Understanding Arc Flash

Presented by

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DANGER
HIGH
VOLTAGE

Five to 10 arc flash explosions occur in electric equipment every day in the United States. This number does not include cases in which the victim is sent to an ordinary hospital. Instead, these incidents are so severe the victims require treatment from a special burn center.

Type of faults

- Bolted Fault

  Bolted faults are characterized by a solidly connected fault path causing high levels of current to flow through this solid connection.

- Arcing Faults

  Arcing faults differ in the fact that the current actually flows through ionized air causing an arc.

  The major difference between these two types of faults is that the energy in a bolted fault condition is dissipated in the faulted equipment while an arcing fault releases energy out into the surrounding enviroment

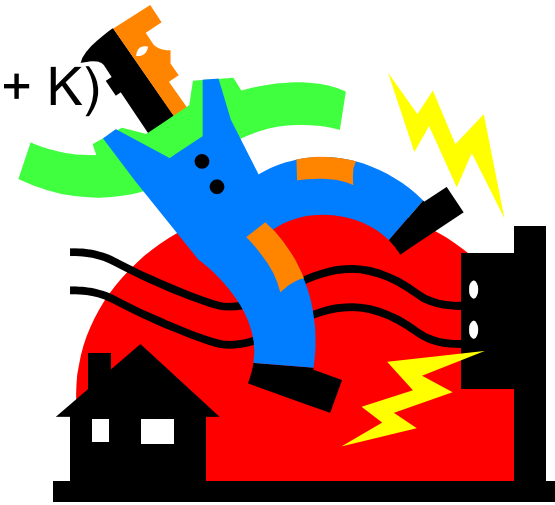
What causes electrical arcing

- Inadvertent contact
- Loose connections
- Insulation failure
- Poorly maintained equipment
- Voltage transients
- Unsuccessful Short Circuit Interruption
- Animals (squirrels, snakes .. Etc)

Why is arc flash dangerous?

An arc is a source of intense heat, light, sound and pressure!

- North Carolina in August: 100° F (311K)
- Surface of the Sun: 8,540° F (5,000 K)
- Arc @ arc terminals: 35,540° F (20,000+ K)



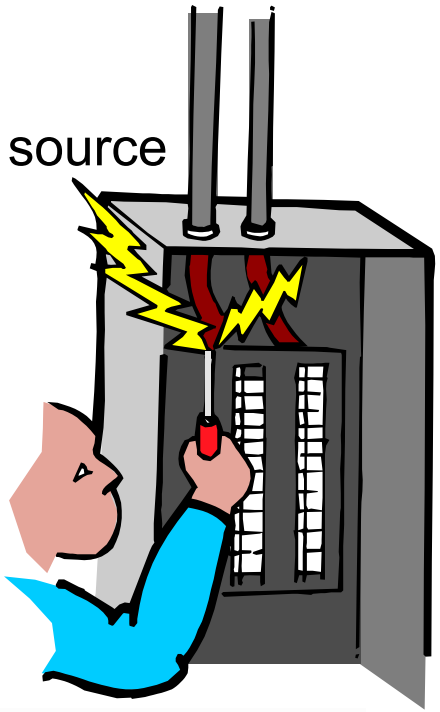
Max. arc power = 1/2 x bolted fault kW

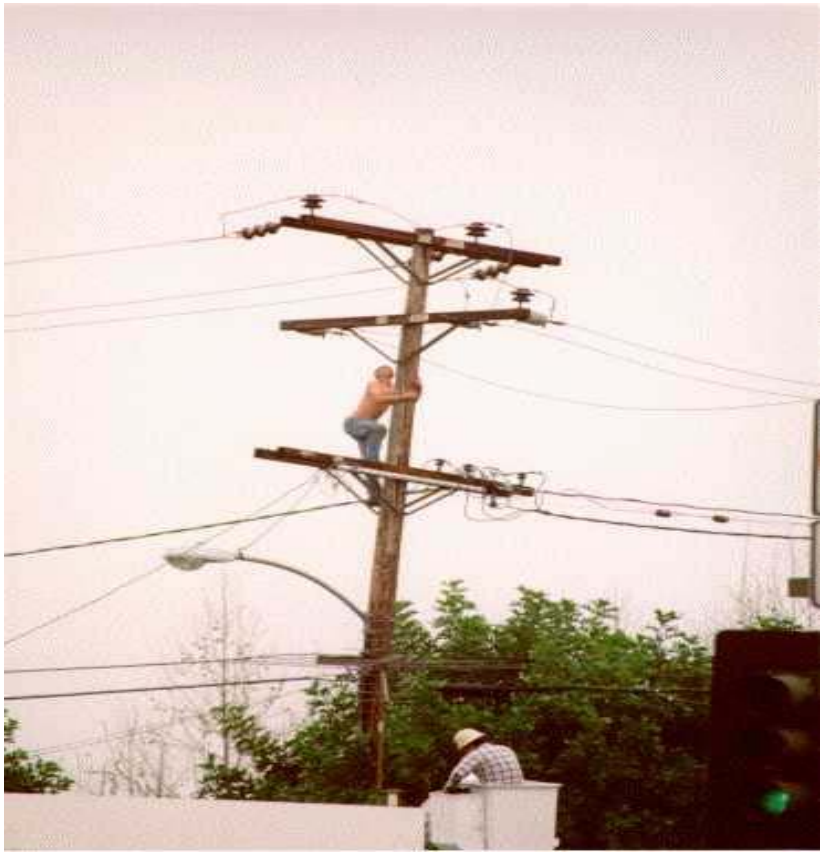
Heat transfer depends on:

