Arc Flash Hazard Mitigation

August 25, 2015

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Powering Business Worldwide

Agenda

- Arc Flash Requirements – NFPA 70E and OSHA
- NEC Arc Energy Reduction
- Arc Flash Hazard Mitigation Techniques
- Arc Resistant Equipment

Arc Flash Requirements
NFPA 70E 2015
OSHA 29 CFR 1910.269

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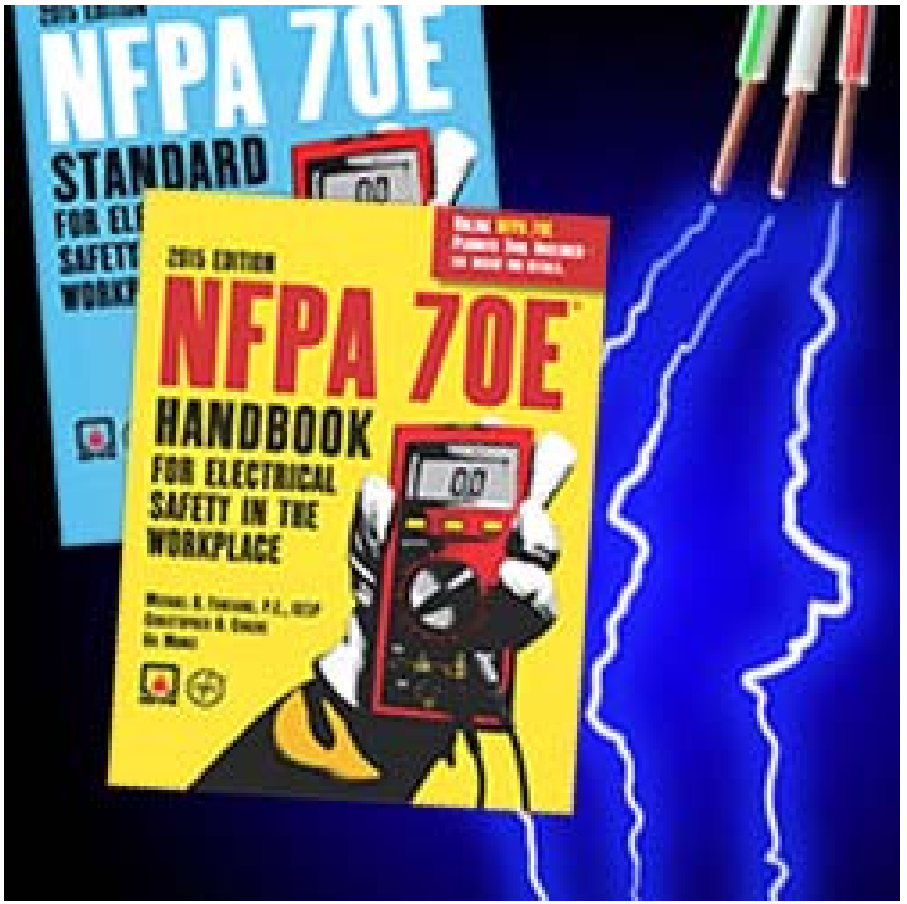
Outline

- NFPA 70E 2015
  - Arc Flash Definition
  - Overview of Arc Flash Requirements
  - Important Changes to Arc Flash in latest Revision
  - Arc Flash PPE Categories vs. Incident Energy Analysis Methodology
- OSHA 29 CFR 1910.269
  - What are The New Requirements?
  - When is Compliance Due?

NFPA 70E 2015



Arc Flash Introduction (NFPA70E Article 100)

Arc Flash Hazard - A dangerous condition associated with the possible release of energy caused by an electric arc.

- An arc flash hazard may exist when energized electrical conductors or circuit parts are exposed or when they are within equipment in a guarded or enclosed condition, provided a person is interacting with the equipment in such a manner that could cause an electric arc.
- Under normal operating conditions, enclosed energized equipment that has been properly installed and maintained is not likely to pose an arc flash hazard.

NFPA70E Overview - Article 130.2(A) Work Involving Electrical Hazards

Am I required to wear PPE for **every** task performed on electrical equipment?

Electrically Safe Working Conditions

NFPA-70E Exceptions

1. Additional Hazards or Increased Risk
2. Infeasibility
3. Less than 50 Volts

New Exception to the 2014 NFPA-70E

4. Normal Operation

NFPA70E Overview - Article 130.2(A)(4) Work Involving Electrical Hazards

Normal operation of electric equipment shall be permitted where all of the following conditions are satisfied 130.2(A)(4):

(1) The equipment is properly installed.

(2) The equipment is properly maintained.

(3) The equipment doors are closed and secured.

(4) All equipment covers are in place and secured.

(5) There is no evidence of impending failure.

Who Does These Changes Affect?

- Qualified personnel working on electrical equipment.
- Personnel working near energized electrical equipment.

New Terms in NFPA-70E

- Risk:
  - "*A combination of the **likelihood of occurrence** of injury or damage to health and the severity of injury or damage to health that results from a hazard.*"
- Risk Assessment
  - "*An overall process that identifies hazards, estimates the potential severity of injury or damage to health, estimates the **likelihood of occurrence** of injury or damage to health, and determines if protective measures are required.*"

NFPA 70E Changes

- Shock Risk Assessment
  - "*..shall determine the voltage to which personnel will be exposed, the boundary requirements, and the PPE necessary in order to minimize the possibility of electric shock to personnel.*"

with leather protectors

NFPA 70E Changes
Article 130.5

- Arc Flash Risk Assessment
  - Is there an arc flash hazard? If so, the risk assessment must contain the following:
    - Appropriate safe-work practices
    - Arc Flash Boundary
    - Appropriate PPE

NFPA 70E Changes
Article 130.5

- Arc Flash Risk Assessment
  - Update studies when major modifications or renovations take place. Study should be reviewed at an interval not to exceed five (5) years.
  - Take into consideration the design and condition of overcurrent devices.

NFPA-70E Article 130.5 (C) Appropriate PPE

Two Methods

Incident Energy Analysis

- Equations / Calculations

SKM Power*Tools

etap Thinking Power

EasyPower® Power made easy.

Arc Flash PPE Categories

- Tables 130.7(C)(15)(A)(a)/(b), 130.7(C)(15)(B), & 130.7(C)(16)
- PPE Categories 1-4

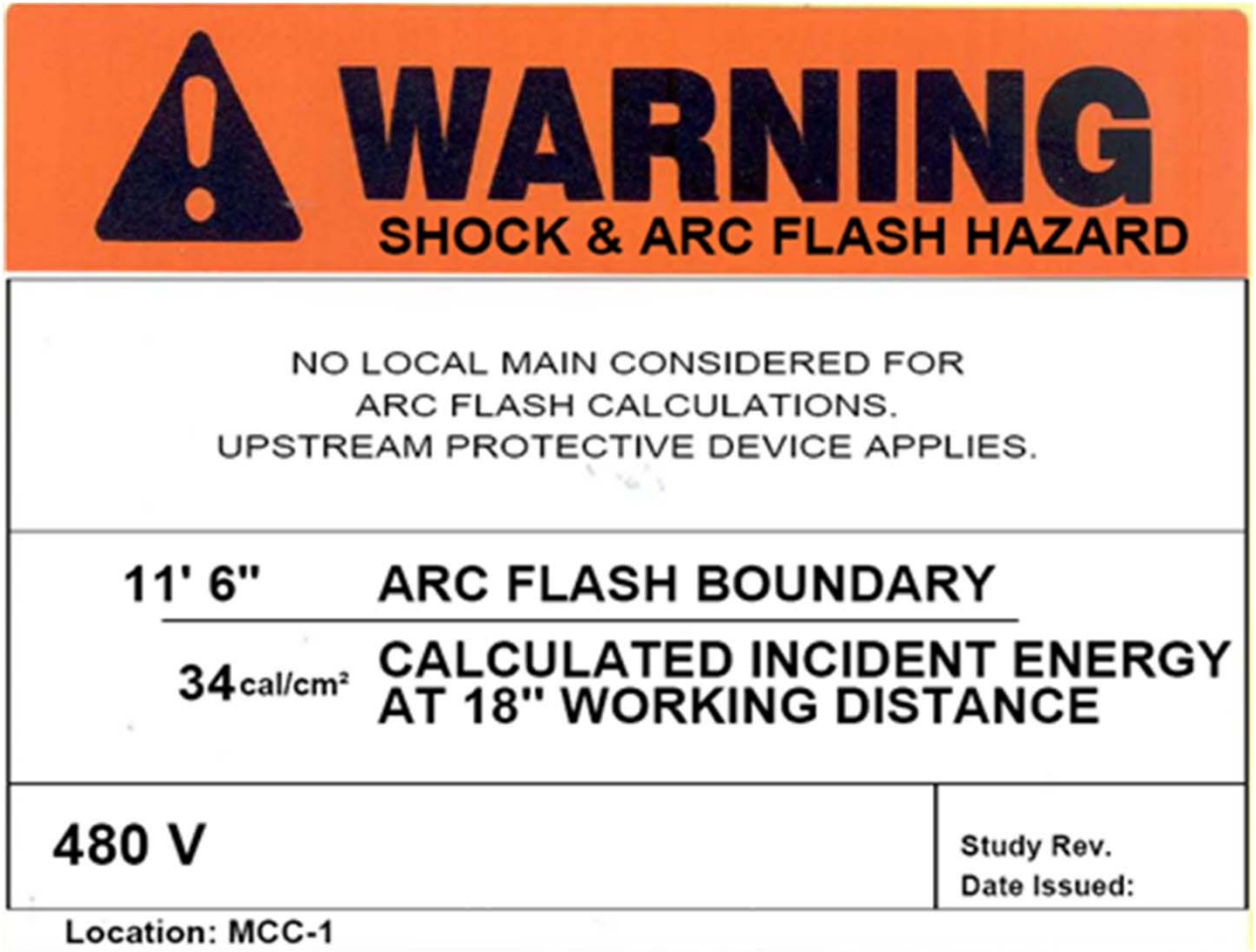
Working in a Situation Where an Arc-Flash Hazard Exists: Arc-Flash Warning Label

Electrical equipment that are likely to require examination, adjustment, servicing or maintenance while energized shall be field marked with a label containing the following (Refer to NFPA 70E-2015, Art. 130.5(D)):

- Nominal systems voltage
- Arc flash boundary
- At least one of the following:
  - Available incident energy and the corresponding working distance, or the arc flash PPE category in Table 130.7(C)(15)(A)(b) or Table 130.7(C)(15)(B) for the equipment, but not both
  - Minimum arc rating of clothing
  - Site-specific level of PPE

The method of calculating and data to support the information for the label shall be documented.

Arc Flash Labels

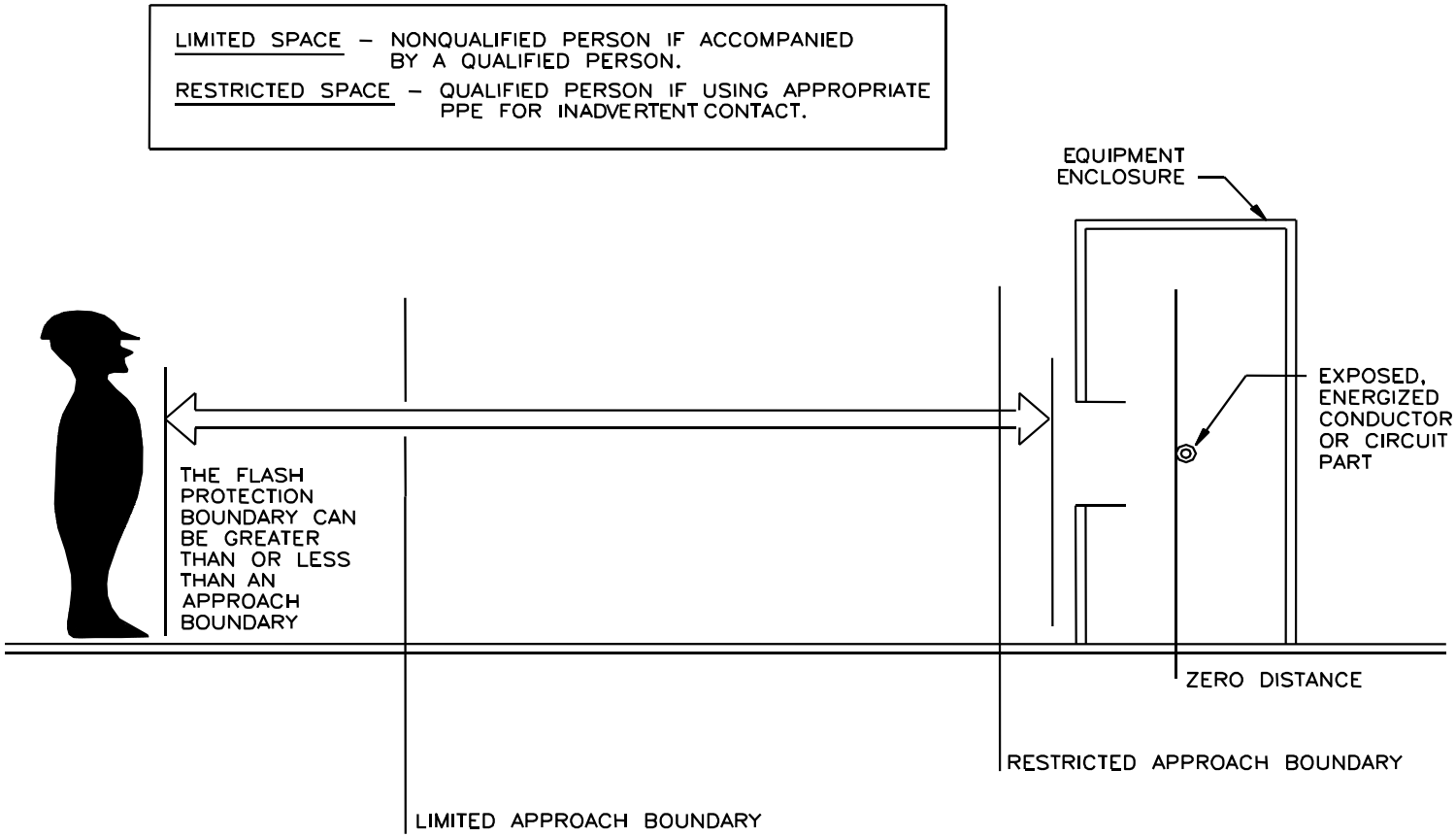


Arc-Flash Boundary

An arc-flash boundary is an approach limit at which a person would be expected to receive a just curable burn on exposed skin if an arc flash were to occur.

If you are required to work within the arc-flash boundary, you are also required to wear arc-rated garments.

Arc Flash Boundary and Limits of Approach



Approach & Arc Flash Boundaries

Arc Flash PPE Categories Process

- Step 1: Refer to Table 130.7(C)(15)(A)(a)

This table identifies arc flash hazards based on a list of common tasks.

Task	Equipment Condition	Arc Flash PPE Required
Removal or installation of CBs or switches	Any	Yes

Arc Flash PPE Categories Process

- Step 2: Refer to Table 130.7(C)(15)(A)(b) for AC Equipment or Table 130.7(C)(15)(B) for DC Equipment

These tables can be used if associated parameters are met.

