NFPA 70E® – Electrical Safety in the Workplace

Changes for 2012

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REV: 9/20/2011

IEEE / NFPA Arc Flash Collaborative Research Project

IAEI Western Section Meeting
Louisville, Kentucky
September 21, 2011

Acknowledgements

Paul Dobrowsky
Innovative Technology Solutions

Jeff Sargent
Michael Fontaine

Dr. Wei-jen Lee

Technical Committee Meetings for the 2012 Edition of NFPA 70E

ROP Meeting – February 2010, Memphis, TN

540 Public Proposals

8 Committee Proposals

ROC Meeting – October 2010, Savannah, GA

433 Public Comments

11 Committee Comments

2012 NFPA 70E
Technical Committee Membership

25 Principal Members
19 Alternate Members

Over 12 Days of Meetings
Over 4000 Man-Hours of Work!

Effective August 31, 2011

ARTICLE 90
Introduction

90.1 Purpose. The purpose of this *Standard* is to provide a practical safe working area for employees relative to the hazards arising from the use of electricity.

90.1 Practical Safeguarding. The purpose of this *Code* is the practical safeguarding of persons and property from the hazards arising from the use of electricity.

ARTICLE 90
Introduction

90.2 Scope

(A) Covered. This standard addresses electrical safety related work practices for employee workplaces that are necessary for the practical safeguarding of employees relative to the hazards associated with electrical energy during activities such as the installation, inspection, operation, maintenance, and demolition of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways.

ARTICLE 90
Standard Arrangement

Applies generally to electrical safety in the workplace	→	**Chapter 1** Safety-Related Work Practices
Safety-related maintenance requirements	→	**Chapter 2** Safety-Related Maintenance Requirements
Safety requirements for special equipment; supplements and/or modifies Chapter 1	→	**Chapter 3** Safety Requirements for Special Equipment

ARTICLE 110
General Requirements for Safety-Related Work Practices

- **Relationships with Contractors**
- **Training Requirements**
- **Electrical Safety Program**
- **Use of Equipment**

110.1 Relationships with Contractors

New –

(C) Documentation. There shall be a documented meeting between the host employer and the contract employer.

110.1 Relationships with Contractors

Electrically Safe Work Condition

Electrial conductors and equipment shall be considered energized until the source of energy is removed.

- **Open disconnecting device(s) for each source**
- **Apply lockout / tagout devices properly**
- **Test each phase conductor (L-L and L-G) to verify they are de-energized**

110.1 Relationships with Contractors

Test Before Touch!

1 – Verify operation of the test instrument before testing

2 – Perform test to verify the absence of voltage

3- Verify operation of the test instrument after testing

110.1 Relationships with Contractors

Can I Work Energized?

