WHEA September 21 Webinar

Maintaining Medium/High Voltage Switchgear

NEI Electric Introduction

Joe Bembnister

Joined NEI Electric in 1997 and is the Senior Vice President out of the Eau Claire, WI shop. He is a State of Wisconsin Designer of Electrical Systems and a Master Electrician with over forty years of experience in the Electrical Construction Industry.

NEI Electric has three locations

- St. Paul, MN
- St. Croix Falls, WI
- Eau Claire, WI

Webinar Disclosure

This is not to be considered training but an informational webinar.

We will be covering some aspects of NFPA 70B, Electrical Equipment Maintenance, along with NFPA 70E, Electrical Safety in the Workplace.

You will not be qualified to work on electrical equipment solely because you attended this webinar.

Electrical Preventive Maintenance (EPM)

Electrical Preventive Maintenance (EPM)

Electrical equipment deterioration is normal and equipment failure is inevitable.

Switchgear maintenance is something often over looked in preventive maintenance programs. Due to most systems high reliability, some components can go decades with very little notice. This could be a costly and dangerous mistake.

An unplanned outage could take a facility out of service for months depending on the severity of the failure.

Example of catastrophic failure of Medium Voltage Switchgear

Electrical Preventive Maintenance (EPM)

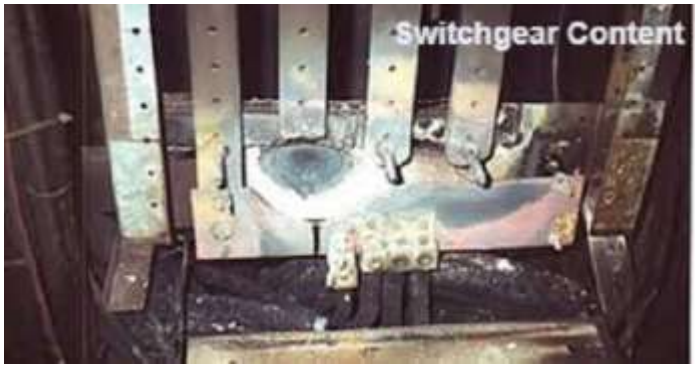
Cause of Switchgear Failure

Dust - can collect in switchgear easily due to the constant air flow thru most systems. Most switchgear cabinets use convection for cooling which uses vents at the top and bottom of the gear to allow air to freely flow up through the gear.

While an effective means of cooling, this setup allows for the accumulation of dust on components. Dust on interior surfaces can produce paths for electricity to track back to grounded surfaces especially if moisture or conductive dust are present. Dust can also collect on contact surfaces causing poor connections. Poor connections can increase resistance there by producing heat. Dust and any other debris should be cleaned from the gear on a regular schedule.

Electrical Preventive Maintenance (EPM)

Moisture/Humidity - High humidity, condensation and leaks from nearby pipes, ducts and roof leaks can all be a source of water issues. Even small amounts of moisture can cause corrosion on mechanical components which might cause them to not function as intended. Corroded connection points can be a source of heating due to the high resistance of the corrosion. Any signs of water issues should be dealt with immediately.



Electrical Preventive Maintenance (EPM)

Overheating - Excessive heat in switchgear can be caused by several things. Poor connections on contact surfaces as pointed out previously. Heat can also be produced by lose of torque on bolted connections.

This can happen several ways. The bolted connection might not have been torqued properly in the initial installation. The bolted connection may have lost its torque due to a heavily loaded circuit that has been cycling for years.

The normal expansion and contraction as the metal heats and cools can cause bolts to loosen. Poorly ventilated spaces can cause excessive heat buildup. Heat can degrade or melt lubricants in switchgear components.

Electrical Preventive Maintenance (EPM)

Aging - The age of the switch gear can have a large effect on its function. Lubricants can dry out over time. This can cause mechanical components to not function properly such as disconnect blades not opening or fully closing.

Example of a Aged/Rusted Dry-Type Transformer – ABB.com

Electrical Preventive Maintenance (EPM)

Electrical Preventive Maintenance (EPM)

A preventive maintenance program should be implemented to help identify many of the previous situations. A program such as this helps to identify deficiencies of the equipment and provide corrective means of repair or replacement the equipment.

The NFPA 70 B Annex H suggests maintenance intervals of weekly to 6 years depending on the equipment, system criticality and the environment in which the equipment is located. Most facility engineering staff should have a basic knowledge of the electrical system in their facility and a solid understanding of the hazards involved in maintaining them. If there is any question an outside contractor should be brought in to perform the maintenance.