Equipment	Arc Flash PPE Category	Arc Flash Boundary
600V class motor control centers (MCCs) Parameters: Maximum of 65 kA short circuit available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 18 inches.	2	5 ft

Arc Flash PPE Categories Process

- Step 3: Refer to Table 130.7(C)(16) for Personal Protective Equipment (PPE)

2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm²** (see Note 1) Arc-rated long-sleeve shirt and pants of arc-rated coverall Arc-rated flash suit hood or arc-rated face shield (see Note 2) and arc-rated balaclava Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Heavy duty leather gloves (see Note 3) Leather footwear (AN)

Arc Flash PPE Categories Process

- Step 1: Refer to Table 130.7(C)(15)(A)(a)

This table identifies arc flash hazards based on a list of common tasks.

Task	Equipment Condition	Arc Flash PPE Required
Normal operation of a circuit breaker, switch, contactor, or starter	All of the following: The equipment is properly installed The equipment is properly maintained All equipment doors are closed and secured All equipment covers are in place and secured There is no evidence of impending failure	No
	One or more of the following: The equipment is not properly installed The equipment is not properly maintained Equipment doors are opened or not secured Equipment covers are off or not secured There is evidence of impending failure	Yes

Maintenance Requirements NFPA-70E Article 205.3

- Electrical equipment shall be maintained in accordance with manufacturer's specifications and/or industry standards.
- Improper maintenance may result in increased opening time of devices

Increased Incident Energy

PPE may not provide adequate protection

OSHA 29 CFR

Excerpts from OSHA 29 CFR 1910

The final rules for general industry and construction include new and revised provisions on host employers (facility operator) and contractors.

- training
- job briefings
- fall protection
- work on transmission and distribution lines
- working in manholes and vaults
- **electrical hazards (including arc flash)**

Protection from Flames & Electric Arcs OSHA 1910.269 (Appendix E)

The employer shall:

1. Assess the workplace to identify employees exposed to hazards from flames or from electric arcs.
2. Estimate incident energy values.
3. Ensure employees wear flame-resistant clothing and PPE with adequate arc ratings that will not melt or ignite and continue to burn.

Frequently Asked Questions
OSHA Final Ruling

What Methods are acceptable per OSHA Final Ruling?

- Below is a table taken from the final rule that illustrates what methods OSHA will accept for calculating incident energy.

TABLE 3-SELECTING A REASONABLE INCIDENT-ENERGY CALCULATION METHOD [1]

Incident-energy calculation method	600 V and Less [2]			601 V to 15 kV [2]			More than 15 kV		
	1Φ	3Φa	3Φb	1Φ	3Φa	3Φb	1Φ	3Φa	3Φb
NFPA 70E-2012 Annex D (Lee equation)	Y-C	Y	N	Y-C	Y-C	N	N[3]	N[3]	N[3]
Doughty, Neal, and Floyd	Y-C	Y	Y	N	N	N	N	N	N
IEEE Std 1584b-2011	Y	Y	Y	Y	Y	Y	N	N	N
ARCPRO	y	N	N	Y	N	N	Y	Y[4]	Y[4]

Frequently Asked Questions
OSHA Final Ruling

From OSHA Final Ruling:

- OSHA based the determination of the level of PPE required under the final rule solely on incident heat energy. OSHA's final rule separates the determination of risk (that is, whether an employee is exposed to hazards posed by electric arcs), as required by final paragraph (g)(1), from the calculation of incident energy, as required by final paragraph (g)(2). Therefore, the Agency concludes that NFPA 70E Table methodology, is not a reasonable method of estimating incident energy under final paragraph (g)(2) and, therefore, is not referencing that table in Appendix E in the final rule.

When is Arc Flash Compliance Required?

- No later than **January 1, 2015**, employers must estimate the incident heat energy of any electric-arc hazard to which a worker would be exposed.

- No later than **April 1, 2015**, employers generally must provide workers exposed to hazards from electric arcs with protective clothing and other protective equipment with an arc rating greater than or equal to the estimated heat energy.

Frequently Asked Questions
OSHA Final Ruling

Question: I have already completed an arc flash study assessment for my facility. Do I need rerun the analysis per new OSHA regulations?

Answer: Maybe?

- As long as the incident energy analysis was completed according to the guidelines in 1910.269 Appendix E.
- NFPA 70E requires that arc flash study assessments be updated at a minimum of every 5 years or when major changes are implemented to the power system.

Frequently Asked Questions
OSHA Final Ruling

Question: What kinds of fines does OSHA impose for violations?

Answer: OSHA violations are defined as:

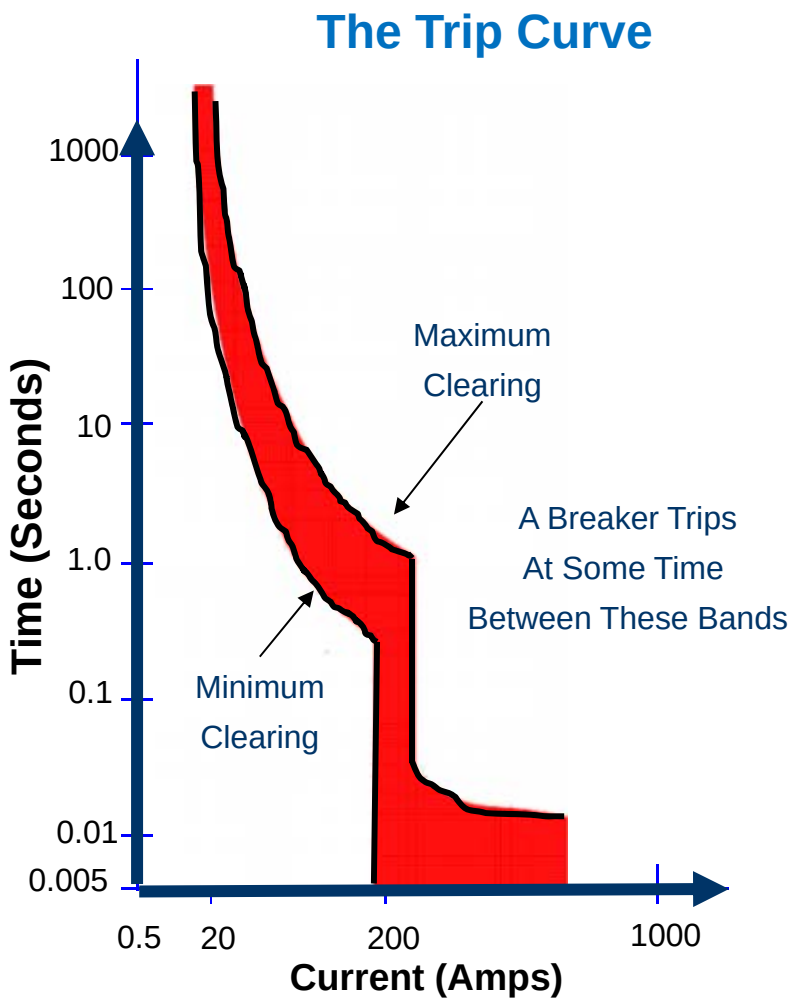
- Other than serious: Proposed penalty ($7,000 maximum) per violation
- Serious: Mandatory penalty ($7,000 maximum) per violation
- Willful: Minimum penalty of $5,000 up to $70,000 per violation
- If an employer is convicted of a willful violation of a standard that has resulted in the death of an employee, the offense is punishable by a court-imposed fine or by imprisonment for up to six months, or both. A fine of up to $250,000 for an individual, or $500,000 for a corporation, may be imposed for a criminal conviction.

National Electrical Code

Arc Energy Reduction

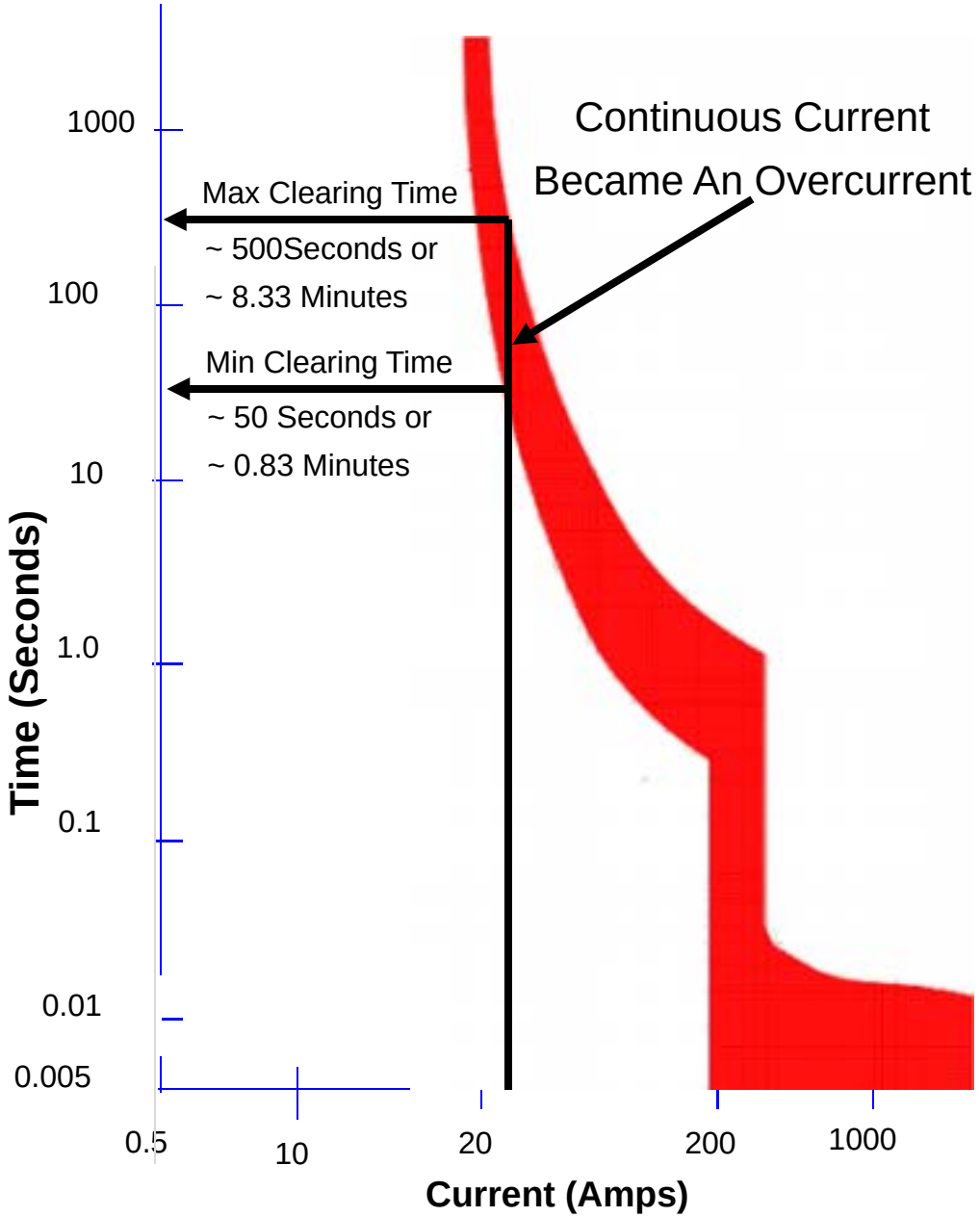
Circuit breaker basics

- A trip curve is plotted Time vs. Current
- The curve tells the trip times for various levels of current
- Minimum and maximum clearing times



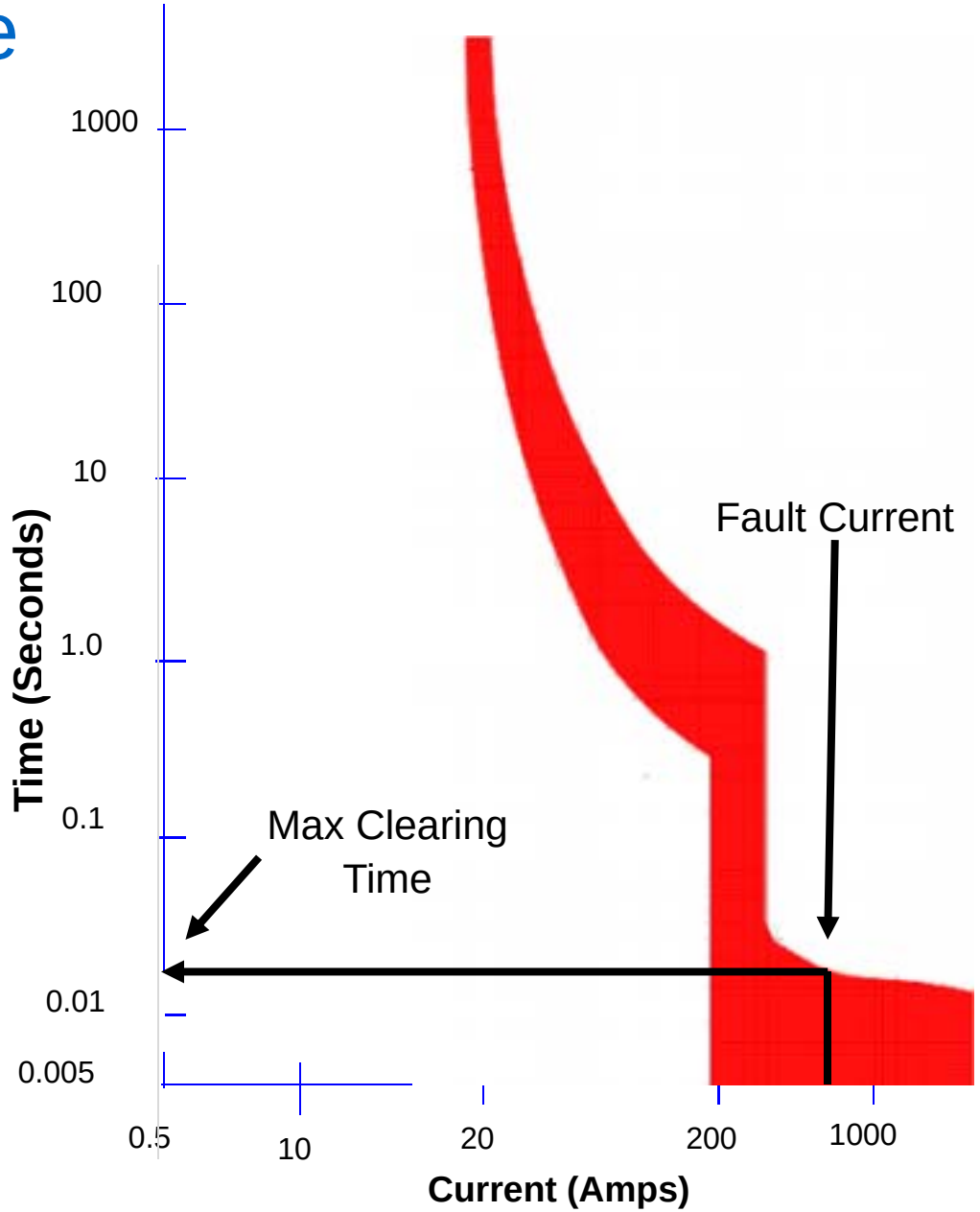
Overload Example

Overload currents can take quite some time to clear



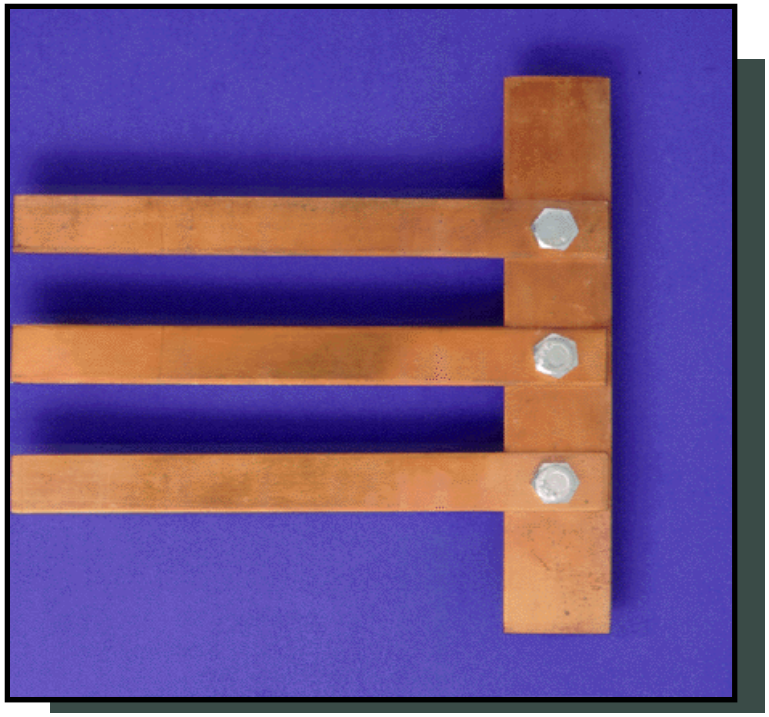
Short Circuit Example

- Calculated maximum fault currents may be quite high resulting in very fast tripping times
- This fault current is in the instantaneous region of the circuit breaker
- Maximum fault current is based on a bolted fault condition



