work together to provide a safer workplace for all. OSHA provides the legislation and regulations for worker safety regarding electrical hazards. The NFPA's role is to provide detailed guidance of OSHA's requirements. NFPA 70E details the electrical aspects of workplace safety.

OSHA 1910.132(d), and 1926.28(a) requires employers to assess electrical hazards in the workplace. Additionally, they must select, have, and use the correct Personal Protective Equipment (PPE), in addition to documenting the assessment. While OSHA does not enforce the NFPA 70E, any employer that uses the standard for their hazard/risk assessment, and follows the guidelines for PPE as stated in the NFPA 70E standard is typically considered to be in compliance with the Hazard Assessment and Equipment Selection OSHA Standard as well.



Image from Construction Book Express



Image from the Electricity Forum

WARNING	
Arc Flash and Shock Hazard Appropriate PPE Required	
1' - 8.7" 27.7 #4	Flash Hazard Boundary cal/cm ² Flash Hazard at 18 Inches PPE Level Cotton Underwear + FR Shirt & Pants + Multi Layer Flash Suit
480V 0' - 8" 0' - 4.5" 0' - 3.6"	Voltage Shock Hazard When Cover Is Removed Limited Approach Restricted Approach Prohibited Approach
Equipment: MDP	

Image courtesy of Dolphin Software

NFPA 70E

The NFPA 70E's goal is to protect electrical safety professionals while working around devices capable of generating an arc flash.

The NFPA 70E is the standard for safe electrical work practices published by the NFPA in response to OSHA safety requirements. Compliance with NFPA 70e is voluntary; however, OSHA does reference and recognize the standard.

The NFPA 70E's goal is to protect electrical safety professionals while working around devices capable of generating an arc flash. Additionally, it provides detailed safety practices for organizations that install, repair, and maintain electrical systems.

The NFPA 70E addresses four areas:

- safety related work practices,
- safety related maintenance requirements,
- safety requirements for special equipment, and,
- safety requirements for installation of equipment.

The NFPA 70E standard was originally released in 1979, and was intended to assist OSHA in preparing a set of consensus standards that could be used as a basis for evaluating electrical safety in the workplace. Through the years, there have been several revisions and the NFPA 70E Standard has become the standard for safe work-practices throughout the world. The revision in 2000 clarified the PPE requirements and required flame resistant clothing to protect workers from the hazards associated with an arc flash. The most recent version also included PPE changes that eliminated the allowance for cotton jeans and protective eye glasses as acceptable for Level 1, specifying that PPE clothing and a face shield are now required. Over the last nine years, there have been several revisions each with updated protective recommendations.

The latest version, released in 2009, introduced several changes including new PPE suggestions and most notably for thermographers the addition of infrared thermography as a task noted in the Hazard/Risk Classification (HRC) Table 130.7(C) (9).

Table of Hazard/Risk Categories for Protective Clothing

Hazard / Risk Category	Clothing Description
0	Non-melting, flammable materials (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a fabric weight at least 4.5 oz/yd ²
1	Arc-rated FR shirt and FR pants or FR coverall
2	Arc-rated FR shirt and FR pants or FR coverall
3	Arc-rated FR shirt and pants or FR coverall, and arc flash suit selected so that the system arc rating meets the required minimum
4	Arc-rated FR shirt and pants or FR coverall, and arc flash suit selected so that the system arc rating meets the required minimum

One of the most relevant changes for infrared inspection workers is associated with work permits for energized circuits.

Previously, the standard did not specify whether a work permit was required for inspections that did not alter the enclosure, such as looking through an IR window. The new standard however, specifies that no permit is required if the enclosure is not disturbed.

One of the most relevant changes for infrared inspection workers is associated with work permits for energized circuits. Previously, the standard did not specify whether a work permit was required for inspections that did not alter the enclosure, such as looking through an IR window. The new standard however, specifies that no permit is required if the enclosure is not disturbed.

The NFPA 70E advocates a complete arc flash hazard analysis prior to inspection of electrical equipment. In the event that a complete analysis has not been completed, the HRC serves as a guide for both workers and managers in selecting proper levels of PPE.

A hazard/risk category rating of 3 has been assigned to “perform(ing) infrared thermography and other non-contact inspections outside the restricted approach boundary” which is equal to “opening hinged covers (to expose bare, energized electrical conductors or circuit parts)” on 1kV to 38kV switchgear. Where the removal of bolted covers is required to allow for inspection of equipment still carries a category 4 hazard/risk ratings in most applications which are 600V and higher.

Best Practices in Infrared Inspection

Many practices can reduce the risk of injury while inspecting electrical equipment. A good preventive maintenance program will reduce the risk of an arc flash occurring from dirty or failing components. Preventive maintenance programs should require that equipment be thoroughly cleaned regularly and have routine inspections performed by properly trained personnel. Further reductions in risk can be realized through a proper worker training program on safety.