Electrical Preventive Maintenance (EPM)

Annual Inspection & Testing

Annual Inspection & Testing Process

Perform an IR Survey of the MV/HV equipment.

Complete a Visual Inspection, Cleaning, Mechanical Operation Check

- Surveying for deficiencies, signs of wear, integrity of connective surfaces and cleaning of all equipment and devices surfaces. Then Exercise the Switchgear.
- Clean shall be defined as the removal of all of the following from all inner, outer surfaces and conductive, mechanical, operational gear within:
    1. evidence of moisture or corona.
    2. signs of arcing and tracking
    3. oxidation
    4. particulate debris
    5. adhesive debris
    6. corrosion
    7. excess lubrication, liquids
    8. harborage, nesting, signs of bird-insect-rodent activity
    9. biomass including vegetation, mold
    10. foreign materials or coatings that were not part of the original equipment manufacturer's design
    11. pieces from cracked or damaged parts, tools, fasteners, any non-specification materials or parts within or at bottom of enclosure.

Conductivity Maintenance – ensure conductivity where surfaces connect or meet.

- Tightness will be verified by calibrated torque-wrench method in accordance with manufacturer's published data or ANSI/NETA MTS-2015 tables.
- Remake all connection that require re-torque.
- Contact resistance will be measured with the use of a low resistance ohm meter.

Testing, Adjustments - ensure proper operation of conductive device controls.

- Lubricate and re-exercise all moveable parts
- Adjust alignments, contact surfaces
- Resistance recordings across Circuit Breaker and Fuse attachments
  Exercise Manual trip mechanisms and resets
- Bolted electrical connections will be tested for high resistance. Tightness will be verified by calibrated torque-wrench method in accordance with manufacturer's published data or ANSI/NETA MTS-2015.
- Test for resistance at connections, continuity.

Frequency of Annual Inspection & Testing

APPENDIX B

Frequency of Maintenance Tests

NETA recognizes that the ideal maintenance program is reliability-based, unique to each plant and to each piece of equipment. In the absence of this information and in response to requests for a maintenance timetable, NETA's Standards Review Council presents the following time-based maintenance schedule and matrix.

One should contact a NETA Accredited Testing Company for a reliability-based evaluation.

The following matrix is to be used in conjunction with Appendix B, Inspections and Tests. Application of the matrix is recognized as a guide only.

Specific condition, criticality, and reliability must be determined to correctly apply the matrix. Application of the matrix, along with the culmination of historical testing data and trending, should provide a quality electrical preventive maintenance program.

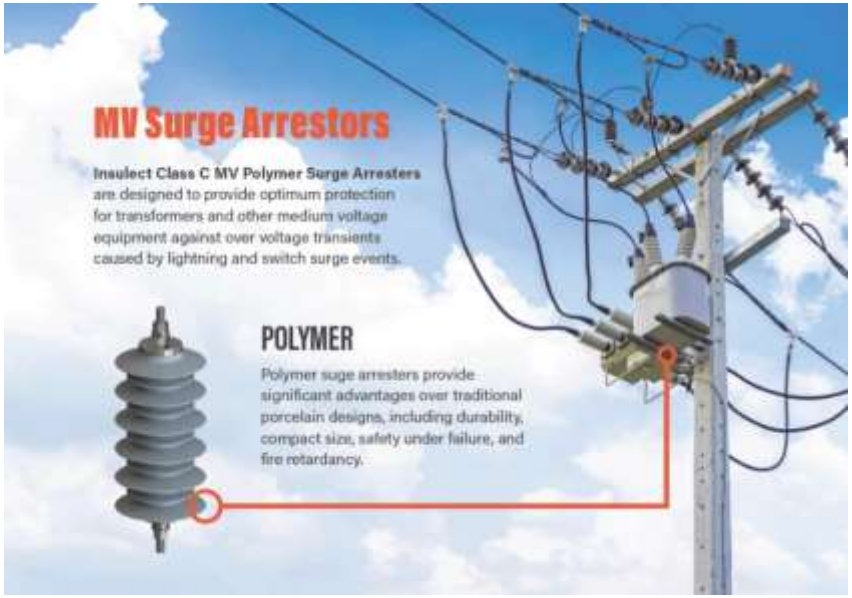
MAINTENANCE FREQUENCY MATRIX				
		EQUIPMENT CONDITION		
		POOR	AVERAGE	GOOD
EQUIPMENT RELIABILITY REQUIREMENT	LOW	1.0	2.0	2.5
	MEDIUM	0.50	1.0	1.5
	HIGH	0.25	0.50	0.75