Bolted Fault vs. Arcing Fault

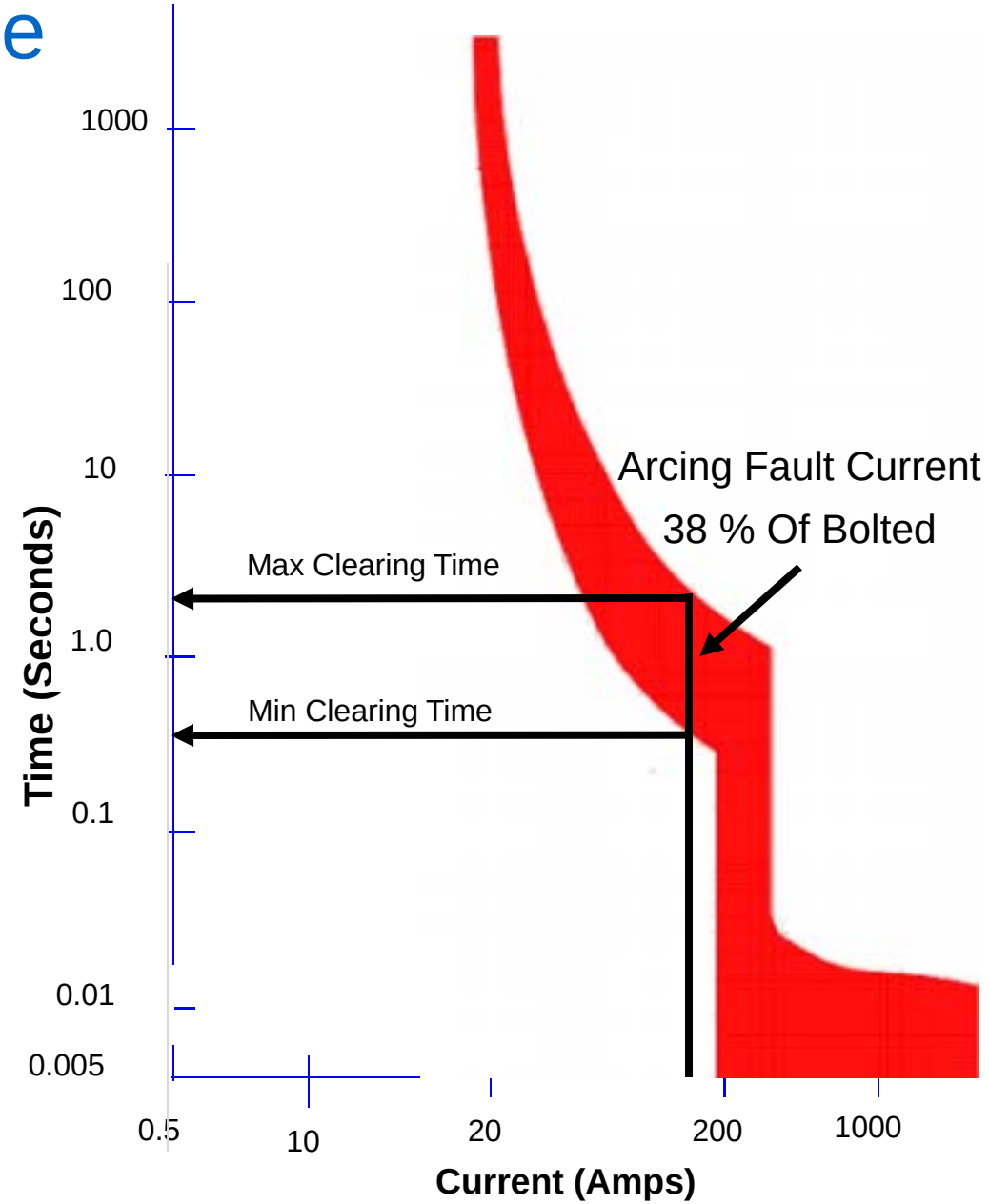
Bolted Fault



Arcing Fault

Arcing Fault Example

- Arcing currents are calculated based on the 3-Phase bolted fault
- IEEE 1584: “IEEE Guide for Performing Arc-Flash Hazard Calculations”
- Arcing currents are often cleared in the overload range of the circuit breaker



Pre - NEC 2011 Language

NFPA 70

Prior To 240.87

110.16 Arc-Flash Hazard Warning

The only installation requirement specific to the arc flash hazard

110.16 Arc-Flash Hazard Warning. Electrical equipment, such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers, that are in other than dwelling units, and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential electric arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

Informational Note No. 1: NFPA 70E-2009, *Standard for Electrical Safety in the Workplace*, provides assistance in determining severity of potential exposure, planning safe work practices, and selecting personal protective equipment.

Informational Note No. 2: ANSI Z535.4-1998, *Product Safety Signs and Labels*, provides guidelines for the design of safety signs and labels for application to products.

2011 NEC Addition

240.87 Noninstantaneous Trip. Where a circuit breaker is used without an instantaneous trip, documentation shall be available to those authorized to design, install, operate, or inspect the installation as to the location of the circuit breaker(s).

Where a circuit breaker is utilized without an instantaneous trip, one of the following or approved equivalent means shall be provided:

(1) Zone-selective interlocking

(2) Differential relaying

(3) Energy-reducing maintenance switching with local status indicator

Informational Note: An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to "no intentional delay" to reduce the clearing time while the worker is working within an arc-flash boundary as defined in NFPA 70E-2009, Standard for Electrical Safety in the Workplace, and then to set the trip unit back to a normal setting after the potentially hazardous work is complete.

NEC 2014 Section 240.87

240.87 Arc Energy Reduction. Where the highest continuous current trip setting for which the actual overcurrent device installed in a circuit breaker is rated or can be adjusted is 1,200 amperes or higher then (A) and (B) shall apply.

(A) Documentation. Documentation shall be available to those authorized to design, install, operate, or inspect the installation as to the location of the circuit breaker(s).

(B) Method to Reduce Clearing Time. One of the following or approved equivalent means shall be provided:

(1) Zone-selective interlocking or

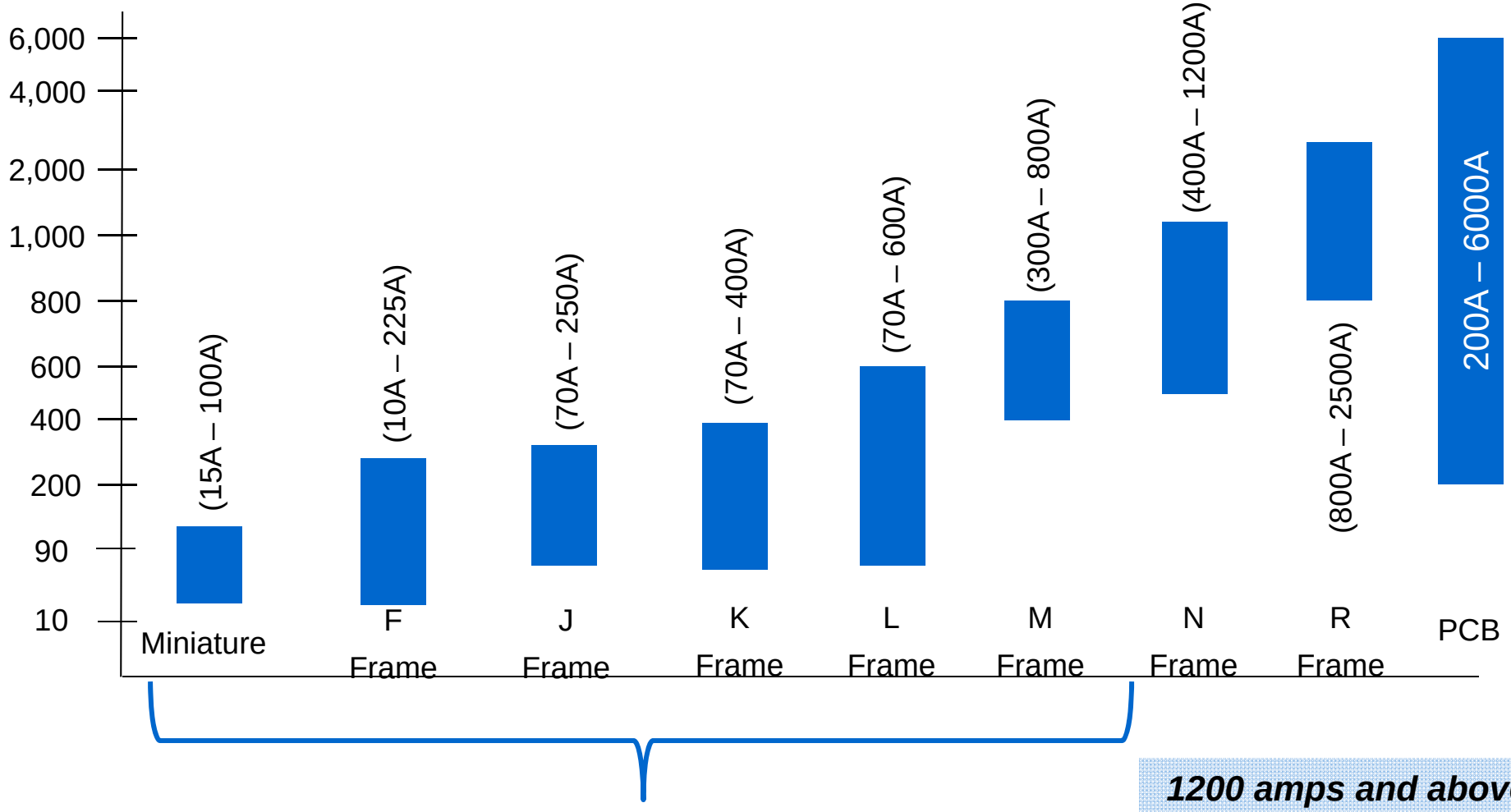
(2) Differential relaying or

(3) Energy-reducing maintenance switching with local status indicator or

(4) Energy-reducing active arc flash mitigation system or

(5) An approved equivalent means

Current circuit breaker ranges on the market



Not impacted by requirement

1200 amps and above agreed upon by consensus of code making panel 10

NEC 2014's Section 240.87

(B) Method to Reduce Clearing Time. One of the following or approved equivalent means shall be provided:

(1) Zone-selective interlocking or

(2) Differential relaying or

(3) Energy-reducing maintenance switching with local status indicator or

(4) Energy-reducing active arc flash mitigation system or

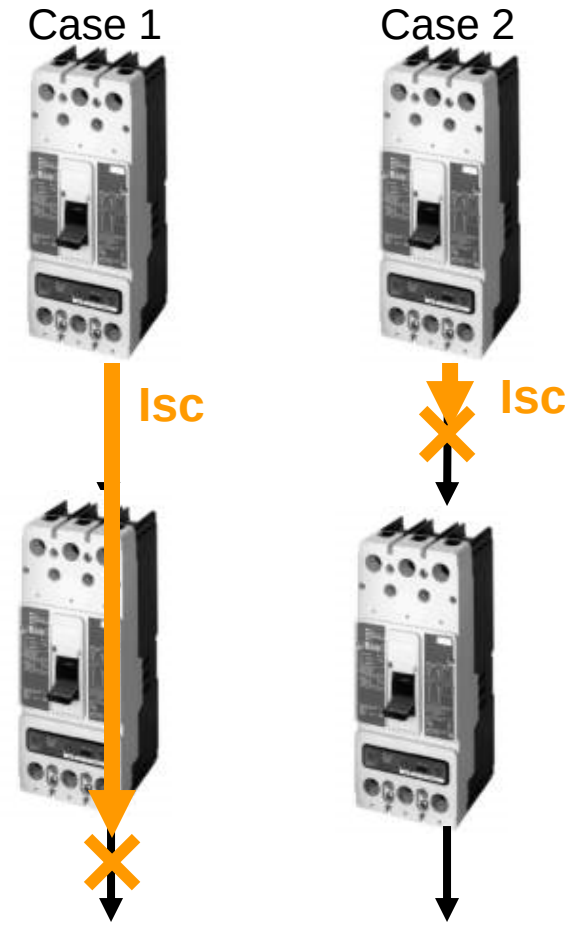
(5) An approved equivalent means

(1) Zone selective interlocking

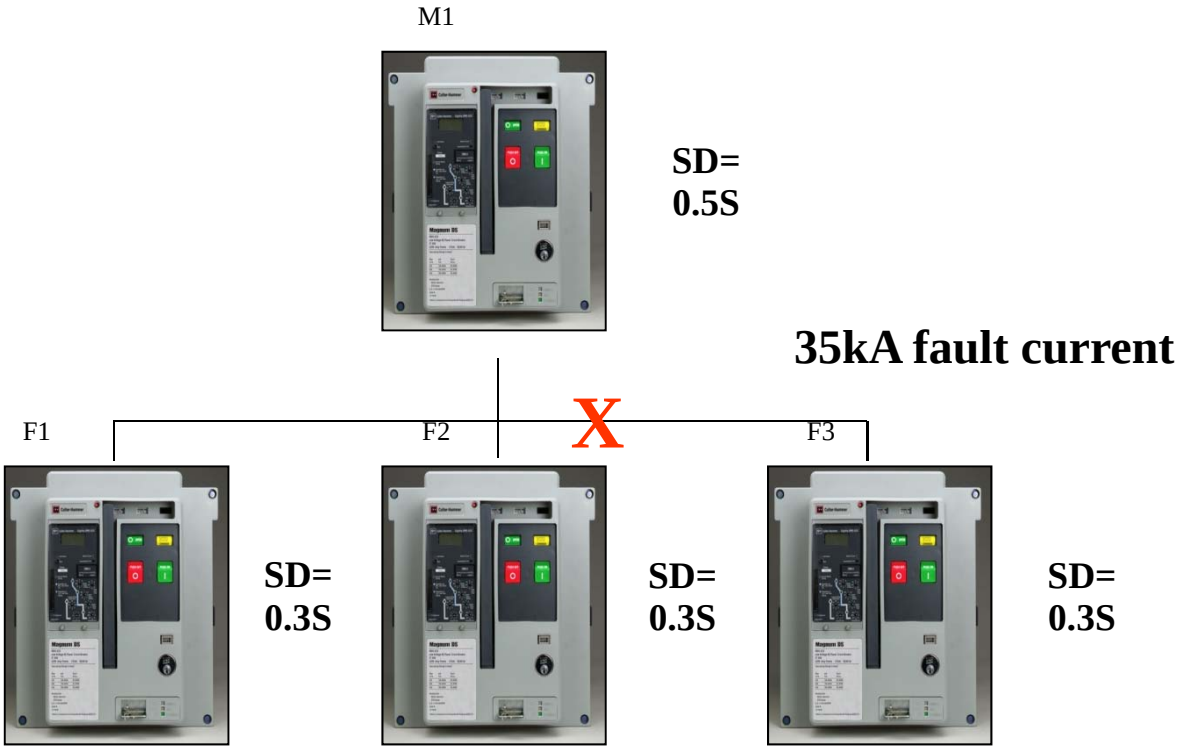
- Communication between circuit breakers
- Acts to reduce trip times
- Helps reduce arc flash energy

Case 1:
- Both breakers see fault
- Upstream breaker waits as designed

Case 2:
- Only upstream breaker sees fault
  - No input from downstream breaker
  - Trip as fast as possible



Zone Selective Interlock Example



<u>Without</u> ZSI = 0.5 S:

43.7 Cal/cm^2

<u>With</u> ZSI = 0.08 S:

7.0 Cal/cm^2

What do we put on the Arc Flash label?