Size of arc (arc power)
Duration of arc
Distance from arc (1/x^2)
Enclosure ("arc in a box" focuses heat in one direction)

Physical Effects of Arc Blast

- Metal vapor and air expand very rapidly due to arc heating
- Pressure wave knocks worker away from arc
  - Good: removes personnel from heat source
  - Bad: removes personnel from ladder
- Pressure propels molten metal droplets out from arc source
  - Hot enough to ignite clothing
- Structural damage to buildings
- Damaging sound pressure
  - Eardrum rupture
  - Blindness
  - Lung damage
  - Death!





Standards used to protect workers from Arc-flash hazards.

NFPA 70E-2000

*"Covers electrical safety-related **work practices and procedures** for employees who work on or near exposed energized electrical conductors or circuit parts in work places…"*

NEC-2002

*"Switchboards, panelboards, industrial control panels, and motor control centers … **shall be field marked** to warn qualified persons of potential electric arc flash hazards."*

OSHA 1910

*" The **employer shall ensure** that each employee exposed to electric arcs shall not wear clothing that could increase the injury when exposed to these arcs."*

IEEE 1584

*"This guide presents **methods for the calculation** of arc-flash incident energy and arc-flash boundaries in three-phase ac systems to which workers may be exposed."*

Safe operations

NEC (Installation)

OSHA (Workplace Safety)

Employer (Facility)

Equipment

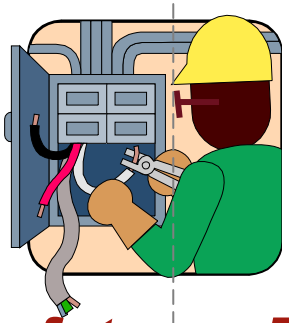
(Product Standards)

Electrical Safety Program

Practices | **Training** | **Analysis**

OSHA Standards
NFPA 70E

IEEE 1584
Calculations



Employee

(Work, PPE)

Enforcement by inspectors

Enforcement by OSHA

Design for Safety

Electrical Safety Program

NEC 110.16

"Switchboards, panelboards, industrial control panels, and motor control centers that are in other than dwelling occupancies 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."

Warning for awareness, to prepare for future work

Field marked - not marked by manufacturer

No mention of values - only warning of hazard

OSHA 29 CFR 1910.335

Personal Protective Equipment

"Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed."

Notice that OSHA does not specifically mention calculations or NFPA 70E. However, since NFPA 70E is a recognized, published standard available to the industry, OSHA will cite using requirements of NFPA 70E.

OSHA 29 CFR 1910.333

- **Safety related work practices shall be employed to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts."**
- **"Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible."**

The fundamental requirement is to de-energize!

Working on energized equipment is always a risk!

When is it acceptable to work on energized equipment?

Examples of increased or additional hazards

- Interruption of:
  - Life support systems
  - Emergency alarm systems
  - Hazardous location ventilation

Examples of unfeasibility:

- Start-up testing
- Trouble shooting diagnostics
- Continuous process segment

NFPA 70E 2-1.3.3

"Flash hazard analysis shall be done before a person approaches any exposed electrical conductor or circuit part that has not been placed in an electrically safe work condition."

Electrically Safe

The following steps must be taken to ensure an electrically safe work condition.

- Find all possible sources of supply
- Open the disconnecting device for each source
- Where possible visually verify the device is open
- Apply lock-out/tag-out devices
- Test voltage on each conductor to verify that it is de-energized
- Apply grounding devices where stored energy or induced voltage could exist or where de-energized parts could contact live parts

Remember personal protective equipment must be worn when working within the flash protective boundary until the circuit is verified to be de-energized.