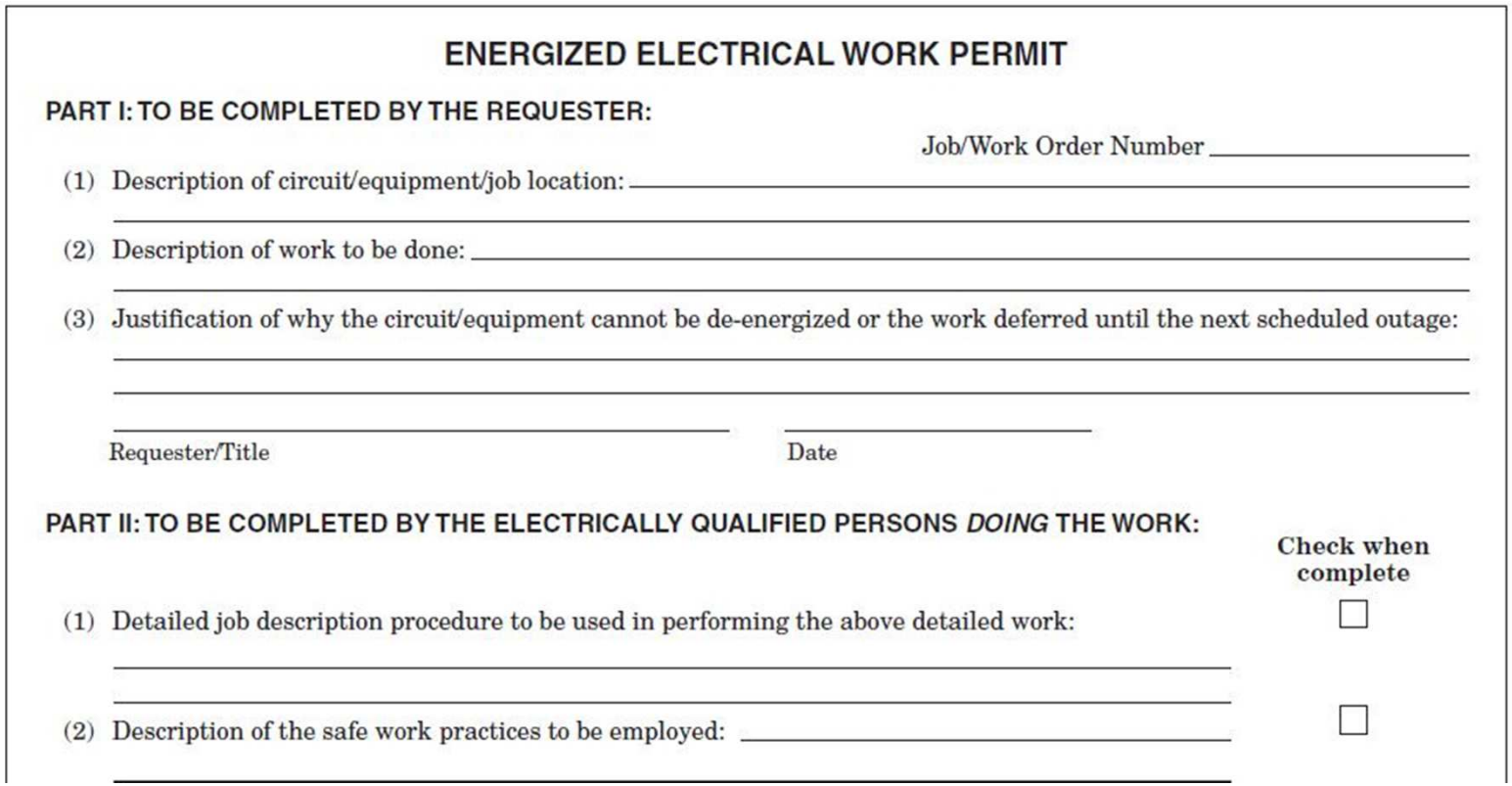
1 – Less than 50 Volts

2 – Demonstrate that de-energizing introduces additional hazards or increased risks

3 - Demonstrate that de-energizing is infeasible due to equipment design or operational limits

110.1 Relationships with Contractors

Except for testing, troubleshooting, voltage measurement, or visual inspection, an Energized Electrical Work Permit is required for energized work.



ENERGIZED ELECTRICAL WORK PERMIT

PART I: TO BE COMPLETED BY THE REQUESTER:

Job/Work Order Number _____

(1) Description of circuit/equipment/job location: _____

_____

(2) Description of work to be done: _____

_____

(3) Justification of why the circuit/equipment cannot be de-energized or the work deferred until the next scheduled outage:

_____

_____

_____ _____

Requester/Title Date

PART II: TO BE COMPLETED BY THE ELECTRICALLY QUALIFIED PERSONS *DOING* THE WORK:

Check when complete

(1) Detailed job description procedure to be used in performing the above detailed work: ☐

_____

_____

(2) Description of the safe work practices to be employed: _____ ☐

_____

110.1 Relationships with Contractors

Who approves energized work?

PART III: APPROVAL(S) TO PERFORM THE WORK WHILE ELECTRICALLY ENERGIZED:

Manufacturing Manager	Maintenance/Engineering Manager
Safety Manager	Electrically Knowledgeable Person
General Manager	Date

Note: Once the work is complete, forward this form to the site Safety Department for review and retention.

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110.1 Relationships with Contractors

What about the normal operation of equipment?

Normal operation of enclosed equipment, operating at 600 Volts or less, is not likely to expose an employee to an electrical hazard, provided it has been properly installed and maintained.

110.2 Training Requirements

(C) including cardiopulmonary resuscitation and Automatic External Defibrillator (AED) use shall be ...

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***New* - (D)(1)(f) The employer shall determine, through regular supervision or through inspections conducted on at least an annual basis that each employee is complying with the safety-related work practices required by this standard.**

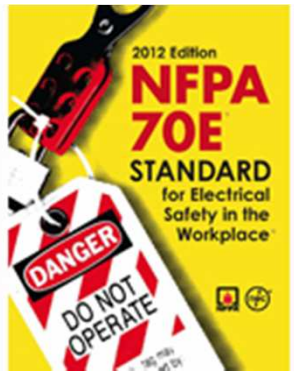
(E) The documentation shall contain the content of the training, each employee's name and dates of training.