Zone Selective Interlocking – Pros and Cons

Pros

- Standard feature on most Power Circuit Breaker and Insulated Case Breaker Trip Units
- Available on many Molded Case Breaker Trip Units
- Inexpensive where electronic trip units are already specified
- Reduces clearing time for short circuits and ground fault

Cons

- Requires multiple (at least 2) layers of electronic trip breakers
- Requires inter-wiring between breakers to work
- Difficult to apply outside of an assembly
- Not recommended to mix manufacturers
- Gets more complicated with complex systems (M-T-M, etc.)
- Slower than instantaneous trip due to communication lag
- Probably won't reduce PPE requirements.
- Not applicable in certain assemblies (MCC, Meter Center)
- Difficult to Test

NEC 2014's Section 240.87

(B) Method to Reduce Clearing Time. One of the following or approved equivalent means shall be provided:

(1) Zone-selective interlocking or

(2) ***Differential relaying*** or

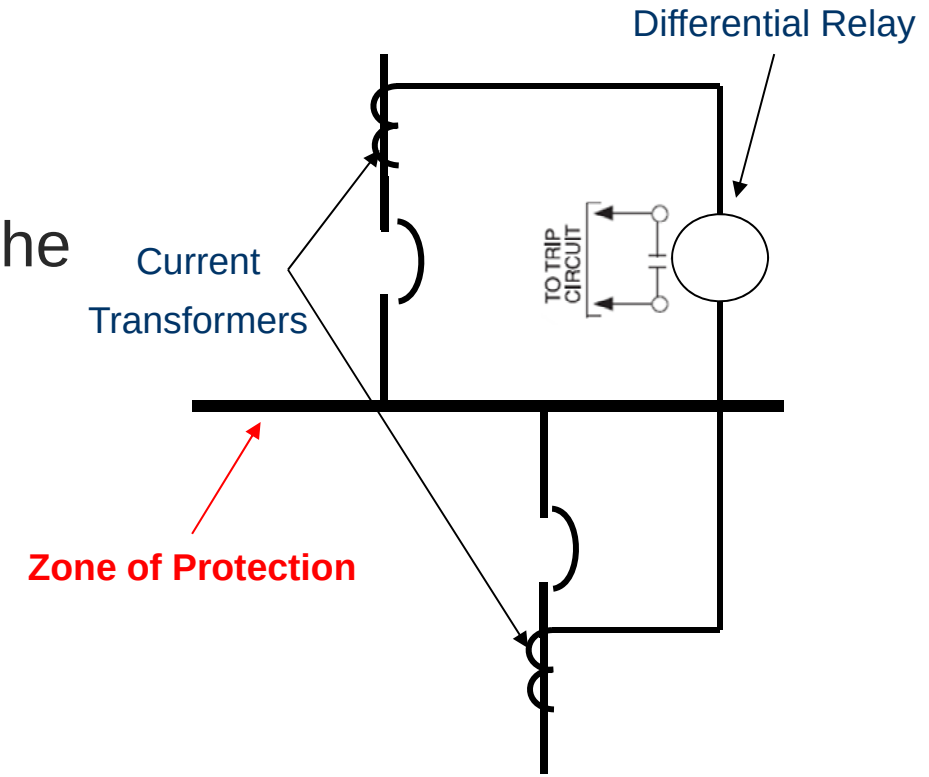
(3) Energy-reducing maintenance switching with local status indicator or

(4) Energy-reducing active arc flash mitigation system or

(5) An approved equivalent means

(2) Differential relaying

- Similar to zone selective interlocking
- Recognizes faults within the zone of protection
- Acts to reduce arc flash



Not a practical solution in LV equipment due to space limitations.

NEC 2014's Section 240.87

(B) Method to Reduce Clearing Time. One of the following or approved equivalent means shall be provided:

(1) Zone-selective interlocking or

(2) Differential relaying or

(3) ***Energy-reducing maintenance switching with local status indicator*** or

(4) Energy-reducing active arc flash mitigation system or

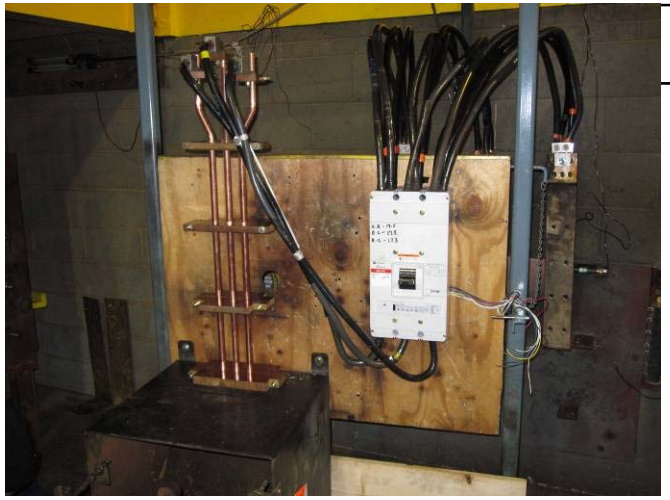
(5) An approved equivalent means

(3) Energy-reducing maintenance switching with local status indicator

- Manually or automatically enables an instantaneous pickup
- Trip times may vary between manufacturers
  - Some may be same as instantaneous
  - Some may be faster than instantaneous
- Reduces arc energy to downstream equipment/personnel
- Limits energy available during maintenance

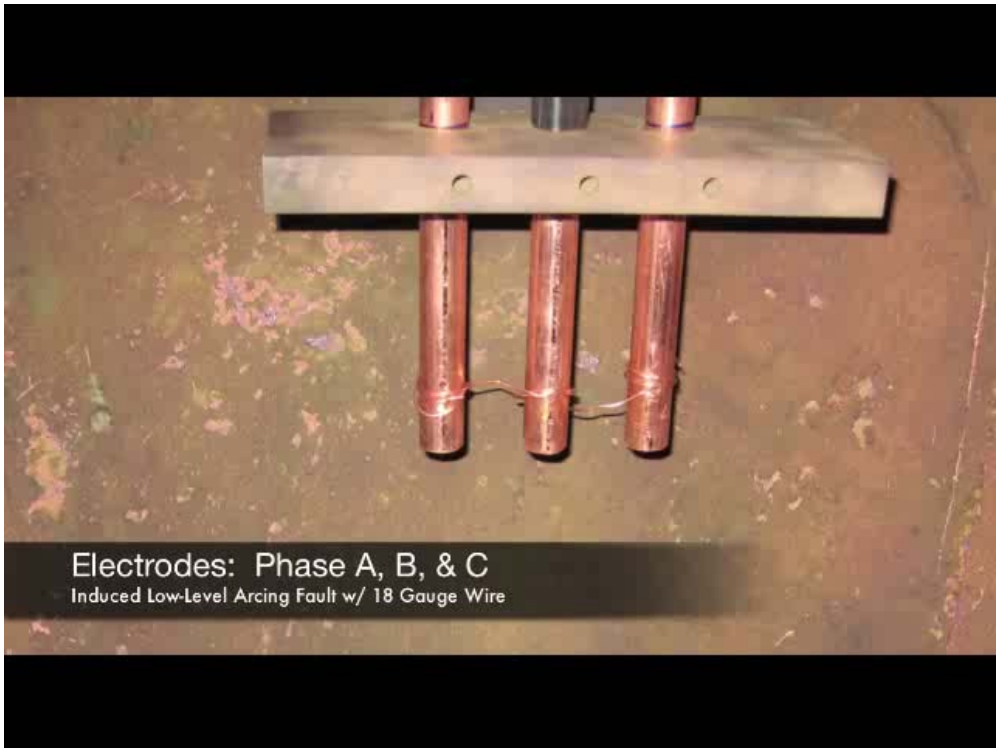
Door Mounted Hardware

MCCB
310+ Maintenance Mode



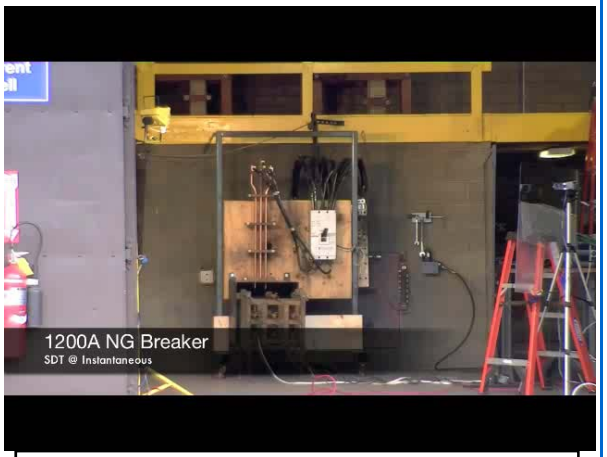
Arcing fault test apparatus

Arc chamber and calorimeter



(Click video to view – no sound)

MCCB
1200A Interrupting Devices (9kA @ 480V)



Breaker w/ Instantaneous

Breaker w/ **Maintenance Mode**

(Click videos to view)

MCCB
1200A Comparison Data Table (9kA @ 480V)

Device	NG w/ Instantaneous	NG w/ Maint. Mode
Peak Fault Current (kA)	14.8	14.5
Time to Clear (ms)	45.9	18.2
[improvement vs. Instantaneous]		60%
Arcflash Energy (Cal/cm^2)	1.63	0.41
[improvement vs. Instantaneous]		75%

Arc Flash Reduction Maintenance System – Pros and Cons

Pros

- Available on many Power, Insulated Case and Molded Case Breaker electronic trip units
- Inexpensive where electronic trip units are already specified
- Can be applied only on the breakers required (no inter-wiring)
- Can be provided in different types of assemblies
- Extremely fast acting – faster than instantaneous for some manufacturers
- Reduces both the trip setting and the trip time
- Easy to test

Cons

- Requires user interaction to provide protection
- Does not reduce trip time for ground faults

NEC 2014's Section 240.87

(B) Method to Reduce Clearing Time. One of the following or approved equivalent means shall be provided:

(1) Zone-selective interlocking or

(2) Differential relaying or

(3) Energy-reducing maintenance switching with local status indicator or

(4) ***Energy-reducing active arc flash mitigation system*** or

(5) An approved equivalent means

(4) Energy-reducing active arc flash mitigation system

- When activated, this technology continuously monitors current and voltage to identify an arc flash
- When an arc flash occurs, the arc is automatically dealt with, without changes to the circuit breaker

Informational Note No. 2: An energy-reducing active arc flash mitigation system helps in reducing arcing duration in the electrical distribution system. No change in circuit breaker or the settings of other devices is required during maintenance when a worker is working within an arc-flash boundary as defined in NFPA 70E-2012, Standard for Electrical Safety in the Workplace.

NEC 2014's Section 240.87

(B) Method to Reduce Clearing Time. One of the following or approved equivalent means shall be provided:

(1) Zone-selective interlocking or

(2) Differential relaying or

(3) Energy-reducing maintenance switching with local status indicator or

(4) Energy-reducing active arc flash mitigation system or

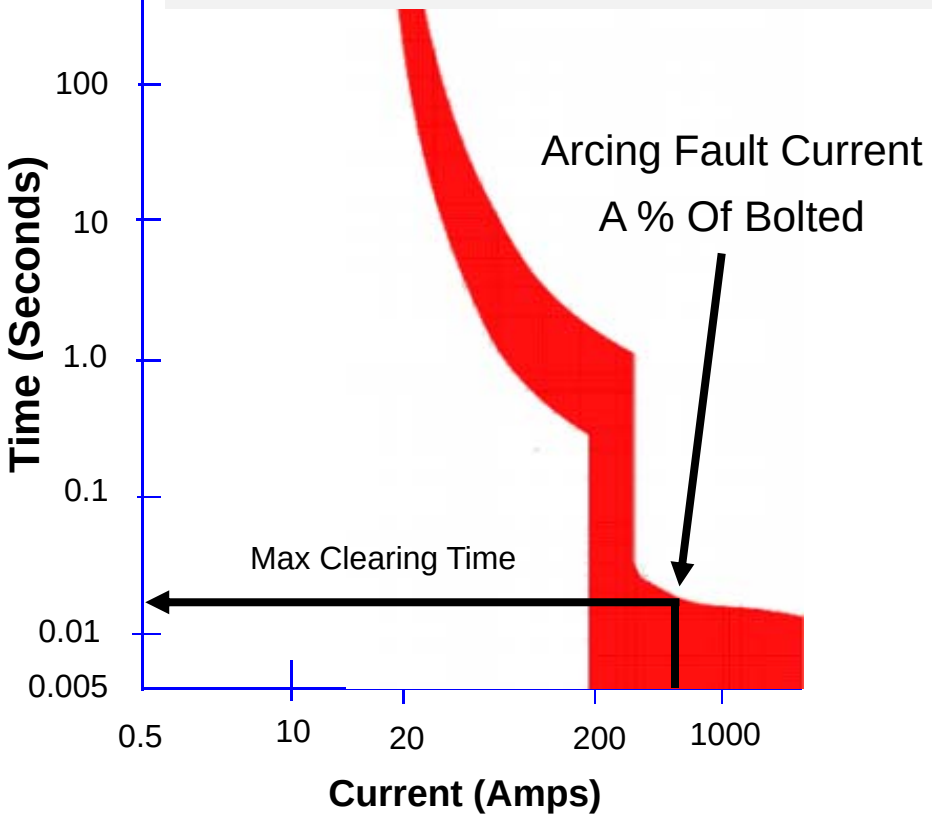
(5) ***An approved equivalent means***

(5) An approved equivalent means

Confirm approved equivalent means by requesting a copy of arc flash study

Confirm approved equivalent means by requesting a copy of arc flash study

Compare with one of the four listed methods



(5) An approved equivalent means

Confirm any approved equivalent means by comparing arc flash calculated values

- Calculated arc flash values based on any one of the listed options
- Calculated arc flash values when applying the technology which is seeking to be an approved equivalent

Subject to AHJ Approval

Questions and Discussion

- Enforcement?
- Handbook?