Frequency of Annual Inspection & Testing

APPENDIX B

Frequency of Maintenance Tests (*continued*)

Inspections and Tests Frequency in Months (Multiply These Values by the Factor in the Maintenance Frequency Matrix)				
Section	**Description**	**Visual**	**Visual & Mechanical**	**Visual & Mechanical & Electrical**
7.9	Protective Relays			
7.9.1	Electromechanical and Solid State	1	12	12
7.9.2	Microprocessor-Based	1	12	12
7.10	Instrument Transformers	12	12	36
7.11	Metering Devices	12	12	36
7.12	Regulating Apparatus			
7.12.1.1	Step-Voltage Regulators	1	12	24
	Sample Liquid	–	–	12
7.12.1.2	Induction Regulators	12	12	24
7.12.2	Current Regulators	1	12	24
7.12.3	Load Tap-changers	1	12	24
	Sample Liquid	–	–	12
7.13	Grounding Systems	2	12	24
7.14	Ground-Fault Protection Systems	2	12	12
7.15	Rotating Machinery			
7.15.1	AC Induction Motors and Generators	1	12	24
7.15.2	Synchronous Motors and Generators	1	12	24
7.15.3	DC Motors and Generators	1	12	24
7.16	Motor Control			
7.16.1.1	Low-Voltage Motor Starters	2	12	24
7.16.1.2	Medium-Voltage Motor Starters	2	12	24
7.16.2.1	Low-Voltage Motor Control Centers	2	12	24
7.16.2.2	Medium-Voltage Motor Control Centers	2	12	24
7.17	Adjustable Speed Drive Systems	1	12	24
7.18	Direct-Current Systems			
7.18.1	Batteries	1	12	12
7.18.2	Battery Chargers	1	12	12
7.18.3	Rectifiers	1	12	24
7.19	Surge Arresters			
7.19.1	Low-Voltage Devices	2	12	24
7.19.2	Medium- and High-Voltage Devices	2	12	24



Frequency of Annual Inspection & Testing

APPENDIX B

Frequency of Maintenance Tests (*continued*)

Inspections and Tests Frequency in Months (Multiply These Values by the Factor in the Maintenance Frequency Matrix)				
Section	**Description**	**Visual**	**Visual & Mechanical**	**Visual & Mechanical & Electrical**
7.20	Capacitors and Reactors			
7.20.1	Capacitors	1	12	12
7.20.2	Capacitor Control Devices	1	12	12
7.20.3.1	Reactors, Dry-Type	2	12	24
7.20.3.2	Reactors, Liquid-Filled	1	12	24
	Sampling	–	–	12
7.21	Outdoor Bus Structures	1	12	36
7.22	Emergency Systems			
7.22.1	Engine Generator	1	2	12
	Functional Testing	–	–	2
7.22.2	Uninterruptible Power Systems	1	12	12
	Functional Testing	–	–	2
7.22.3	Automatic Transfer Switches	1	12	12
	Functional Testing	–	–	2
7.23	Telemetry/Pilot Wire SCADA	1	12	12
7.24	Automatic Circuit Reclosers and Line Sectionalizers			
7.24.1	Automatic Circuit Reclosers, Oil/Vacuum	1	12	24
	Sample	–	–	12
7.24.2	Automatic Line Sectionalizers, Oil	1	12	24
	Sample	–	–	12
7.27	EMF Testing	12	12	12

Hospital Back-up Generators

Medium Voltage Uninterruptible Power Supply – ABB Group

Arc Flash

What is an Arc Flash?

It is an explosive burst of heat and light, caused by a sudden, uncontrolled electrical arc (or current passing through the air). Temperatures may reach as high as 35,000°F in just 1/1000 of a second, vaporizing metal, causing fatal burns, and generating a blast wave that can collapse workers' lungs and rupture eardrums. Shrapnel, toxic gases, and intense UV rays can cause additional injuries. Arc flash accidents can kill in an instant, or cause a long, slow, and painful death. Even non-fatal injuries from an arc flash may require months or years of medical care and therapy.

Arc Flash (Continued)

This video shows Donnie Johnson's brush with an Arc Blast that left him with 3rd degree burns down to his muscles on both arms and hands. He also created a website to promote Arc safety: Donnie's Accident.