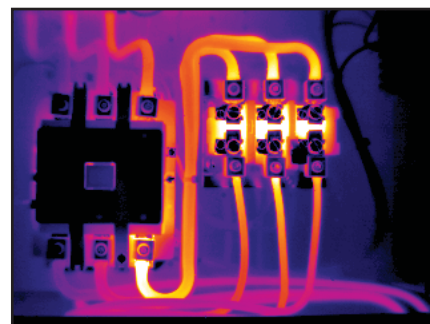
To further mitigate risk the NFPA 70E recommends that a Hazard/Risk analysis to determine the shock and arc flash boundaries, be conducted prior to working on or inspecting electrical equipment, which must be conducted by a qualified electrical engineer.

The flash protection boundary is based on the voltage, available fault current, and the time it takes for the protective device to operate and clear the fault and is considered to be the safe approach distance from energized equipment or parts.

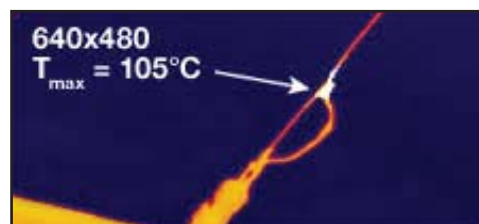
Additionally, a Hazard/Risk analysis will determine the proper level of PPE to be used by inspectors, in addition to determining the voltage to which personnel will be exposed. Shock protection boundaries are identified as either limited, restricted, or prohibited for various distances associated with various voltages. The NFPA 70E Table 130.7-C9a provides guidelines for most situations where a complete analysis cannot or has not been completed. Some applications will always require an analysis prior to inspection.

It is generally acknowledged that one of the safest and most effective ways to inspect electrical equipment is thermal imaging. Thermal imaging provides a hands-off approach to inspection and can identify problems that may not be identifiable through traditional means.

Infrared cameras can be used to locate and identify problems in electrical systems and have been commonplace in inspection for many years. One of the typical symptoms of system problems is overheating in connections and conductors. Overheating can occur as the result of increased resistance, loose or corroded connections, or simply load imbalances. In these cases, an infrared camera can quickly and easily identify these problems from a safe distance. In addition to preventing accidents, thermal imaging can reduce down time caused by equipment failure and increase overall safety.



Over the last few years, infrared camera technology has provided for greater resolution in images. This allows for thermal inspection of smaller parts and connections within the systems. Additionally, larger areas can be inspected while maintaining resolution and provides for a better picture of the systems health as a whole. Rather than having to look at several images of one system a single image can be captured easing analysis of captured images.



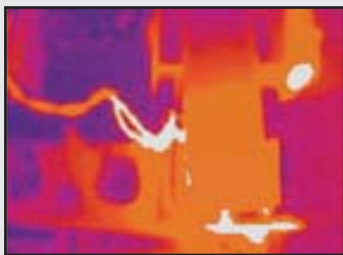
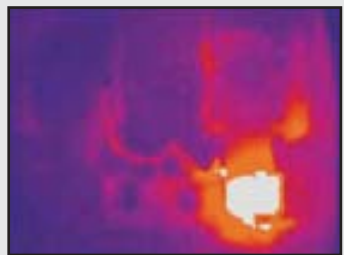
Additionally, image fusion can be used to provide an easy to read image. Image fusion, fuses an infrared image with a standard image to aid in viewing of the images. Image fusion makes the image easier to read by giving the parts not being inspected a more traditional look and allows the reader to focus on the inspected parts.



One of the biggest obstacles to thermal imaging for inspections is cabinet design. Thermal inspections are more effective when performed on systems that are under peak or heavy loads and require complete line of sight access to the systems being imaged often-requiring inspectors to open cabinets or enclosures and providing a higher level of risk to inspectors, and is counter to the methods suggested by NFPA 70E.



To counter these problems infrared windows can be installed and eliminate many of the risks associated with live inspections of electrical systems. Infrared windows allow inspectors to inspect the systems without the need to open up the enclosures, thus reducing risk and PPE requirements levels as the enclosure remains closed. Inspection via these windows can eliminate 99% of the arc flash triggers while conducting a thermal inspection because the enclosure remains closed.

Image of Hot Fuse Clip <i>Clear View</i>	Image of Hot Fuse Clip <i>Thru 2" Window</i>
	
Images taken through IR windows showing issues due to load imbalance, hot connections, etc.	

Conclusion

The inspection of live electrical systems is dangerous and accidents can be serious or even fatal. The danger levels associated with electrical systems inspections can be mitigated dramatically by utilizing proper safety techniques and thermal imaging inspections. Thermal imaging offers the ability to remain outside safety boundaries while identifying problems within a system. The advent of new higher resolution infrared cameras also allows for the inspection of smaller parts from greater distances. The addition of installed infrared windows in enclosures can further reduce the risks and requires fewer workers for inspections.

References

1. For a complete understanding and a review of the NFPA 70E, visit the NFPA web site at www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=70E
2. "NFPA-70E 2009 and the IR Professional", The Snell Group, 2009.

IMAGE USE SOURCES

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Arc Flash Information Resource Center (www.arcflash.me)
A+ Electrical Safety Equipment (www.aplusafety.net)
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