Arc Flash Hazard Mitigation

Design Considerations for New Projects

Options for Existing Facilities

NFPA 70E Summary

- ***The intent of NFPA 70E regarding arc flash is to provide guidelines which will limit injury to the onset of second degree burns (1.2 cal/cm^2).***

Note: The heat reaching the skin of the worker is dependent primarily upon:

- ***Power of the arc at the arc location***
- ***Distance of the worker to the arc***
- ***Time duration of the arc exposure***

SOLUTIONS THAT REDUCE ARC FLASH INJURIES and DAMAGE

Direct:

- Reduce Available Fault Current
- Faster Clearing Time
- Move People Further Away

Indirect:

- Label Equipment & Train Personnel
- Minimize Risk with Good Safety Practices
- Redirect Blast Energy

Reduce Available Fault Current (Reduce Incident Energy)

Practical Non-PPE Arc Flash Solutions

Reducing the Short Circuit Current:

- Current Limiting Reactors
- Design using more smaller transformers instead of fewer larger transformers
- Increasing cable lengths
- Specifying higher impedance transformers
- Open Transition Transfers

Beware:

Reducing the short circuit current by too much can increase the duration of the arc, causing the incident energy to increase!

Faster Clearing Time

Design Considerations for New Projects – Faster Clearing Time

- Meet the requirements of 240.87

  (1) Zone-selective interlocking or

  (2) Differential relaying or

  (3) Energy-reducing maintenance switching with local status indicator or

  (4) Energy-reducing active arc flash mitigation system

- It’s OK to employ more than one of the above and/or use where not required by code.

Practical Methods for Reducing Arc Flash Hazards

Multiple Settings Groups

- **Similar to LV maintenance switch, only for MV applications**
- **Used to reduce the trip delay of medium-voltage relays while maintenance is being performed on equipment.**
- **Requires relay with multiple settings groups capability**

Options for Existing Facilities – Faster Clearing Time

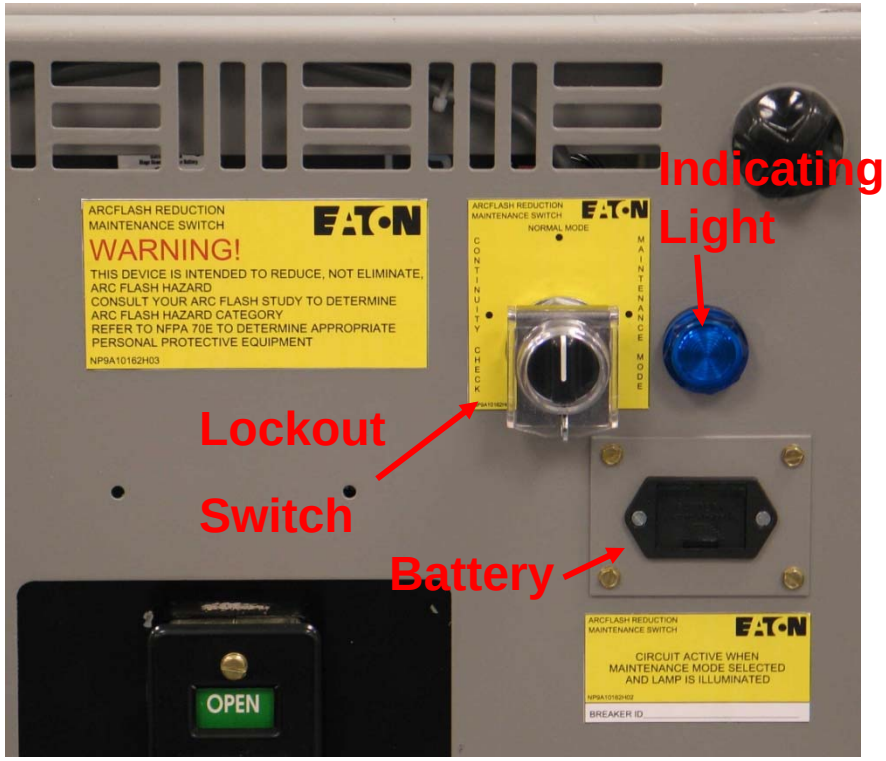
- Zone Selective Interlocking
- Energy Reducing Maintenance Switches
- Substation Retrofits

Options for Existing Facilities – Faster Clearing Time

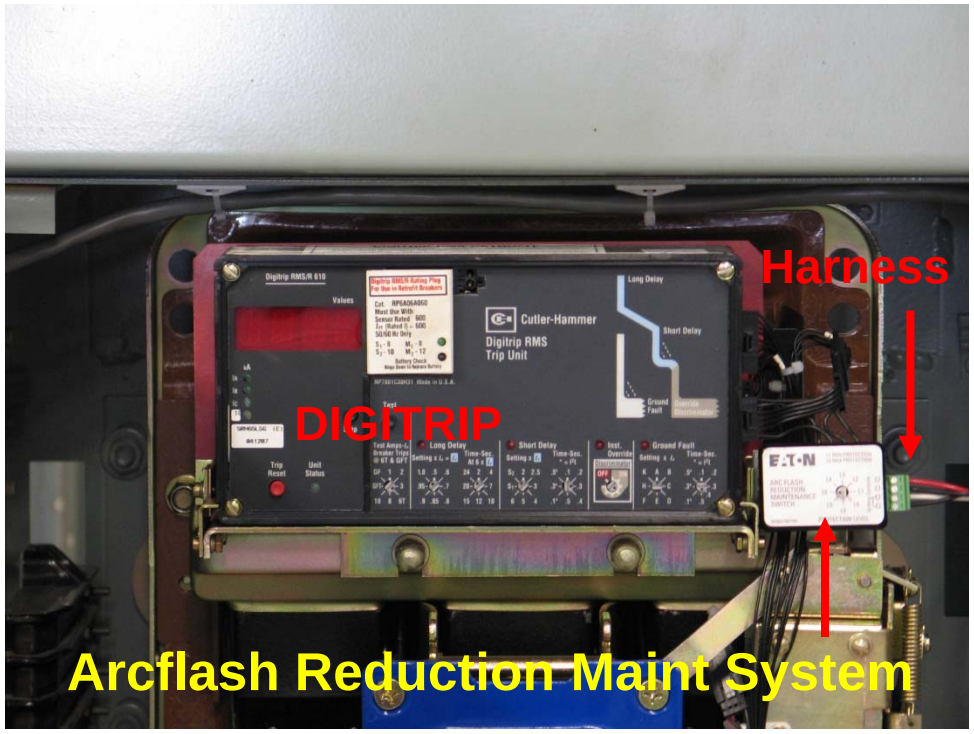
- Energy Reducing Maintenance Switches
  - Maintenance Switch Retrofits
  - Trip Unit Retrofits
  - Switchgear Retrofills

Arcflash Reduction Maintenance System™ - Retrofit of LV - PCBs

- Door Mounted Components



- Breaker Mounted Components



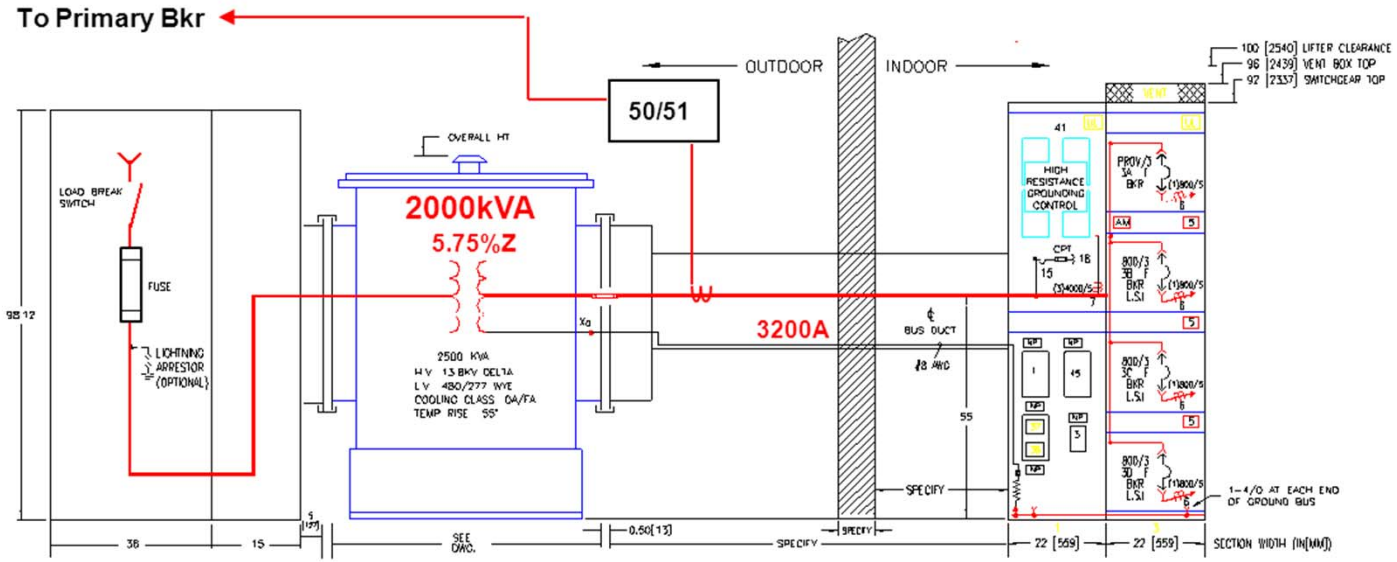
Retro Fill Example – with “ARMS”

- 2000-Amp Fuses Supplying 480V Glass Furnaces
- Incident Energy was 61 Cal / PPE Level=Danger
- Retro-filled Fuses with Breakers
- 35 cal with trip Unit
- 6 cal with New Breaker + Built-in ARMS

Low Voltage Air circuit breaker Replacement (LVAR)

Technologies/Upgrades to Reduce Arc-Flash Hazard

2000kVA Unit Substation – Addition of 50/51 Overcurrent Relay



Design Limitations

- Secondary bus fault protection
- Secondary bus overload protection

NEC Article 240.21(C)2 Allows unprotected secondary conductor

Transformer Secondary Conductors not over 3 meters long

Technologies/Upgrades to Reduce Arc-Flash Hazard

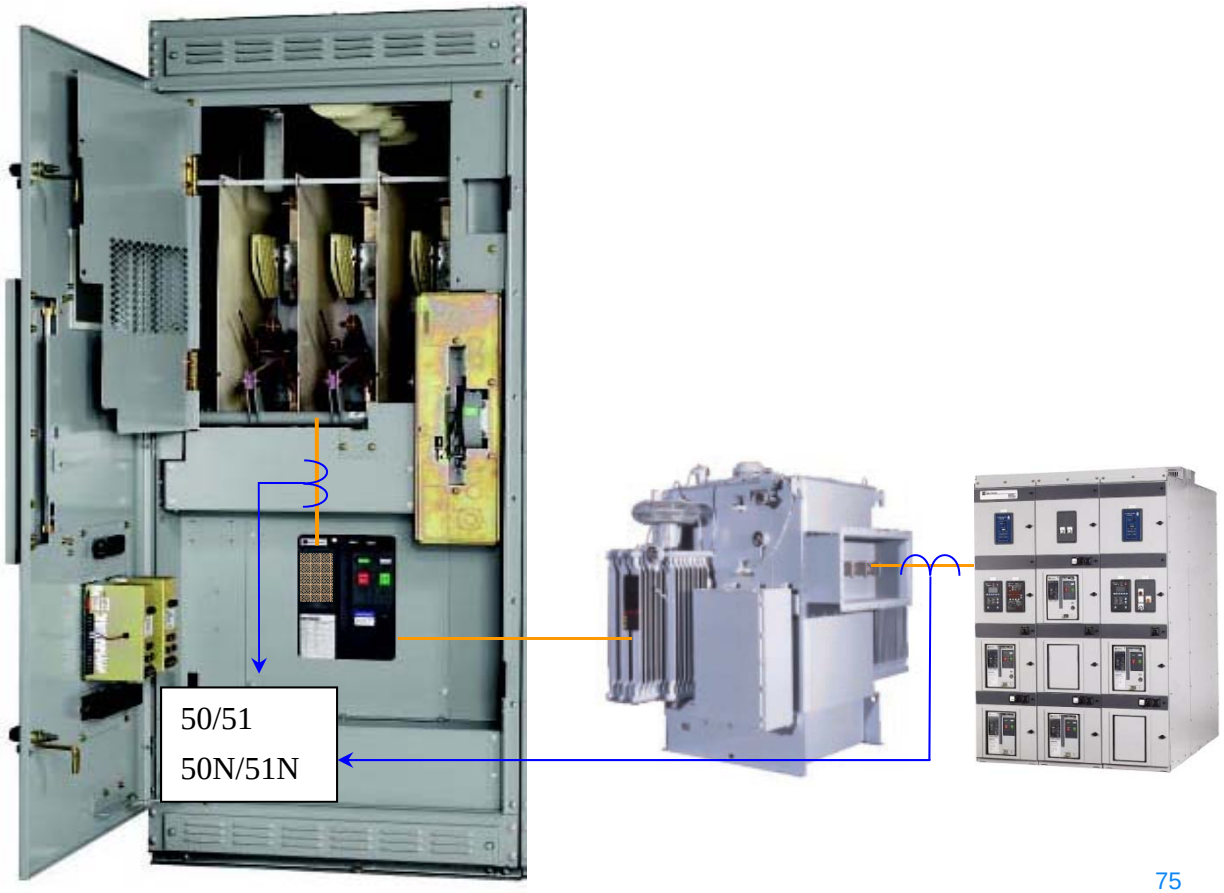
Power Distribution technologies to Reduce Arc-Flash Hazards

Substation Primary
Fusible Switch

Substation Primary Switch
and Vacuum Circuit Breaker

Substation Primary Switch and Vacuum Circuit Breaker

- Combines the protection of a power breaker with the visible disconnect of a load interrupter switch.
- CT's on Primary Side Connect to Protective Relay for Transformer Protection
- CT's on Secondary Side Connect to Relay for Switchgear Line Side Protection
- During normal operating conditions, standard system coordination is maintained
- Relays can include the Arc Flash Reduction Maintenance system that **lowers the arcing energy for an entire Unit Substation during down stream maintenance.**
- .



Move People Further Away

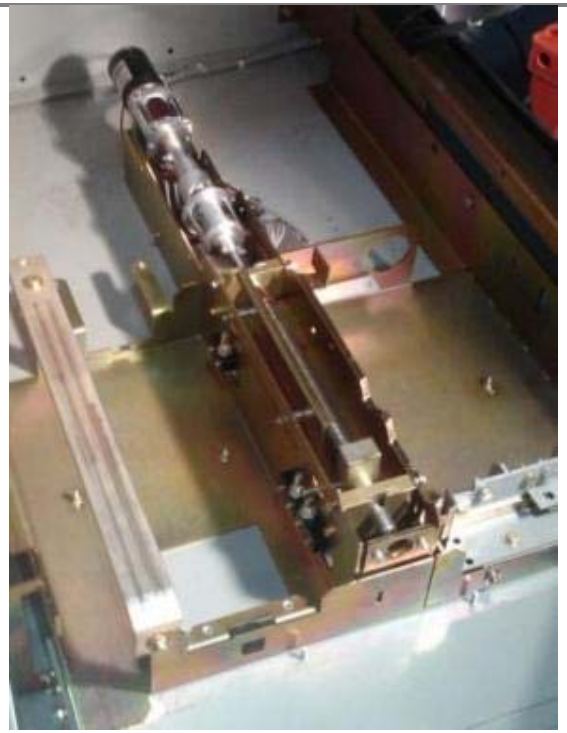
Remote Racking

Universal Racking Devices

VS.