Arc Flash (Continued)

This video is of a real life switchgear explosion.

Arc Flash Injuries

Electrical Burns

Entrance Wound: High resistance of skin transforms electrical energy into heat, which produces burns around the entrance point (dark spot in center of wound). This man was lucky, the current narrowly missed his spinal cord.

Exit Wound: Current flows through the body from the entrance point, until finally exiting where the body is closest to the ground. This foot suffered massive internal injuries, which weren't readily visible, and had to be amputated a few days later.

https://www.osha.gov/etools/construction/electrical-incidents/burn-examples

Arc Flash Injuries (Continued)

Arc Flash Burns

This man was near a power box when an electrical explosion occurred. Though he did not touch the box, electricity arced through the air and entered his body. The current was drawn to his armpits because perspiration is very conductive.

Thermal Contact Burns

Current exited this man at his knees, catching his clothing on fire and burning his upper leg.

https://www.osha.gov/etools/construction/electrical-incidents/burn-examples

Arc Flash Injuries (Continued)

Internal Injuries

This worker was shocked by a tool he was holding. The entrance wound and thermal burns from the overheated tool are apparent.

Same hand a few days later, when massive subcutaneous tissue damage had caused severe swelling (swelling usually peaks 24-72 hours after electrical shock). To relieve pressure which would have damaged nerves and blood vessels, the skin on the arm was cut open.

https://www.osha.gov/etools/construction/electrical-incidents/burn-examples

Arc Flash Labels

Arc Flash Label Requirements
from NFPA 70E 2021

NFPA 70E is the accepted industry standard for electrical safety in the workplace. Created by the National Fire Protection Association, it specifies hazard identification practices and warning systems, including labels for arc flash hazards. The most recent edition of the standard is NFPA 70E 2021.

Arc flash labels are described in section 130.5(H), which states that workplace electrical equipment that is likely to be examined, adjusted, or serviced while energized should be labeled with all three of the following:

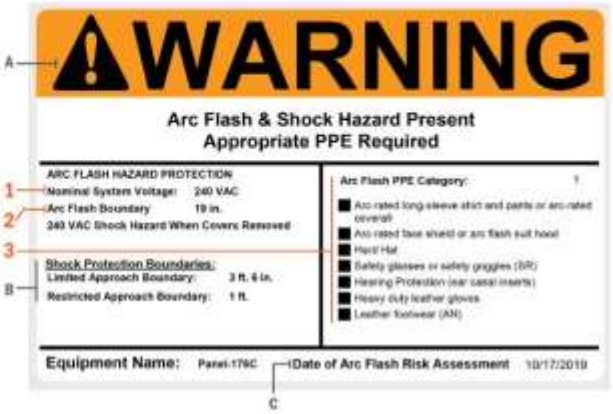
1. Nominal System Voltage - The first label requirement, the nominal system voltage, offers a quick way to assess the potential shock hazard and general degree of danger represented by a system. It can be measured in VAC (volts, alternating current) or VDC (volts, direct current). Common values are 120, 208, 220, and 480, but high-powered systems can use much higher values.

2. Arc Flash Boundary - The second label requirement, the arc flash boundary, is the distance from the equipment at which an unprotected person would receive second-degree burns in the event of an arc flash. Specifically, the energy at that point would be 1.2 calories (5 Joules) of heat energy per square centimeter of exposed area, or 1.2 cal/cm². This distance is calculated in a variety of ways, and the calculation method must be documented, although it does not need to appear on the label.

3. Protective Equipment - The third label requirement provides workers with information about the personal protective equipment (PPE) needed to work on the labeled equipment safely. There are four different choices for this requirement:

- **Available Incident Energy at a Working Distance*** provides the most detailed technical information. With this option, a label displays the amount of thermal energy (usually in cal/cm²) to be expected at a given working distance from an arc fault. With this information, the worker can identify the type of protection needed.
- **Arc Flash PPE Category*** is a "shortcut" for determining PPE requirements. Engineers can look up common equipment and tasks on a table to identify the category, instead of performing detailed calculations. Categories are numbered from 1 to 4, with higher numbers for greater danger, and each category is associated with a prescribed set of PPE. The Arc Flash PPE Categories replace the Hazard/Risk Category (HRC) system from the 2012 edition of NFPA 70E.
- **Minimum Arc Rating of Clothing** details the amount of protection needed to work on the equipment safely, using an Arc Rating (AR) number. These rating numbers, provided by the PPE manufacturer, represent the amount of energy in cal/cm² that can be blocked or absorbed by the clothing.
- **Site-Specific Level of PPE** is a listing of the required PPE using a facility-specific system, such as "ACME Gray-Level Suit" or even a piece-by-piece list of equipment. If this approach is used, it is critical that the listing system in use is documented, and workers are thoroughly trained.

