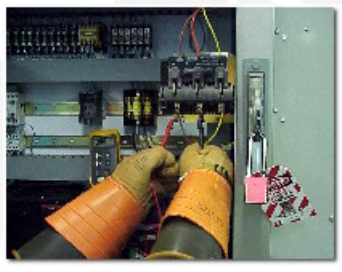
Electrical Safety Program

NFPA 70E



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Arc Flash Hazards

- **Electric arcs produce some of the highest temperatures known to occur on earth – up to 35,000 degrees Fahrenheit. This is four times the surface temperature of the sun**
- **All known materials are vaporized at this temperature. When materials vaporize they expand in volume (Copper – 67,000 times, Water–1670 times). The air blast can spread molten metal to great distances with force.**
- **Rapidly expanding gases, extreme pressure and sound waves, molten metal and metal plasma.**

Arc Flash Hazards

- **Pressure: Blast pressure waves have thrown workers across rooms and knocked them off ladders. Pressure on the chest can be higher than 2000 lbs/ sq. ft. – blows clothing off body.**
- **Clothing can be ignited several feet away. Clothed areas can be burned more severely than exposed skin if clothing melts.**
- **Hearing loss from sound blast. The sound can have a magnitude as high as 140 dB at a distance of 2 feet from the arc.**

Electrical Arc Flash Burn

Electrical Arc Flash Accident

Arc Flash Causes

- Dust and impurities **- Dust and impurities on insulating surfaces can provide a path for current, allowing it to flashover and create arc discharge across the surface.**
- Corrosion **- Corrosion of equipment creates impurities on insulating surfaces. Corrosion also weakens the contact between conductor terminals, increasing the contact resistance through oxidation or other contamination. Heat is generated on the contacts; sparks may be produced; can lead to arcing faults closest ground source.**
- Condensation - **water vapor can drip causing tracking on the surface of insulating materials. Can create a flashover to ground.**
- Spark discharge – **Accidental contact; dropping tools**
- Overvoltage across narrow gaps
- Failure of insulating materials
- Improper work procedures

Arc Flash in Our Equipment

- **For a low voltage system (480/277 V), a 3 to 4-inch arc can become “stabilized” and persist for an extended period of time.**
- **Energy released is a function of system voltage, fault current magnitude and fault duration.**
- **Arcs in enclosures, such as a Motor Control Center (MCC) or panelboard, magnify blast and energy transmitted as the blast is forced to the open side of the enclosure and toward the worker (Arc-in-the-Box).**

Arc Flash in a Panelboard

Ionization cloud barely visible

Small arc – burn to hand

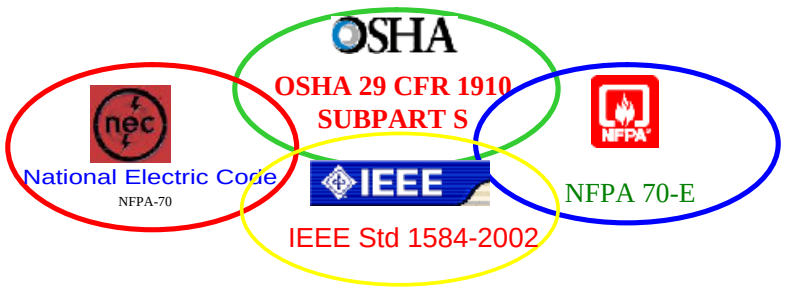
Clearly visible ionized gas

Medium arc – burn to hand, arm and chest

Exploding plasma of gases and vaporized metal

Severe arc – whole body burns

Standards Interaction



NFPA 70 E Standard

- National Consensus Standard
- 2004 Edition: *Electrical Safety in the Workplace*
- Can be cited by OSHA
- Provides guidance on electrical safety-related work practices and maintenance of electrical systems

Regulatory Requirement

- **Per OSHA Rule <u>and</u> NFPA 70E :**

DO NOT WORK ON EQUIPMENT HOT

➢ **Equipment must be put in an electrically safe work condition prior to maintenance.**

It's The Law

But. . .

- **We must test live circuits before repairs are done.**
- **Even after Lock Out / Tag Out, we must verify the absence of voltage – "not dead until tested dead".**
- **During this process, a worker could be exposed to electrical hazards.**
- **Troubleshooting work requires that the power be left on.**

Necessary Loophole

Because of this there are two exceptions to "THE RULE".