Equipment-Specific Remote Racking – Medium Voltage Switchgear Example

Integral Racking – Motorized Remote Racking



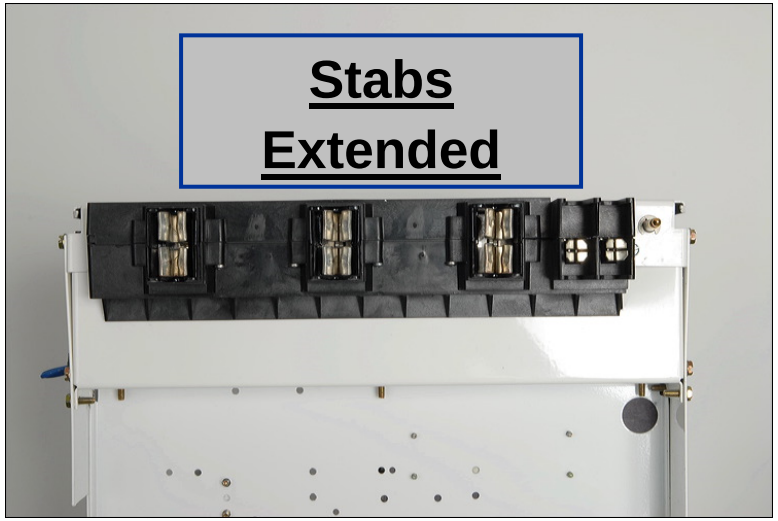
- Integral motor is part of the breaker cell
- Racking of breakers and auxiliaries (CPT, VT)

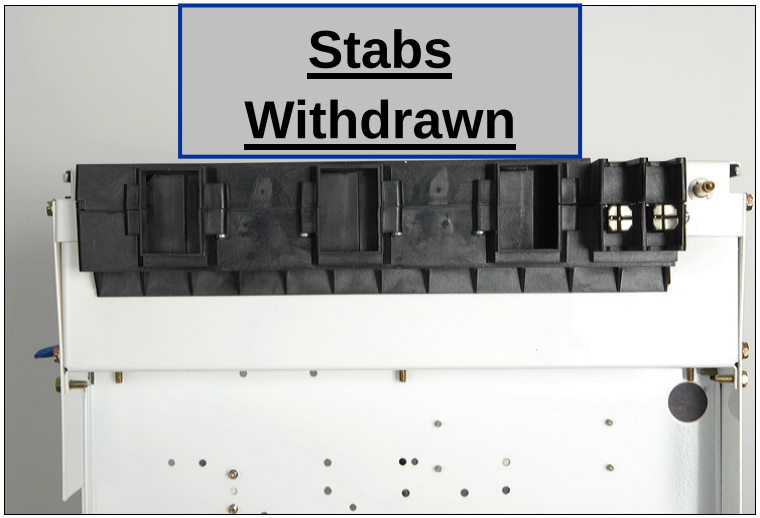
Equipment-Specific Remote Racking – Low Voltage Switchgear Example

- ✓ Pendant Controlled with Enable Button for Safety
- ✓ Allows Racking & Operation (Open / Close)
- ✓ Mounts to Breaker w/o Additional Door or Breaker Modifications Required
- ✓ Position Indicating Lights

Remote Racking of MCC Buckets

- Some manufacturers offer a draw-out MCC bucket
- A remote operator can be used to rack the MCC stabs on and off the bus





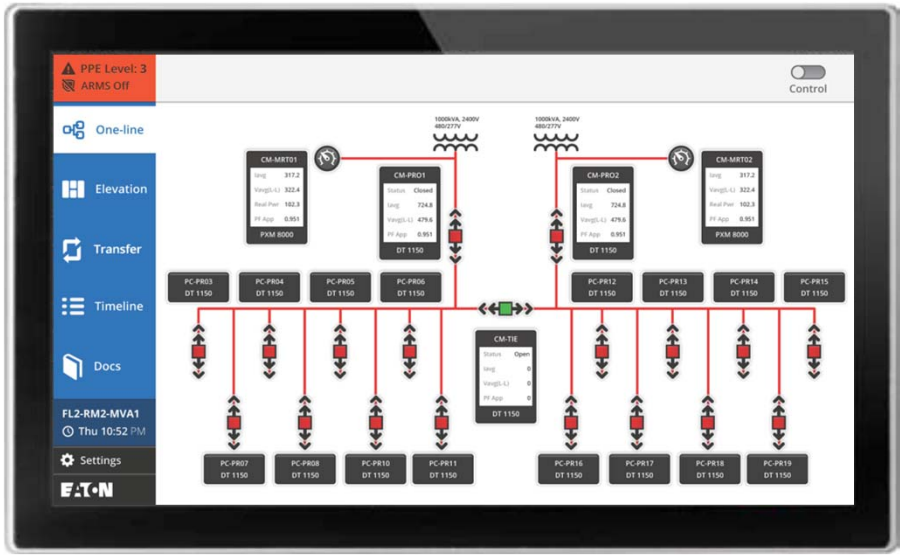
Remote Switching

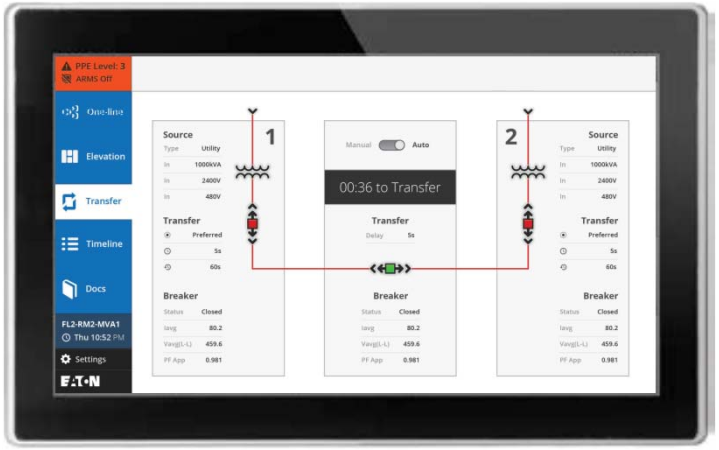
Example of Custom Remote Switching Panel

Marshalling panel individual controls for mains, tie and all feeders in a switchgear line-up.

Close-up of individual breaker controls: Open-Close-Trip plus PBs to connect-disconnect and lights indicating Connected-Test-Disconnected

Touchscreen “Dashboard”





Avoid Opening Enclosure Doors

- Infrared Scanning Windows for LV/MV Assemblies

SOLUTIONS THAT REDUCE ARC FLASH INJURIES and DAMAGE

Direct:

- Reduce Available Fault Current
- Faster Clearing Time
- Move People Further Away

Indirect:

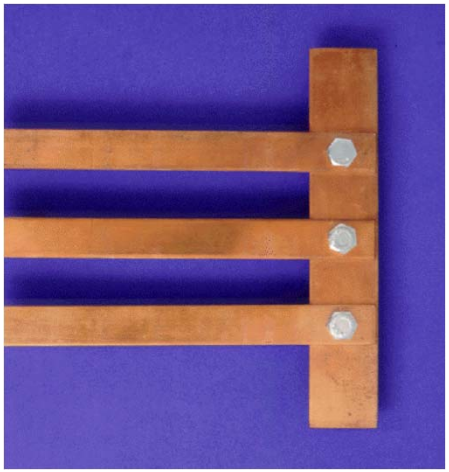
- Label Equipment & Train Personnel
- Minimize Risk with Good Safety Practices
- Redirect Blast Energy

Redirect Blast Energy

Arc Resistant Equipment

WHY ARC RESISTANT EQUIPMENT???

- Bolted fault
- No arc



- Resistance fault
- Severe arc

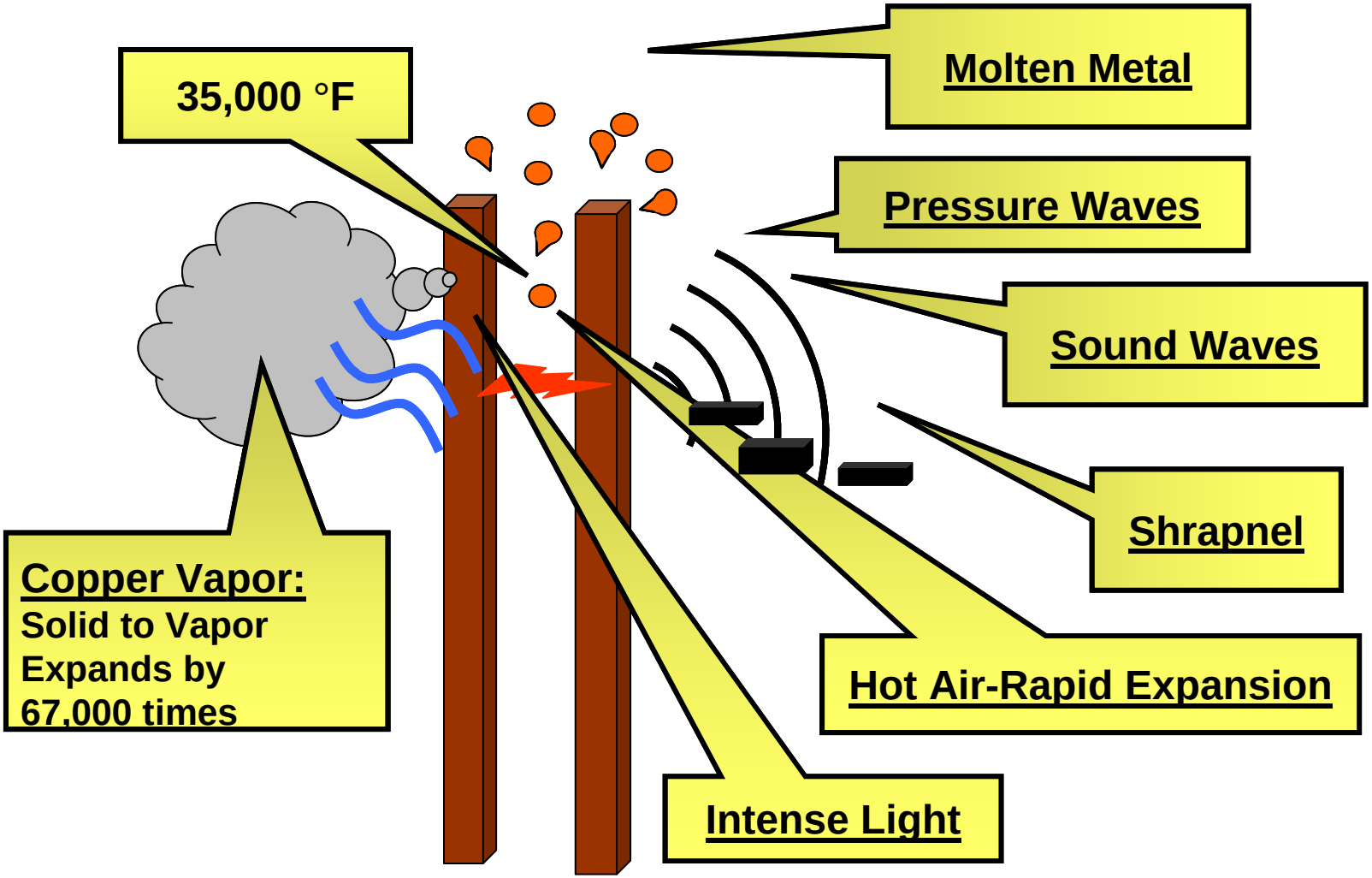
WHY ARC RESISTANT EQUIPMENT???

- Arcing occurs when there is impedance between a phase and ground or between phase & phase
- Arc faults release large amounts energy in the form of heat, light and pressure
- The arc is generating heat at temperatures up to 35,000°F
- Materials are vaporized

WHY ARC RESISTANT EQUIPMENT???

- Arc is maintained through vapor of the vaporized material which is highly conductive
- Arc faults release large amounts in the form of heat, light and pressure
- If arc fault occurs within the equipment, arc materials and an overpressure wave will exit the assembly

WHY ARC RESISTANT EQUIPMENT???



Arc Flash Concerns

- To put Arc Flash Concerns into perspective
  - Temperatures
    - Arc temperatures 35,000ºF
    - Surface of the Sun 9,000 ºF
    - Skin Temperature for a curable burn (2nd Degree) 176 ºF
    - Skin Temperature causing cell death 205 ºF
      - Requires skin grafts
  - Pressure Wave
    - Copper vapor expands 67,000 in volume
      - 1” of copper expands to the size of a refrigerator

Arc Flash Concerns

- To put Arc Flash Concerns into perspective
  - Sound
    - Can exceed 145dB @ 2 feet
    - 105dB is jet engine
    - dB is on a logarithmic scale (~ doubles every 10dB increase)
  - Vision
    - Flash of light can create serious and permanent loss of vision

WHY ARC RESISTANT EQUIPMENT???

- Conventional short circuit fault testing is performed on the following basis
  - Tests are based on bolted faults
  - Interrupting & switching devices are tested as components and are not required to be installed in the assembly
  - Dummy breakers can be used for temperature rise tests
  - No consideration is taken for arcing faults within the equipment being tested

WHY ARC RESISTANT EQUIPMENT???

- To protect personnel from arc materials expelled from equipment.
  - During work around energized equipment
    - House-keeping
    - Working on other de-energized equipment in vicinity
  - While opening/closing equipment
  - While racking equipment in/out of compartment
  - Changing settings (if available with door closed)
  - Trouble-shooting control compartment (if tested to 1B or 2B)

WHY ARC RESISTANT EQUIPMENT???

- Lowers PPE requirement per NFPA 70E for racking or operating equipment with doors & panels closed
  - Change in the 2009 edition
  - Previous editions gave no relief
  - Hazard/Risk Category reduced to 0 – Reference Table 130.7(C)(9)

WHAT DOESN'T IT DO?