*Because the calculated Incident Energy/Working Distance information may conflict with the generalized Arc Flash PPE Categories, the NFPA does not permit both of these approaches to be used on the same equipment. Otherwise, multiple details are permitted.



Other Label Elements

A. Warning/Danger Header - These labels warn of a hazard that could result in serious injury or death, so they should use an ANSI Z535-compliant header: either an orange band with the word "WARNING" in black, or a red band with the word "DANGER" in white. "Danger" should be used for more serious threats, but the NFPA does not designate an energy level to use as a cut-off point between the two headers. Many facilities use "Warning" where energized work is permitted with appropriate precautions, and "Danger" where sufficient PPE is not available. Whatever the choice, it should be documented and consistent.

B. Shock Boundaries - Most electrical equipment that poses an arc flash hazard also presents a shock hazard, so many arc flash labels also include these boundaries to protect workers from this second concern. The Limited Approach Boundary is a distance from the equipment that should only be crossed by "qualified" (properly trained and equipped) workers, or other workers when they are properly equipped and accompanied by a qualified worker. The Restricted Approach Boundary, which is closer to the equipment, should only be crossed by qualified workers, and only when they have a written and approved plan of action.

C. Date of Risk Assessment - In addition to the specific elements required by NFPA 70E Article 130.5(H), all arc flash labels should include a Date of Risk Assessment. NFPA 70E requires the analysis to be reviewed at least once every five years, or whenever the circuit is altered, and labels must be updated whenever the relevant information has changed. CSA Z462 (the Canadian "sister standard" to NFPA 70E) specifically requires this date to appear on the label.

Arc Flash PPE

Arc Flash PPE Categories from NFPA 70E 2021

The National Fire Protection Association (NFPA) uses four Arc Flash PPE Categories to classify ranges of arc flash hazards, and the corresponding requirements for Personal Protective Equipment (PPE). These categories are one of the methods used in the current NFPA 70E standard to inform workers about the protection they need while working on energized equipment. The Arc Flash PPE Category system replaces the Hazard/Risk Category (HRC) system from the 2012 edition of the standard.

Each category includes a minimum Arc Rating (AR) value for the required PPE. This value is determined by the PPE manufacturer, and indicates the amount of heat energy (in cal/cm²) that the clothing can absorb or block before the wearer would be likely to receive a second-degree burn. (Second-degree burns are expected when skin is exposed to 1.2 cal/cm² of incident energy.)

Category 1 and 2 requirements can often be met with a single layer of arc-rated PPE. To meet category 3 or 4 requirements, multiple layers of PPE may be required. To ensure effective protection, these layers need to be tested together to receive a complete system arc rating.

Before AR became the standard rating system for arc flash PPE, Fire Resistance (FR) was used. FR and AR are not the same: all arc rated PPE is also fire resistant, but not all fire resistant PPE is arc rated.

PPE CATEGORY 1

Minimum Arc Rating of
4 cal/cm²

Arc Rated Clothing:

- AR long-sleeve shirt and pants, or AR coverall
- AR face shield, or AR flash suit hood
- AR jacket, parka, rainwear, or hard hat liner (as needed)

Protective Equipment:

- Hard hat
- Safety glasses or safety goggles
- Hearing protection (with inserts)
- Heavy-duty leather gloves
- Leather footwear (as needed)

PPE CATEGORY 2

Minimum Arc Rating of
8 cal/cm²

Arc Rated Clothing:

- AR long-sleeve shirt and pants, or AR coverall
- AR flash suit hood, or AR face shield and AR balaclava
- AR jacket, parka, rainwear, or hard hat liner (as needed)

Protective Equipment:

- Hard hat
- Safety glasses or safety goggles
- Hearing protection (with inserts)
- Heavy-duty leather gloves
- Leather footwear

PPE CATEGORY 3

Minimum Arc Rating of
25 cal/cm²

Arc Rated Clothing:

- As required: AR long-sleeve shirt, AR pants, AR coverall, AR flash suit jacket, and/or AR flash suit pants
- AR flash suit hood
- AR gloves
- AR jacket, parka, rainwear, or hard hat liner (as needed)

Protective Equipment:

- Hard hat
- Safety glasses or safety goggles
- Hearing protection (with inserts)
- Leather footwear

PPE CATEGORY 4

Minimum Arc Rating of
40 cal/cm²

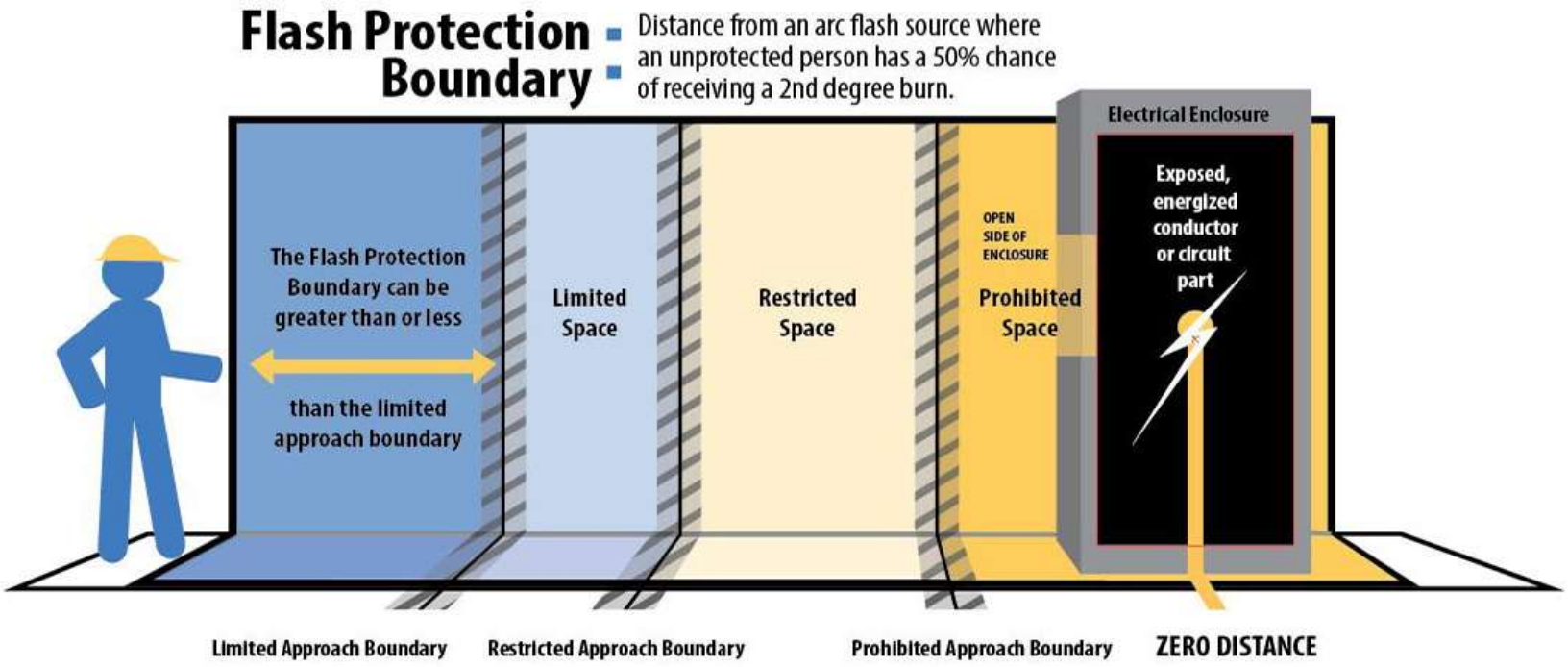
Arc Rated Clothing:

- As required: AR long-sleeve shirt, AR pants, AR coverall, AR flash suit jacket, and/or AR flash suit pants
- AR flash suit hood
- AR gloves
- AR jacket, parka, rainwear, or hard hat liner (as needed)

Protective Equipment:

- Hard hat
- Safety glasses or safety goggles
- Hearing protection (with inserts)
- Leather footwear

Arc Flash Protection Boundary



THANK YOU

Thank you for attending!

If you have any other questions or if a question was not answered, please feel free to email me at jbembnister@neielectric.com.

Hope to see you at **WHEA Technical Exhibition in La Crosse!**

NEI electric

Think safety, work safely.

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