Incident energy

Incident energy:

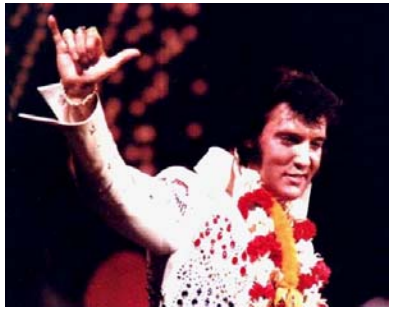
- **The amount of energy impressed on a surface, a certain distance from the source, generated during an arc event.**

- **Incident energy is measured in calories/cm^2 or Joules/cm^2.**

1.2 cal/cm^2 is the minimum amount of Incident Energy to produce second degree burns on human skin. The flash protection boundary is the distance at which the incident energy equals 1.2 cal/cm^2.

Classes of Protective Clothing

NFPA70E lists the clothing that is appropriate for each hazard class.



Incident Energy (cal/cm^2)	Clothing Class	Description	ATPV
0-2	0	Untreated Cotton	n/a
2-5	1	FR shirt and pants	5-7
5-8	2A	Cotton Underwear + Cl. 1	8-18
5-16	2B	FR Underwear + Cl. 1	16-22
8-25	3	FR Coverall + Cl. 2A	25-50
25-40	4	Double Layer Switching Coat + Cl. 2A	40-60+

ATPV - Arc thermal performance exposure value (cal/cm^2)

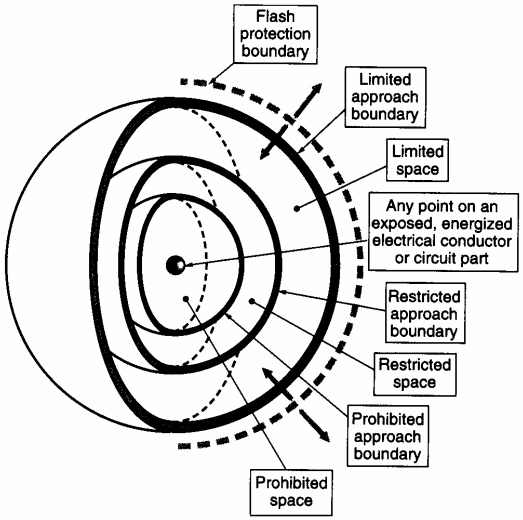
Hazard/Risk Category

Task Assumes Equipment is energized, and work is done within Flash Boundary	Hazard/Risk Category	V-rated Gloves	V-rated Tools
Panelboards or Switchboards rated >240V (with Molded Case or Insulated case circuit breakers) - Notes 1 and 3	-	-	-
CB or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Note 1. 25kA short circuit current available, 0.03 sec (2 cycle) fault clearing			
Note 3. For < 10 kA short circuit current available, the Hazard/Risk Category required may be reduced by one Number.			

Limits of approach

NFPA70E establishes approach boundaries to live parts for shock protection for both qualified and unqualified personnel.

Voltage (L-L)	Limited Approach (movable)	Limited Approach (fixed)	Restricted Approach	Flash Protection
< 300 V	10’	3’ 6”	Avoid Contact	3’
300 – 750 V	10’	3’ 6”	1’	3’
750 – 2,000 V	10’	4’	2’	4’
2,000 – 15,000 V	10’	5’	2’ 2”	16’



IEEE 1584-2002

"IEEE Guide for Performing Arc-Flash Hazard Calculations"

- Incorporates results of extensive testing performed by several parties
- Provides tools to calculating incident arc-flash energy and protection boundries.
- Does not replace NEC or 70E--instead, works with and alongside of them

What is an Arc flash Analysis?

"A study investigating a worker's potential exposure to arc flash energy,

conducted for the purpose of injury prevention

and the determination of safe work practices

and appropriate levels of PPE."

Analysis Process

1 Collect system and installation data
2 Determine system modes of operation
3 Determine bolted fault current
4 Calculate arc fault current
5 Find protective device characteristic and arc duration
6 Select working distances
7 Calculate incident energy
8 Calculate flash protection boundary
9 Determine PPE (risk hazard) category

Arc Flash Study Deliverables

- AFIE and resulting PPE levels
- Single-line diagram
- Short circuit duty assessment
- Time-current coordination settings
- Equipment labels (optional)