1. **Where killing power is "infeasible" due to equipment design or operational limitations (like voltage testing).**
2. **Where de-energizing would introduce increased or additional hazards.**

Work Tasks Impacted

- Circuit Breaker Operation
- Contactor Operation
- Voltage and Amp Readings
  - Control circuitry
  - Power circuitry
  - VFDs
  - Etc..

Voltage Testing

Amperage Testing

Flash Hazard Threshold

Second Degree
Burn Threshold

1.2 cal/cm^2

Note: medical treatment may still be required if bare skin is exposed to this level of flash - full recovery to be expected.

NFPA 70 E Standard

- Safety –Related Work Practices
  - Hazard Analyses for shock and flash
  - Approach boundaries
  - Personal Protective Equipment
  - Training
- Safety-Related Maintenance Requirements
  - Maintaining electrical components, wiring, equipment in a safe condition
- Safety Requirements for Special Equipment
  - Batteries, Lasers and power electronic equip
- Installation Safety Requirements
  - Truncated version of NEC
  - Not to be used in lieu of NEC

Major Work Practice Requirements

NFPA 70E - Requirements

- Electrical Safety Program Elements
  - Awareness training for employees who work on or near exposed energized electrical conductors
  - Inspection/evaluation of electrical equipment
  - Identify hazards – hazard/risk evaluation prior to work on or near live parts operating at 50 volts or more or where an electrical hazard exists
  - Conduct an Electrical Hazard Analysis

Electrical Safety Program Elements – Con't

- Develop procedures for jobs
  - Work permits - procedures for working on or near live parts ≥ 50 volts or where an electrical hazard exists before work is started.

Troubleshooting Exemption

- Protect employees from shock, burn, blast, and other hazards with PPE
- Use electrically-rated tools
- Perform a job briefing prior to each job (unless working alone)
- Perform Audits to ensure compliance with rules

NFPA 70E - Requirements

- Safety Training –
  - Classroom or on-the-job or a combination depending on the risk to the employee
  - Emergency procedures - for employees working on or near exposed energized electrical conductors or circuit parts:
    - Methods of release of victims from contact with exposed energized conductors or circuit parts
    - First Aid, resuscitation, etc.

NFPA 70E - Requirements

- Qualified Person – shall be trained and knowledgeable of the construction and operation of equipment or a specific work method and trained to recognize and avoid the electrical hazards that might be present with respect to that equipment or work method.

Only Qualified Persons are authorized to work on or near live parts

Qualified Person Training

Required by OSHA and NFPA 70E

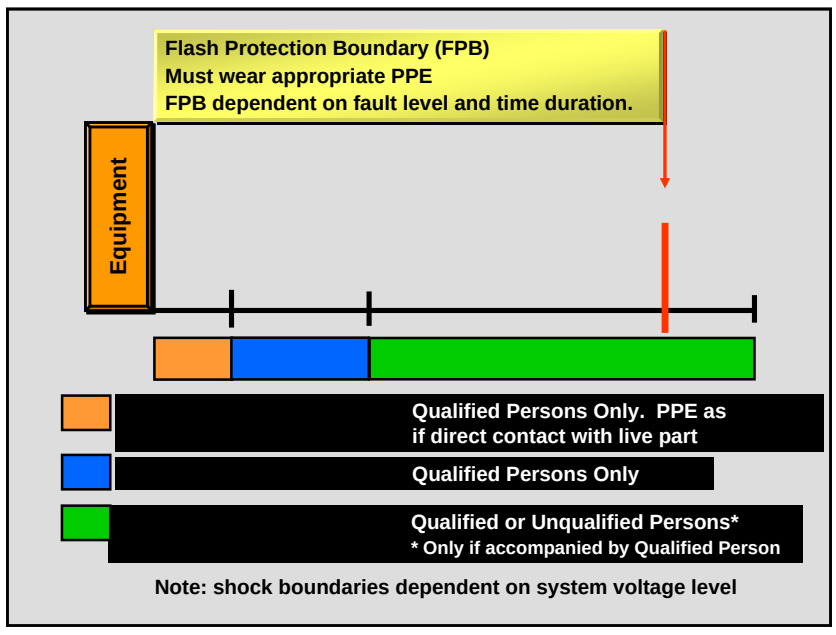
- Basic requirements
  1. Must have knowledge of construction and operation of equipment and specific work methods to recognize and avoid electrical hazards while performing work.
  2. Must be familiar with the precautionary techniques, PPE, insulating and shielding materials, insulated tools and test equipment.
- Specific requirements
  1. Able to distinguish exposed energized parts from other parts
  2. Able to determine nominal voltage of exposed live parts
  3. Approach distances and corresponding voltages in the Standard