ARTICLE 120
Establishing an Electrically Safe Work Condition

- **Process of Achieving Safe Work Conditions**
- **Lockout / Tagout**
- **Temporary Protective Grounding**

120.2 Lockout/Tagout Devices

(C)(2) Form of Control. ~~Three~~ Two forms of hazardous electrical energy control shall be permitted: ~~individual employee control,~~ simple lockout/tagout, and complex lockout/tagout. For the ~~individual employee control and the~~ simple lockout/tagout, the qualified person shall be in charge. For the complex lockout/tagout, the person in charge shall have overall responsibility.
Informational Note: For an example of a lockout/tagout procedure, see Annex G.



(D)(1) Deletes Individual Qualified Employee Control Procedure

ARTICLE 130
Work Involving Electrical Hazards

- **Electrically Safe Work Conditions**
- **Approach Boundaries**
- **Arc Flash Hazard Analysis**
- **Other Precautions / PPE**

DC Shock Boundaries and DC Hazard/Risk Categories

- **Existing Table 130.2(C) becomes Table 130.4(C)(a), for AC systems. New Table 130.4(C)(b) for the approach boundaries associated with DC system voltages.**

- **Existing Table 130.7(C)(9) becomes Table 130.7(C)(15)(a), for AC systems. New Table 130.7(C)(15)(b) for DC Hazard/Risk categories.**

- **Adds a new Annex D.10: DC Incident Energy Calculations.**

DC Shock Boundaries and DC Hazard/Risk Categories

Table 130.4(C)(a) Approach Boundaries to Energized Electrical Conductors or Circuit Parts for Shock Protection for Alternating-Current Systems (All dimensions are distance from energized electrical conductor or circuit part to employee.)

(1)	(2)	(3)	(4)	(5)
	Limited Approach Boundary[b]		Restricted Approach Boundary[b]; Includes Inadvertent Movement Adder	
Nominal System Voltage Range, Phase to Phase[a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		Prohibited Approach Boundary[b]
<50 V	Not specified	Not specified	Not specified	Not specified
50 V–300 V	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact	Avoid contact
301 V–750 V	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)	25 mm (0 ft 1 in.)

Table 130.4(C)(b) Approach Boundaries[a] to Energized Electrical Conductors or Circuit Parts for Shock Protection, Direct-Current Voltage Systems

(1)	(2)	(3)	(4)	(5)
	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder	
Nominal Potential Difference	Exposed Movable Conductor[b]	Exposed Fixed Circuit Part		Prohibited Approach Boundary
<100 V	Not specified	Not specified	Not specified	Not specified
100 V–300 V	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact	Avoid contact
301 V–1 kV	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)	25 mm (0 ft 1 in.)

130.3 (2009) Exception 1
Arc Flash Hazard Analysis

Deletes the exception

~~*An arc flash hazard analysis shall not be required where all of the following conditions exist:*~~

~~*(1) The circuit is rated 240 volts or less.*~~
~~*(2) The circuit is supplied by one transformer.*~~
~~*(3) The transformer supplying the circuit is rated less than 125 kVA.*~~

and adds an Informational Note:

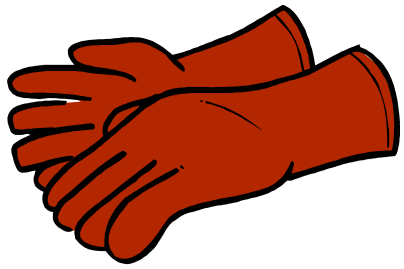
Informational Note: An arc flash hazard analysis may not be necessary for some three-phase systems rated less than 240 volts. See IEEE 1584 for more information. (Sec. 130.5 for 2012)

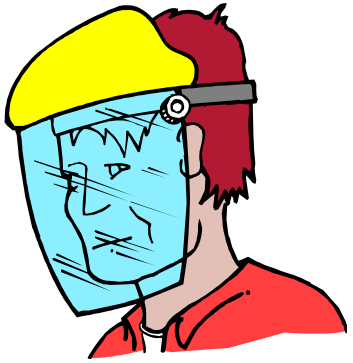
130.5(B) Protective Clothing and Other PPE

(1) Incident Energy Analysis

130.5(B)(1) FPN: For information on estimating the incident energy, see Annex D. For information on selection of arc-rated clothing and other personal protective equipment (PPE), see Table H.3(b) in Annex H.

(2) Hazard / Risk Categories





130.5(B) Protective Clothing and Other PPE

(1) Incident Energy Analysis

Informative Annex D Incident Energy and Arc Flash Boundary Calculation Methods

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 Introduction. Annex D summarizes calculation methods available for calculating arc flash boundary and incident energy. It is important to investigate the limitations of any methods to be used. The limitations of methods summarized in Annex D are described in Table D.1.