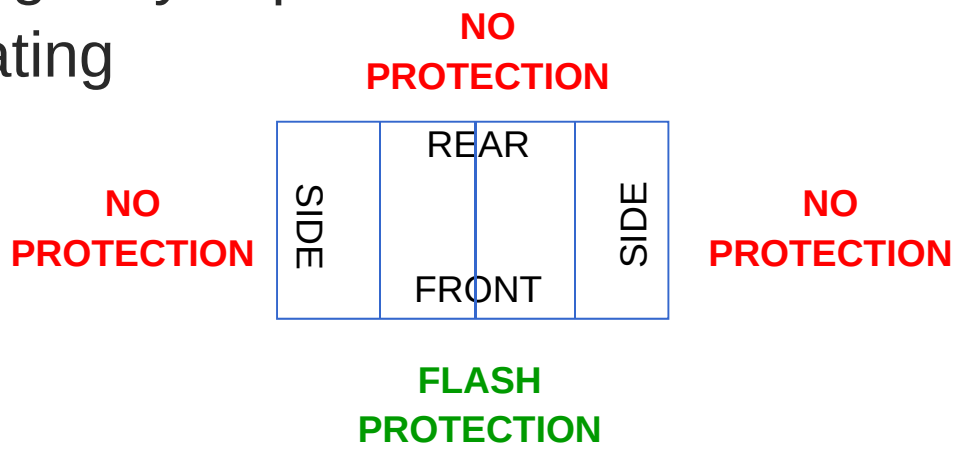
- Lower Incident Energy Values
- Offer protection to operator with any door opened or panel removed (except 2B instrument compartments)
- Lower the PPE requirement when working on energized equipment with doors open
- Prevent or preclude damage to the equipment

TYPES OF ARC RESISTANT EQUIPMENT

- Type 1 – Arc resistant at front of equipment only
- Type 2 – Arc resistant at front, sides, and rear of equipment
- Suffix B – Arc resistant with doors open on compartments designated as low voltage control or instrumentation compartments
- Suffix C – Isolation between adjacent compartments
- Suffix D – Applies only to Type 1 and adds protection on additional sides

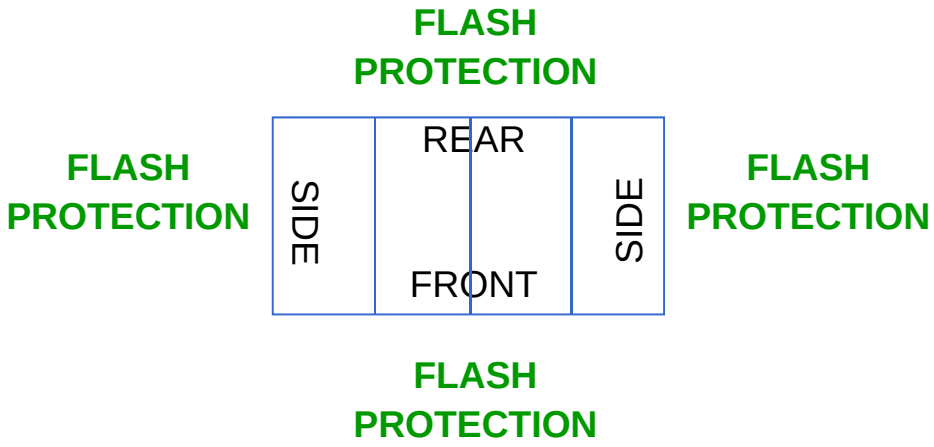
TYPES OF ARC RESISTANT EQUIPMENT

- Type 1
  - Not many products available with this rating
  - Usually not specified particularly for rear accessible equipment
  - Testing very expensive and not much demand for this rating



TYPES OF ARC RESISTANT EQUIPMENT

- Type 2
  - Commercially available
  - Typically specified



TYPES OF ARC RESISTANT EQUIPMENT

- Type 1B & 2B
  - Allows access to the rear of meters, relays, terminal blocks for troubleshooting while equipment is energized
  - Standard does not imply that equipment can be operated continuously with door open

TYPES OF ARC RESISTANT EQUIPMENT

- Type 1C & 2C
  - Limited availability
  - Costly
  - Couples personnel protection with internal arc propagation for equipment
  - Isolation between adjacent units from effects of internal arcing fault
  - May also require isolation between individual circuits in same vertical structure where two high design used
  - May restrict construction to single high design

TYPES OF ARC RESISTANT EQUIPMENT

- Types 1BC & 2BC
  - Includes features for both suffixes
- Type 1D
  - Limited availability
  - Must include additional characters to indicate which additional sides are protected
    - SR – Side Right
    - SL – Side Left
    - R – Rear
  - Due to cost of testing, might as well test to Type 2

RATINGS – ARCING CURRENT

- Standard does not list desired ratings
  - Manufacturer can chose ratings and test accordingly
  - Ratings are typically 30kA, 40kA, 50kA, 63kA for MV
  - Ratings are typically 85kA & 100kA for LV
- This is the tested rating of the assembly to withstand an internal arc and not vent to restricted side(s).
- Has nothing to do with breaker interrupting rating

RATINGS – ARCING DURATION

- Preferred duration is 0.5 second
- Minimum duration is 0.1 second
- Maximum duration is 1.0 second
- Most if not all of the equipment available has been tested to 0.5 seconds
- Allows coordination with downstream devices if internal fault limiting techniques such as bus differential relays are not implemented

Internal Arcing Fault - Illustration

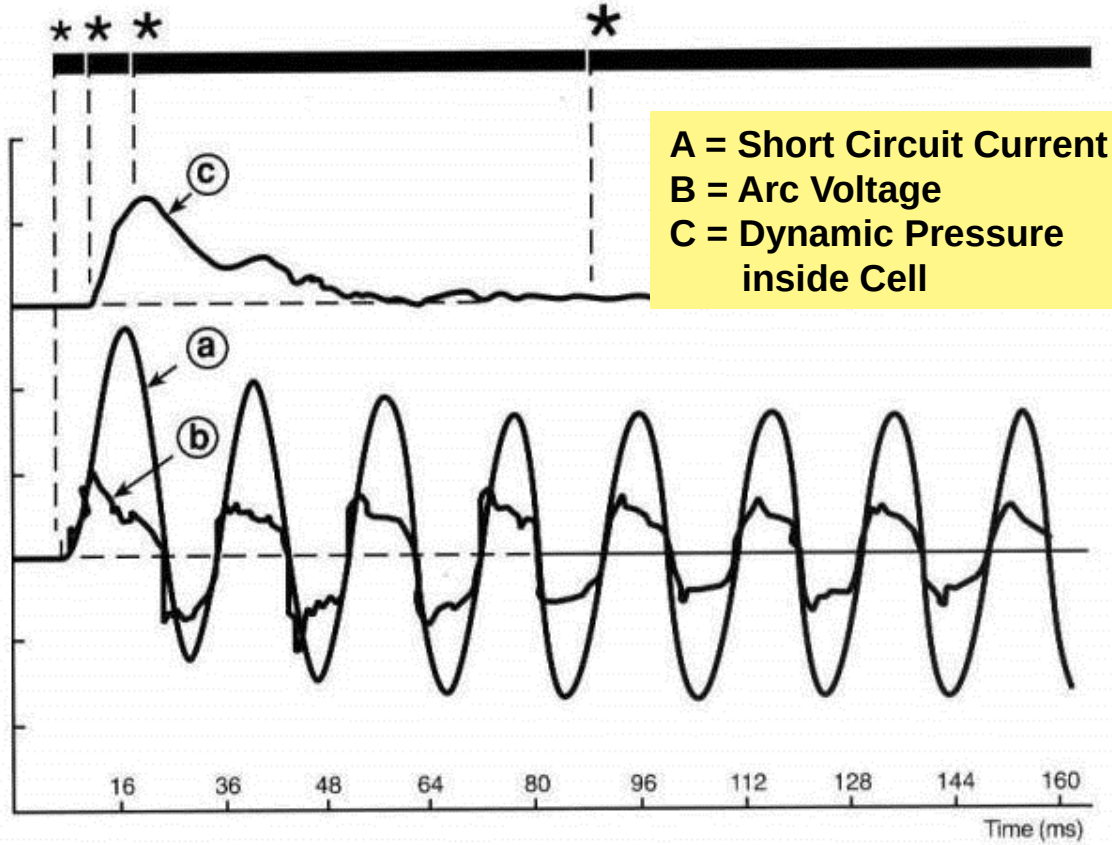
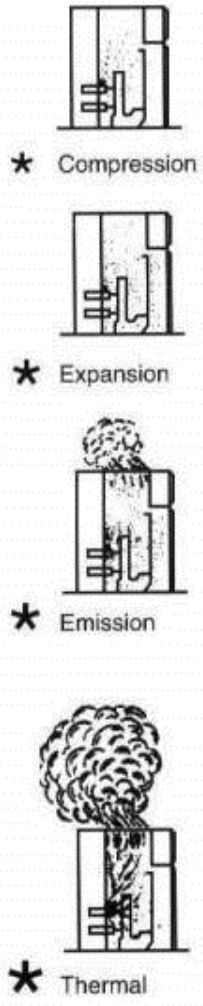


Illustration of a three-phase internal arc fault.

A) Short circuit current B) Arc Voltage C) Dynamic pressure inside the cell



Within 10 ms of arc initiation, pressure could reach more than 4200 lbs/Sq ft in some instances (value is a function of fault current magnitude).

SUCCESSFUL TEST

- All secured doors and panels stay secure
- Bowing and distortion permit so long as it does not touch indicators
- No fragmentation of enclosure occurs
  - Allow small pieces with individual wt of no more than 60g from external surface above 2m
- Arcing does not cause holes in the structure
- No indicators ignite as result of escaping gas
  - Indicators ignited due to the burning of paint, labels, glowing materials are excluded
  - High speed cameras record and films are reviewed to determine cause of ignition
  - Surface discoloration and charring of indicators permitted

Arc Resistant Video

Arc Resistant Switchgear – Application & Installation Considerations

- ✓ Arc resistant equipment often has different floor plan / height / surrounding space requirements.
- ✓ Is direct venting possible?
- ✓ How are cables entering and exiting the equipment?
- ✓ Will a plenum and associated arc duct be required?
- ✓ If arc plenum and duct is required, has a safe exhaust location been determined?
- ✓ Has the duct layout been established?
- ✓ Is a firewall required at exhaust penetration?
- ✓ Is any duct required to be outdoor with N3R rating?

Modification of the enclosure is not allowed as it may void arc resistant rating!

Medium Voltage Switchgear

Arc Resistant MV Switchgear Key Features

- Heavier Gauge Steel, Reinforced Doors and Covers,
- Levering Mechanism mechanically interlocked with Door
- Closed Door Breaker Operation
  - Breaker Racking
  - Breaker Spring Charging
  - Manual Open/Close
  - Viewing of Breaker Status & Position
- Typically indoor construction only

Arc Resistant MV Switchgear – Type 2B Construction

Relay box on breaker compt. door

Arc Resistant Switchgear Dimensions

- Dimensions for Bottom Entry

  5/15 kV Switchgear
  - 36” W x 97.5” D x 97” H for 1200 A (101.38” H for 2000 or 3000A)

  27 kV Switchgear
  - 42” W x 109” D x 92.38” H for 1200 A (96.38” H for 2000 A)

  38 kV Switchgear
  - 42” W x 129” D x 100” H
- Dimensions for Top Entry

  Add minimum 12” to depth for up to 2 cables/phase
- Arc Plenum – Additional height required to accommodate arc plenum and installation of the plenum.

Arc Resistant Metal-Clad Switchgear
Minimum Recommended Clearances

- **5/15 kV**

  Front = 70” Rear = 36”
  Left Side = 40” Right Side = 4”
  Above The Gear = Refer to Next Slide

- **27 kV**

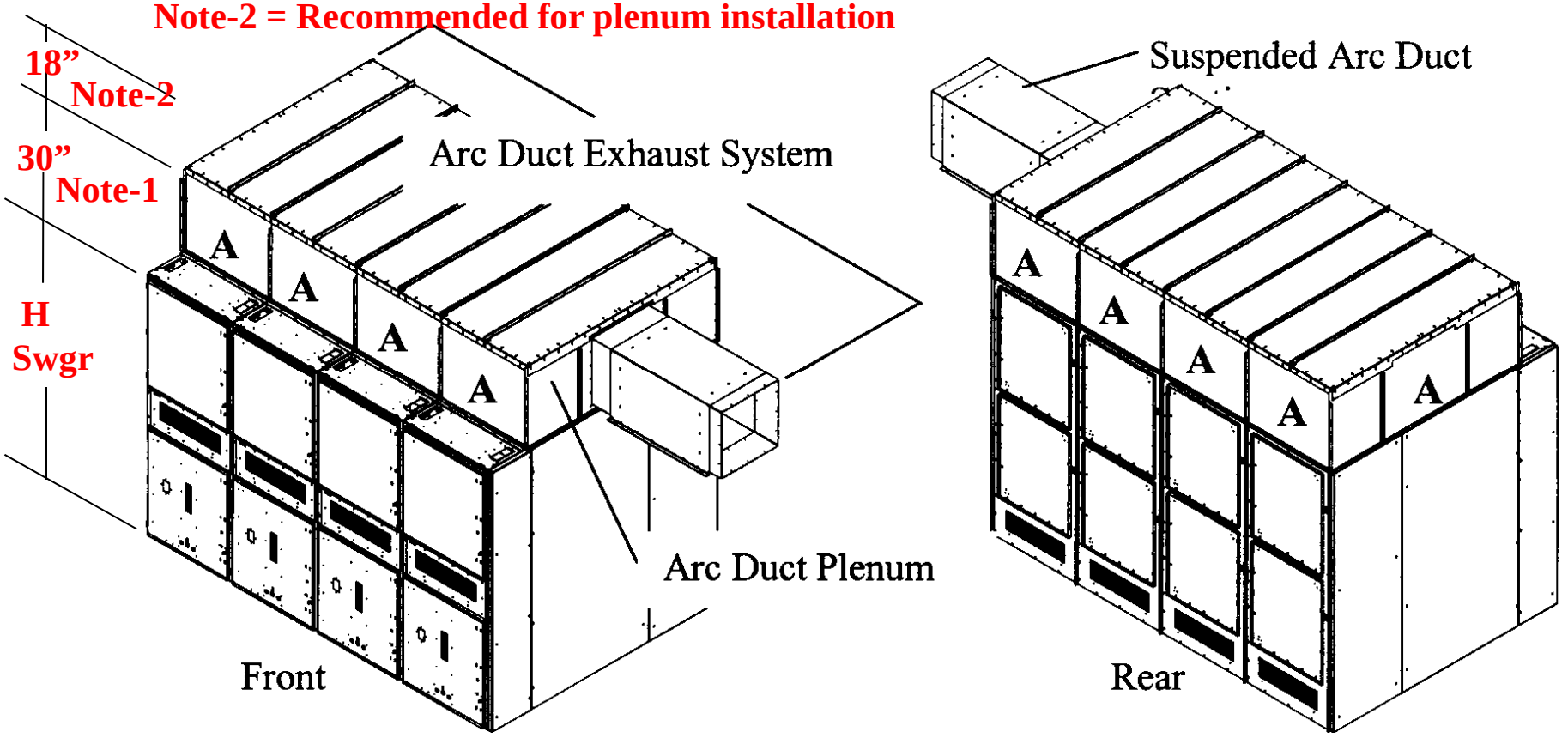
  Front = 70” Rear = 42”
  Left Side = 42” Right Side = 4”
  Above The Gear = Refer to Next Slide

- **38 kV**

  Front = 84” Rear = 42”
  Left Side = 42” Right Side = 4”
  Above The Gear = Refer to Next Slide

Arc Duct System above the Gear

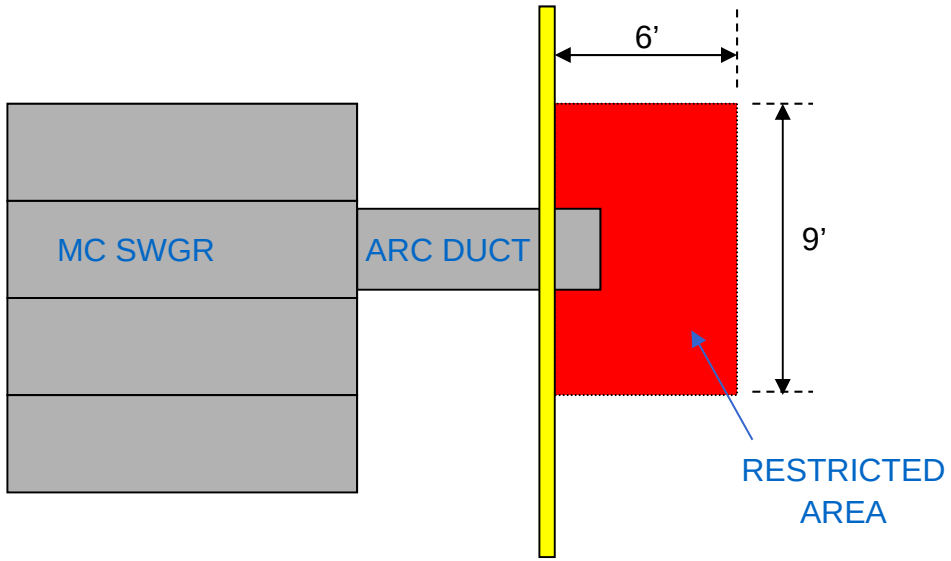
Note-1 = Plenum is field installed
Note-2 = Recommended for plenum installation



Minimum Clearance required above the gear = 30+18 =48 inches
Arc Duct can exit from any one of the locations marked “A”
Multiple duct exits may be required depending on rating

INSTALLATION CONSIDERATIONS
ARC EXHAUST DUCT WORK

- Where the duct exits the building there is an restrictive area that must be fenced off.
- Depends on manufacturer and type of equipment
- This must be taken into consideration when design access door, cable trays, walk areas, etc.