Hazard Risk Analysis

Hazard/Risk Analysis is a decision making process:

- **Evaluate equipment and circuit information to determine the degree and extent of hazards**
- **Job planning necessary to safely perform task**
- **Determine "***Shock Approach Boundaries***"**
- **Determine "***Flash Protection Boundary***"**
- **Determine** *"Incident Energy Exposure"*
- **Determine appropriate Personal Protective Equipment (PPE)**

When working "on or near" energized parts (within Limited Approach Boundary), must perform Shock and Flash Hazard Analyses



Shock Hazard Analyses

- Shock Hazard Analysis
  - Determines the Approach Boundaries to use to guard against contact with energized parts.
  - Required PPE to prevent contact injury given in default tables
  - Shock Protection Approach Boundaries – Limited, Restricted, and Prohibited Approach Boundaries determined by voltage – in the Standard.

Approach Boundaries

- Use highest voltage level of exposure
- Boundary distance based solely on voltage
- Boundaries drawn from table in standard – no calcs necessary:
  - Limited – a safe approach boundary. Only qualified employees and escorted unqualified employees may cross
  - Restricted – Only qualified employees may cross. When working within this boundary, must use special precautionary techniques and PPE
  - Prohibited – Only qualified employees protected by insulating materials

Approach Boundaries

Approach Boundaries Specified in NFPA-70E

		Limited Approach Boundary		Restricted Approach Boundary	
Condition	Nominal System Voltage Range, Phase to Phase	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Inadvertent Movement Adder	Prohibited Approach Boundary
1	0 to 50	Not Specified	Not Specified	Not Specified	Not Specified
2	51 to 300	10 ft. 0 in.	3 ft. 6 in.	Avoid Contact	Avoid Contact
3	301 to 750	10 ft. 0 in.	3 ft. 6 in.	2 ft. 2 in.	0 ft. 1 in.
4	751 to 15kV	10 ft. 0 in.	5 ft. 0 in.	2 ft. 7 in.	0 ft. 7 in.
5	15.1kV to 36kV	10 ft. 0 in.	6 ft. 0 in.	2 ft. 9 in.	0 ft. 10 in.

Flash Hazard Analysis

A Flash Hazard Analysis Shall Determine:

- Flash Boundary
  - Approach boundary from exposed energized parts within which a person without proper PPE could receive the onset of a 2nd degree burn
- Incident heat energy of possible arc flash based on:
  - Available fault current
  - Fault clearing time
  - Distance from exposed equipment
  - Directional dissipation of energy (arc-in-the-box scenarios)
- PPE Requirements within the Flash Boundary
- Flash boundary > Shock boundary for higher Voltages

Arc Flash Boundary

- Electrical systems 600V or less:
  - 4 feet, or
  - The calculated distance based on established algorithms
- Electrical systems over 600V:
  - Boundary based on incident energy as calculated or as given in default tables in Standard

Work within the Flash Boundary will require electrical PPE to protect the employee from arc flash injury

Approach Boundaries

		Limited Approach Boundary		Restricted Approach Boundary	
Condition	**Nominal System Voltage Range, Phase to Phase**	**Exposed Movable Conductor**	**Exposed Fixed Circuit Part**	**Includes Inadvertent Movement Adder**	**Prohibited Approach Boundary**
1	0 to 50	Not Specified	Not Specified	Not Specified	Not Specified
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Flash Hazard Analysis

- Determines the Flash Protection Boundary
- Determines the required PPE
- 2 Methods available:

1. Can use Default Tables in the NFPA 70E Standard
   - Classifies work tasks in a specific Hazard Risk Category (HRC)
   - Specifies required PPE as a function of HRC
2. Can calculate the incident energy to employees if a fault occurred. Can then specify the required PPE based on predicted hazard level.

We compared default tables to calculated values:

- **Used conservative, but reasonably expected input parameters**
- **Used 2 different calculation models (took highest values)**
- **Found calculated values to be less than default tables**

Example From Default Table

- **Voltage-rated gloves**
- **Voltage-rated tools**
- **Doubled-layered switching hood and hearing protection**
- **Untreated natural fiber: T-shirt & Long pants**
- **FR Clothing: Long –sleeve shirt, Pants, Coveralls**
- **FR Protective Equipment: Hard hat, safety glasses, leather gloves, leather work shoes**

(Note there are footnotes altering above due to fault current levels and duration. And there are some substitutions permitted.)