Personnel Protection Equipment Table

	Incident Energy From (cal/cm2)	Incident Energy To (cal/cm2)	FR Clothing Class No.	Clothing Description	Total Weight (oz/yd2)	Breakopen Threshold Energy (cal/cm2)	Notes
1	0	2	0	Untreated Cotton	4.5-7	N/A	
2	2	5	1	FR Shirt & Pants	4.5-8	5	
3	5	8	2	FR Underwear + FR Shirt & Pants	9-12	8	
4	8	25	3	Cotton Underwear + FR Shirt & Pant + FR Coverall	16-20	25	
5	25	40	4	Cotton Underwear + FR Shirt & Pant + Double Layer Switching Coat	24-30	40	

Reset | OK | Cancel | Help

Flash Hazard Analysis Table

Bus Name	Protective Device Name	kV	Bus Bolted Fault (kA)	Prot Dev Bolted Fault (kA)	Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time (sec.)	Duration of Arc (sec.)	Arc Type	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)	Required Protective FR Clothing Class
208V PNL	MA 600A	0.21	10.54	10.54	8.76	0.025		0.025	In Box	12.26	18.00	0.68	Class 0, Untreated Cotton
208V SEC	KA 225A	0.21	10.77	4.67	4.67	0.017		0.017	In Box	9.47	18.00	0.47	Class 0, Untreated Cotton
480 V PNL	LE 400A	0.48	22.42	22.42	16.31	0.04		0.04	In Box	22.81	18.00	1.70	Class 0, Untreated Cotton
480V PRI	KA 225A	0.48	20.66	20.66	15.24	0.017		0.017	In Box	12.32	18.00	0.69	Class 0, Untreated Cotton
MB - 13.8kV	CO-11 (50/51)	13.80	10.54	10.46	10.46	0.144	0.050	0.194	In Box	136.39	18.00	68.90	**** Dangerous!!! No FR Class Found
MCC	ME 800A	0.48	29.12	26.73	18.83	0.04		0.04	In Box	27.39	18.00	2.23	Class 1, FR Shirt & Pants
MDP - 480V	PE 2500A	0.48	30.80	28.42	19.79	0.04		0.04	In Box	29.11	18.00	2.44	Class 1, FR Shirt & Pants

Can arc flash exposure be reduced?

- Design considerations
  - Main circuit breakers

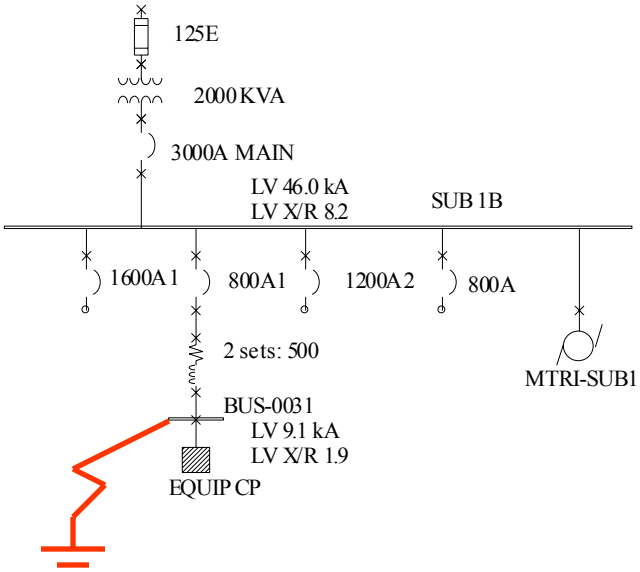
    Especially on the load side of service entrance transformers

  - High resistance grounded systems

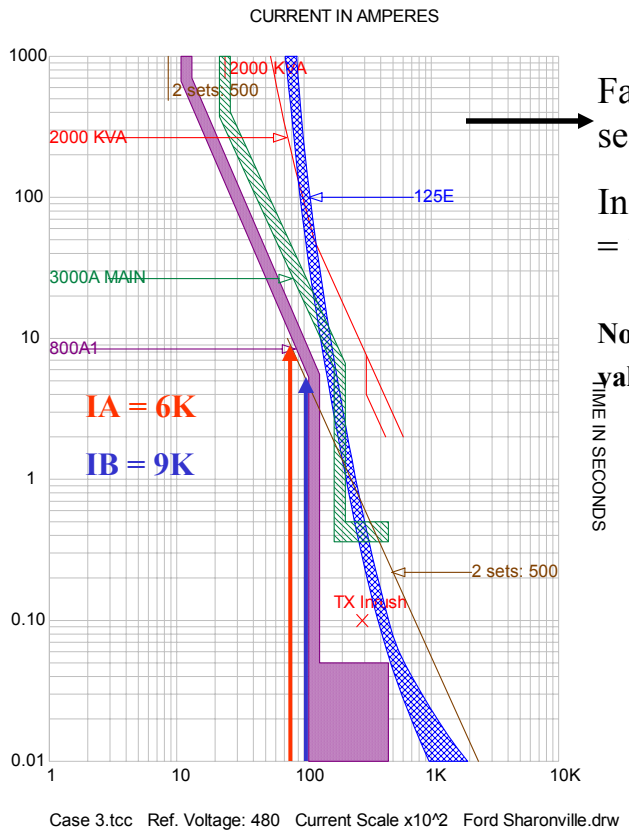
    Limits the line to ground fault energy