Other Arc Resistant Equipment – Medium Voltage Switch

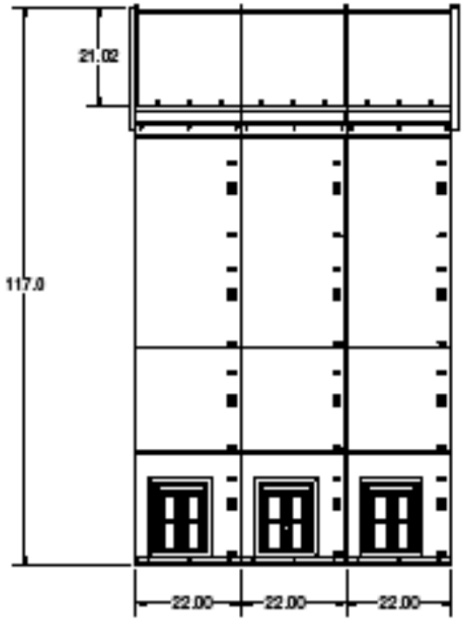
Other Arc Resistant Equipment - Medium Voltage Motor Control

Low Voltage Switchgear

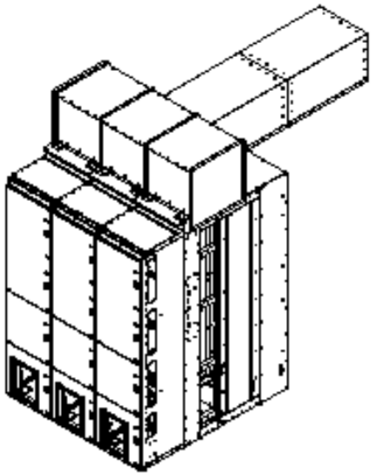
Arc Resistant Switchgear – Typical Dimensions

Dimensions (Inches):

- Width:
  - 22” with 800 to 3200 Amp Breakers
  - 44” with 4000 to 5000 Amp Breakers
  - Overall line-up must be 66” Min
- Depth:
  - Top or Bottom Cables: 72”, 78”, 84”, or 90” – Top Entry will see a reduction of approx 15” in available conduit space.
  - Bus Duct Connection: 84” Min (Top) & 78” Min (Bottom)
- Height:
  - Standard 99” Height with Direct Venting in Room (with Top Mounted Breaker Lifter)
  - 117” Height With Plenum Installed
  - 18” Minimum Clearance above Plenum



FRONT VIEW



Arc Resistant Switchgear – Key Features

Key Features:

- ✓ Through-the-Door Breaker Design
- ✓ Arc Resistance on All 4 Sides (Type 2)
- ✓ Arc Resistant with Control Compartments Open (Type 2B)
- ✓ Stronger Breaker Door & Latch Mechanism
- ✓ 4-High Breaker Design
- ✓ 10 ft Ceiling Height required for Direct Venting with no Plenum
- ✓ Plenum Design Available
- ✓ Breaker Racking with Door Closed

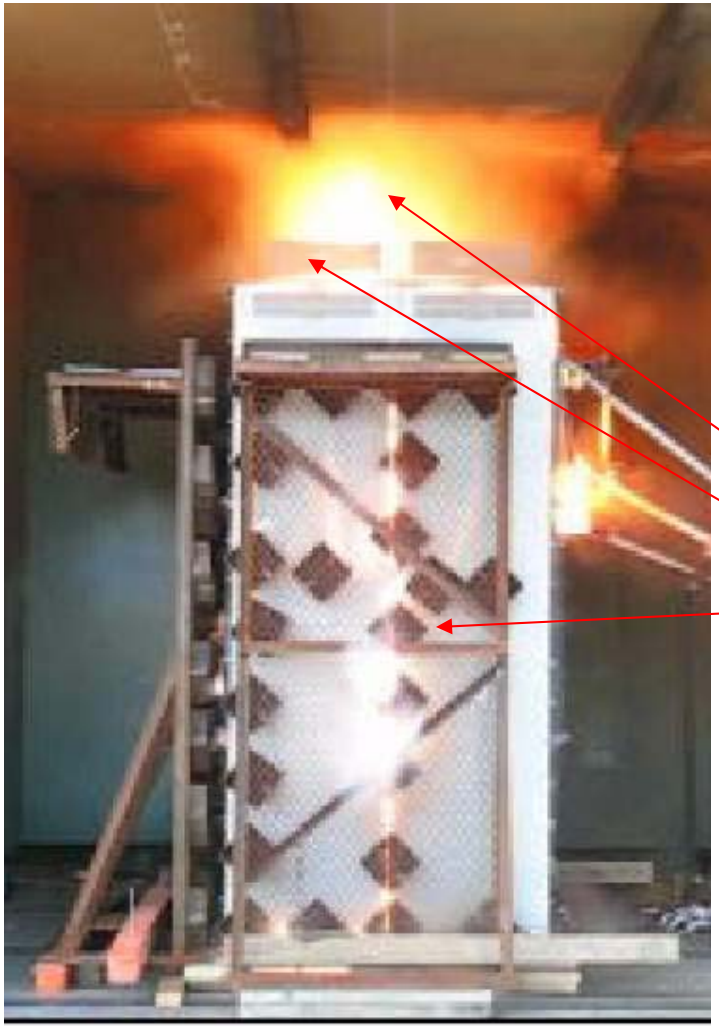
Arc Resistant Switchgear - Testing

- Fig #1 – Baseline test @ 65kA in Dec 06 with arc initiated in bus compartment.
- Fig #2 – Revised test @ 85kA in May 07 with addition of dynamic flaps.

Fig #1 - 65kA Bus Compartment Arc

Fig #2 - 85kA Bus Compartment Arc

Arc Resistant Switchgear - Testing



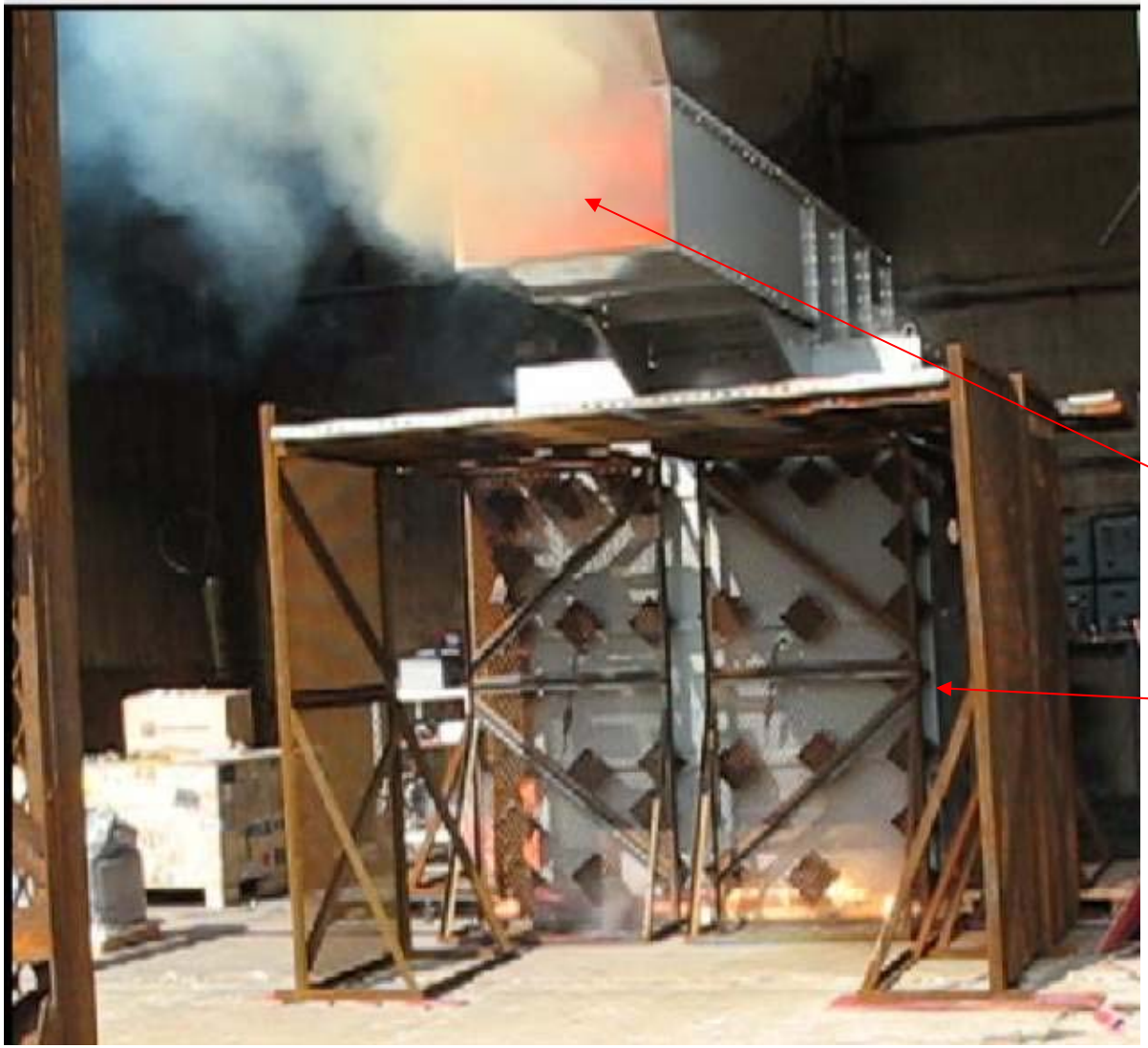
Test @ 85kA / 508V
Arc initiated in bus compartment
Room Simulation (10 feet floor-to-ceiling)
August 2007 - PASS

Arc gasses out of top of bus compartment

Open flaps above bus compartment

No indicators burned

Arc Resistant Switchgear - Testing



Test @ 65kA / 508V

Arc initiated in breaker compartment

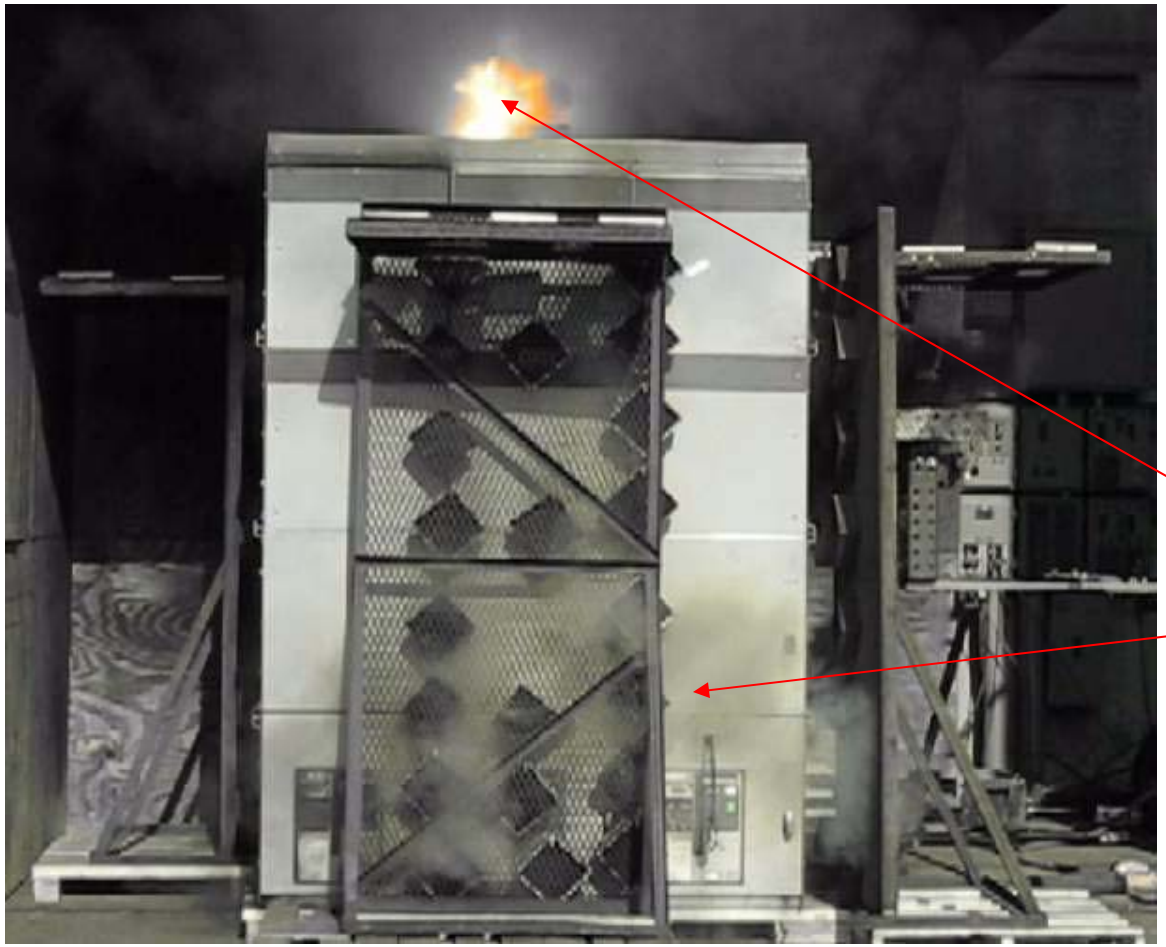
Plenum Design

March 2008 - PASS

Arc out-gassing through plenum

No arc flash out of the front of the gear

Arc Resistant Switchgear - Testing



Test @ 85kA / 508V

Arc initiated in breaker compartment

Room Simulation (10 feet floor-to ceiling)

March 2008 - PASS

Arc out-gassing without plenum

Limited Smoke

Low Voltage Motor Control

Arc Resistant MCC Construction – Key Features

- Main breaker required
- 4” Transitions at each end of lineup
- Enhanced door latches
- Enhanced hinges
- Insulated horizontal bus, labyrinth vertical bus
- Fire barriers between structures
- 12ga side sheets, back sheets, unit doors, and wireway doors
- No arc plenum or extra height required

Arc Resistant Switchgear – Summary

- Arc resistant equipment offers additional personnel safety compared to standard switchgear
- Arc Resistant equipment enables interaction with the switchgear without additional PPE (with equipment doors closed)
- Arc Resistant equipment requires additional design consideration due to physical size and exhausting of the arc

QUESTIONS?

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