Flash Hazard Analysis

Risk Category	Min. Arc Rating of PPE	PPE Requirements - NFPA-70E 2004
0	0-2 cal/cm^2	Untreated Cotton; leather gloves; safety glasses
1	2-4 cal/cm^2	FR shirt and pants (or jeans); rubber gloves; safety glasses; hard hat
2	4-8 cal/cm^2	FR shirt and pants (or jeans); rubber gloves; safety glasses; hard hat; arc face shield
3	8-25 cal/cm^2	FR shirt and pants; rubber gloves; safety glasses; hard hat; arc hood; arc jacket
4	25-40 cal/cm^2	FR shirt and pants; rubber gloves; safety glasses; hard hat; arc hood; multi-layer flash suit

Troubleshooting a 480 V panel is listed in default tables as Hazard Category 2 work.

From: NFPA 70E Default Tables

FR Clothing Criteria

- Use IEEE calculation to predict incident energy levels
- Add 25% to incident energy levels (studies confirm actual measured vs calculated levels under 600V can range $\pm$ 25%)
- Give 100% cotton shirt an ATPV of 1.5 cal/cm^2 (can be more if layered with a cotton undershirt)
- FR Clothing Threshold = 2.2 cal/cm^2
  - 1.2 cal/cm^2 = (Incident Energy x 1.25) - 1.5 cal/cm^2
  - 2.2 cal/cm^2 = Incident Energy

Technician Clothing

- No synthetic fibers allowed, alone or in blends – all cotton shirts and pants
- Shirts – long sleeve – button down; short sleeve – polo (when performing electrical work, arms must be covered by cotton or FR sleeves (long sleeve shirt, removable sleeves or coveralls)
- Pants – Cotton Carhartt-Type
- Color schemes – Blue or grey (by office) – local customers see same look
- Branding – Name and logo specifications
- Vendors
  - National contract with Cintas (purchase or lease with laundry service)
  - other vendors as determined locally

Incident Energy Calculations

	Arc Energy Flux Input Parameters[1]					Incident Energy (cal/cm^2)		
Task Description (Hazard Risk Category 2 as defined in NFPA 70E)	Voltage	Fault Current	Fault Duration	Arc Gap	Distance	IEEE Method	FRC	Duke Power Arc Calculator
Voltage / Ampacity Testing	480	40000	1	1	18	1.7	N	0.3
	480	20000	1	1	18	0.7	N	0.1
	120	40000	1	1	18	1.7	N	0.3
	120	20000	1	1	18	0.7	N	0.1
Starter Operation*	480	40000	6	1	24	6.8	Y	1.1
	480	20000	6	1	24	2.7	Y	0.5
	4160	40000	6	2	24	6.8	Y	1.1
	4160	20000	6	2	24	2.7	Y	0.5
	11000	40000	6	2	24	6.8	Y	1.1
Contactor operation	480	40000	1	1	18	1.7	N	0.3
	480	20000	1	1	18	0.7	N	0.1
Breaker operation	480	40000	6	1	18	10.3	Y	1.7
	480	20000	6	1	18	4.1	Y	0.7