  - Performing Arc-flash analysis

    Review circuit breaker settings (INST)



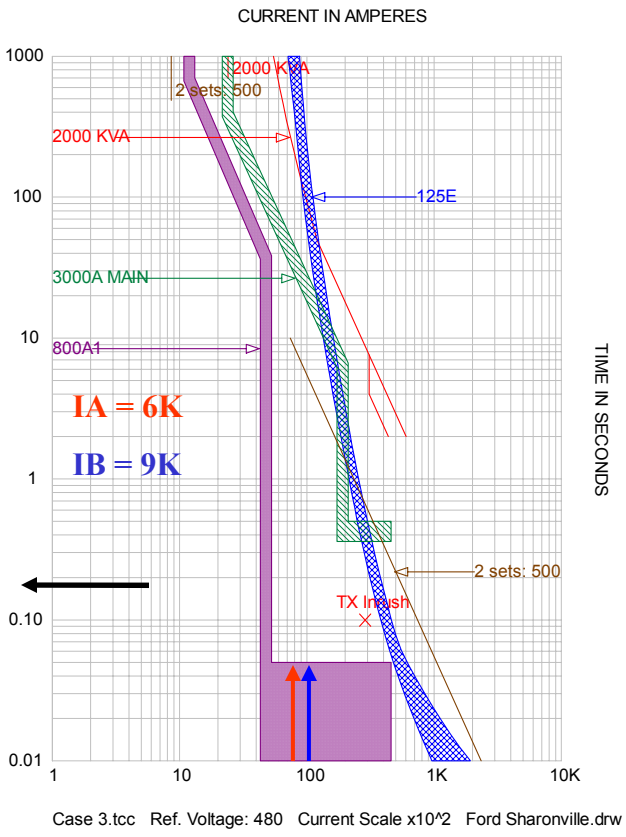
Breaker Settings Comparison



Fault clears in 8 seconds

Incident energy = 718 cal/cm^2

No FR class for IE values this high



Fault clears in 0.1 second

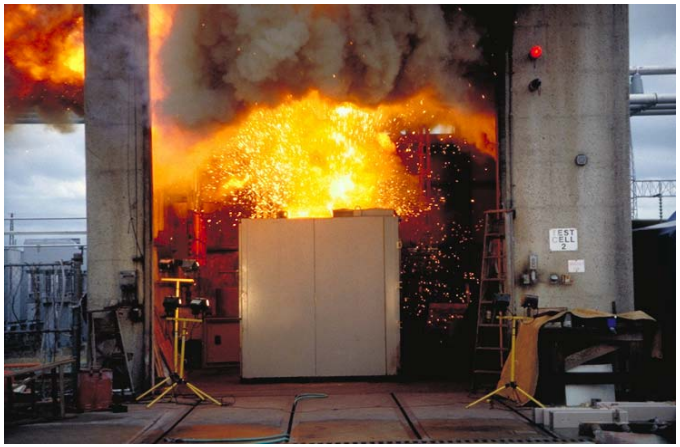
Incident energy = .97 cal/cm^2

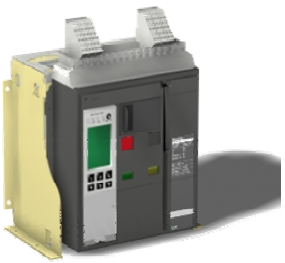
FR class 0

Can arc flash exposure be reduced?

Maintenance considerations

- Direct replacements, reconditioning, retrofills of older devices
  - New, improved protective relays
  - MasterPact clearing times
- Remote racking
- Arc Terminator for MV MetalClad s/g
- Arc resistant switchgear
- HVIR windows, remote thermal monitoring
  - Thermographic imaging requires
    - Equipment energized and serving normal loads
    - Equipment open and visible





Parting thought

Numerous injuries and deaths are caused each year by arc-flash incidents. While arc-flash can not be completely eliminated, there are many things that we can do to prevent it. The single most important thing we can do to prevent arc-flash incidents is to place the equipment in a "safe working condition." If it is more dangerous to turn the equipment off workers must wear appropriate PPE.

Thank you for your time and attention

Merlin Gerin
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