Table D.1 Limitation of Calculation Methods

Section	Source	Limitations/Parameters
D.2, D.3, D.4	Ralph Lee paper	Calculates arc flash boundary for arc in open air; conservative over 600 V and becomes more conservative as voltage increases
D.5	Doughty/Neal paper	Calculates incident energy for three-phase arc on systems rated 600 V and below; applies to short-circuit currents between 16 kA and 50 kA
D.6	Ralph Lee paper	Calculates incident energy for three-phase arc in open air on systems rated above 600 V; becomes more conservative as voltage increases
D.7	IEEE Std. 1584	Calculates incident energy and arc flash boundary for: 208 V to 15 kV; three-phase; 50 Hz to 60 Hz; 700 A to 106,000 A short-circuit current; and 13 mm to 152 mm conductor gaps
D.8	ANSI/IEEE C2 NESC, Section 410, Table 410-1 and Table 410-2	Calculates incident energy for open air phase-to-ground arcs 1 kV to 500 kV for live-line work

D.2 Basic Equations for Calculating Arc Flash Boundary Distances. The short-circuit symmetrical ampacity, I_{sc}, from a bolted three-phase fault at the transformer terminals is calculated with the following formula:

A typical value for the maximum power, P (in MW) in a three-phase arc can be calculated using the following formula:

$$P = [\text{maximum bolted fault, in } MVA_{bf}] \times 0.707^2 \quad [D.2(b)]$$

$$P = 1.732 \times V \times I_{sc} \times 10^{-6} \times 0.707^2 \quad [D.2(c)]$$

The arc flash boundary distance is calculated in accordance with the following formulae:

$$D_c = [2.65 \times MVA_{bf} \times t]^{1/2} \quad [D.2(d)]$$

$$D_c = [53 \times MVA \times t]^{1/2} \quad [D.2(e)]$$

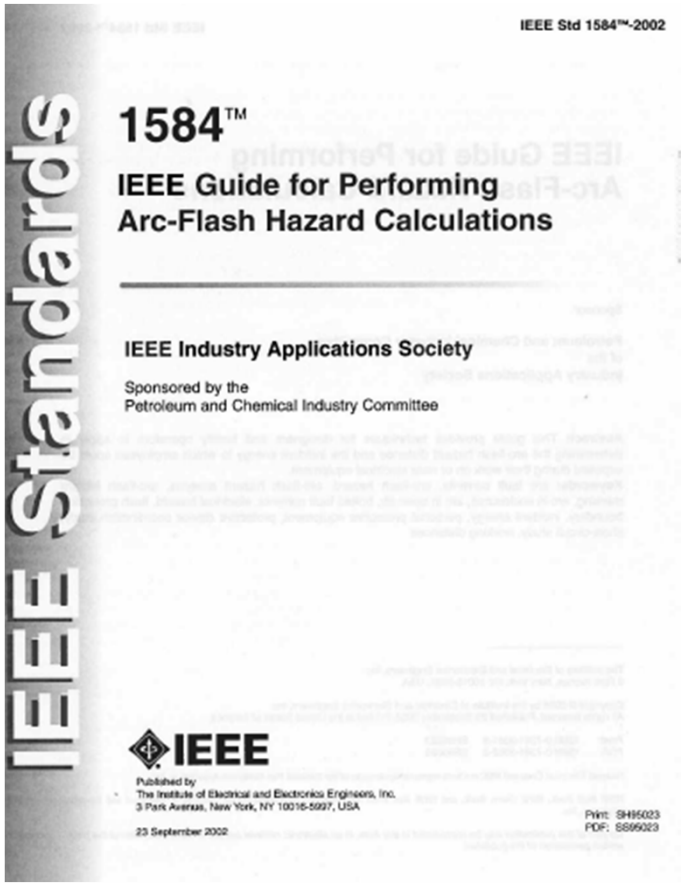
where:

D_c = distance in feet of person from arc source for a just curable burn (that is, skin temperature remains less than 80°C).
MVA_{bf} = bolted fault MVA at point involved.
MVA = MVA rating of transformer. For transformers with MVA ratings below 0.75 MVA, multiply the transformer MVA rating by 1.25.
t = time of arc exposure in seconds.

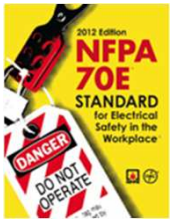
The clearing time for a current-limiting fuse is approximately ¼ cycle or 0.004 second if the arcing fault current is in the fuse's current-limiting range. The clearing time of a 5-kV and 15-kV circuit breaker is approximately 0.1 second or 6 cycles if the instantaneous function is installed and operating. This can be broken down as follows: actual breaker time (approximately 2 cycles), plus relay operating time of approximately 1.74 cycles, plus an additional safety margin of 2 cycles, giving a total time of approximately 6 cycles. Additional time must be added if a time delay function is installed and operating.