PPE Selection From 70E Table

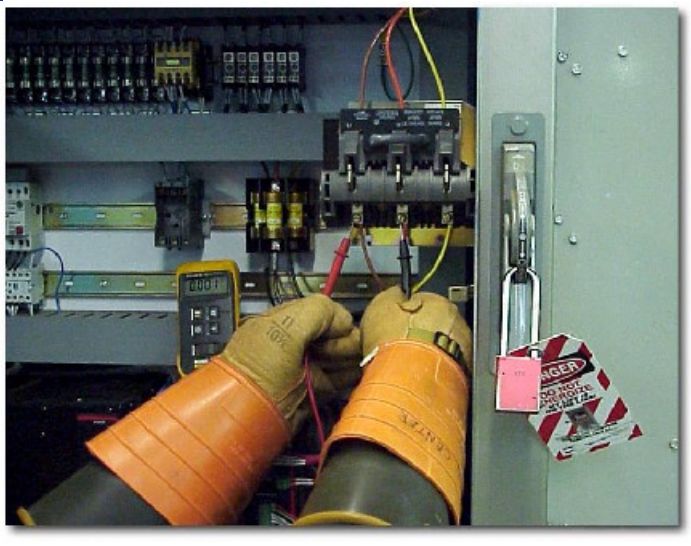
For Most Service and Maintenance Work

Voltage	Clothing	Gloves	Other PPE
Up to 240 Volts	100% long-sleeve cotton shirt and pants	Leather Gloves	Safety Glasses
			Hard Hat
240 - 600 Volts	100% long-sleeve cotton shirt and pants	Class 00 or 0 Insulated Rubber Gloves w/ Leather Protectors	Safety Glasses
			Class E Hard Hat with 8 Cal. ATPV Face Shield
2300-4160 Volts	FR Coveralls - 9.4 ounce Indura Ultra Soft	Class 1 Insulated Rubber Gloves w/ Leather Protectors	Safety Glasses
	100% long-sleeve cotton shirt and pants		Class E Hard Hat with 8 Cal. ATPV Face Shield

Limited work on 2300V and 4160V

Synthetic fibers, such as polyester, nylon, acetate, rayon, either alone or in blends are not permitted – they melt at low temperatures, adhere to the skin and increase the extent of injury.

Insulated Rubber Gloves (with Leather Protectors)



Options to Reduce Hazard Risk

1. Reduce Duration of Arc Flash – Engineering Controls
   - Change type of fusing
     - Faster clearing times
     - Current-limiting fusing
   - Install parallel circuit with rapid trip settings (permanent or temporary)
   - Change CB size or adjust CB trip settings
   - Replace breakers with faster operating devices such as fuses
2. Reduce Exposure
   - Add barriers (installed or portable) eg 1kV plastic rolls
   - Add distance with different tools
   - Install external measurement points
3. Reduce available fault current (Customer/Owner-driven)
   - Reduce Xfmr sizes
   - High-resistance grounded electrical systems

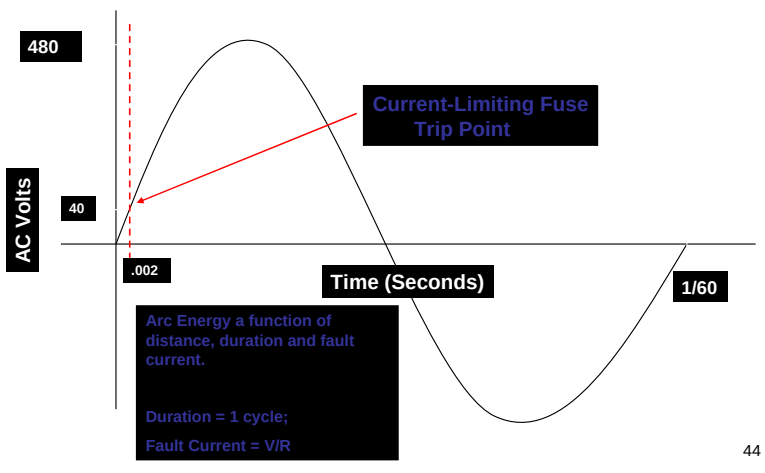
480 Volt Fused Disconnect Switch

Current-Limiting Fuse

Current-Limiting Fuse

43

Current-Limiting Fuse

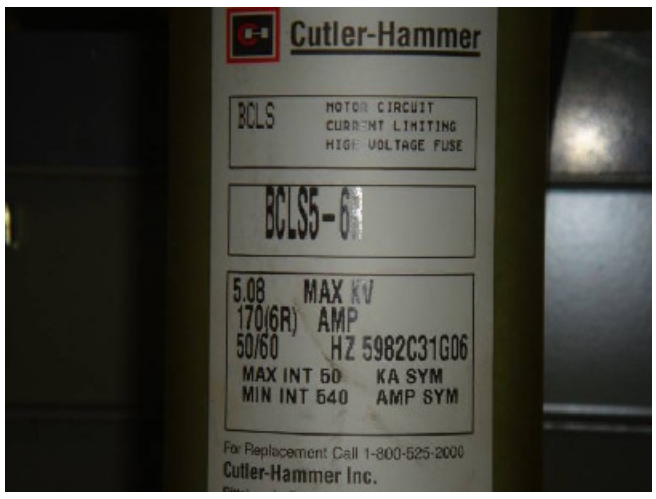


44

4160 Volt Starter Cabinet

45

High Voltage Fuse



Where do we go from here?

- Develop Electrical Safety Program
  - Written electrical safety procedure
  - Safe work practices
  - Training requirements
  - PPE requirements
- Conduct Shock and Flash Hazard Analyses on all electrical equipment and label as appropriate
- Train and outfit all affected personnel
- Design/engineer safety into the job

Thank You

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