The formulas used in this explanation are from Ralph Lee,"The Other Electrical Hazard: Electrical Arc Blast Burns," in *IEEE Trans. Industrial Applications*. Vol. 1A-18. No. 3, Page 246, May/June 1982. The calculations are based on the worst-case arc impedance. *(See Table D.2.)*

D.3 Single-Line Diagram of a Typical Petrochemical



(2) Hazard / Risk Categories



Tasks Performed on Energized Equipment	Hazard/Risk Category	Rubber Insulating Gloves	Insulated and Insulating Hand Tools
Panelboards or other equipment rated 240 V and below Parameters: Maximum of 25 kA short circuit current available; maximum of 0.03 sec (2 cycle) fault clearing time; minimum 18 in. working distance Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 19 in.			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	0	N	N
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	0	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	1	Y	Y
Remove/install CBs or fused switches	1	Y	Y
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	1	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	0	N	N
Work on energized electrical conductors and circuit parts of utilization equipment fed directly by a branch circuit of the panelboard	1	Y	Y

Hazard/Risk Category	Protective Clothing and PPE
0	**Protective Clothing, Nonmelting or Untreated Natural Fiber (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a Fabric Weight of at Least 4.5 oz/yd²** Shirt (long sleeve) Pants (long) **Protective Equipment** Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Heavy duty leather gloves (AN) *(See Note 1.)*
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm²** *(See Note 3.)* Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated face shield *(see Note 2)* or arc flash suit hood 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 1.)* Leather work shoes (AN)

130.5(C) Equipment Labeling

(C) Equipment Labeling. Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures and motor control centers that are likely to require examination, adjustment, servicing or maintenance while energized shall be field marked with a label containing all the following information:

(1) At least one of the following:
- **a. Available incident energy and the corresponding working distance**
- **b. Minimum arc rating of clothing**
- **c. Required level of PPE**
- **d. Highest Hazard/Risk Category (HRC) for the equipment**

(2) Nominal system voltage

(3) Arc Flash Boundary

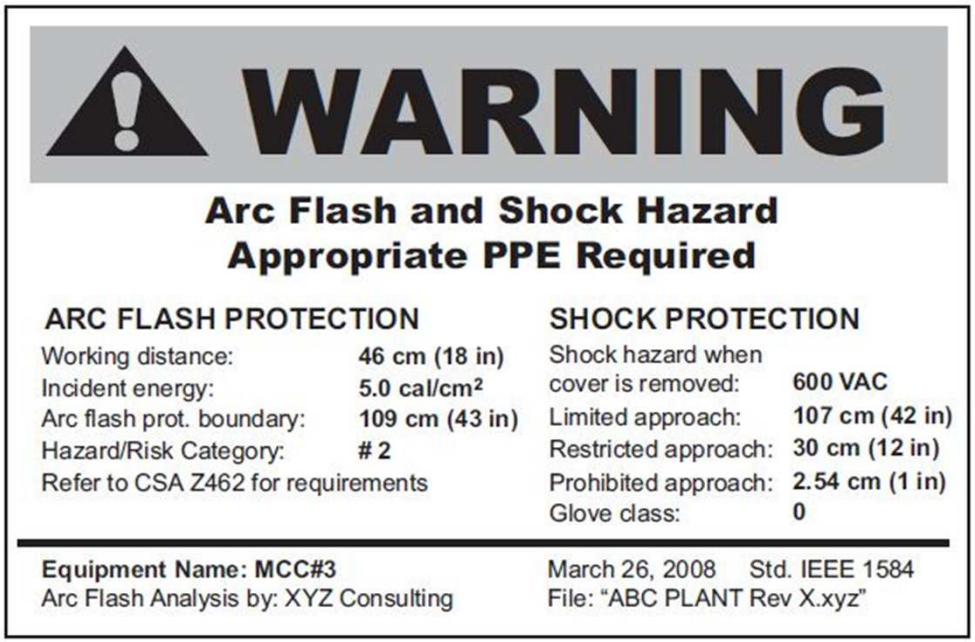
130.5(C) Equipment Labeling

(1) At least one of the following:

- **a. Available incident energy and the corresponding working distance**
- **b. Minimum arc rating of clothing**
- **c. Required level of PPE**
- **d. Highest Hazard/Risk Category (HRC) for the equipment**

(2) Nominal system voltage

(3) Arc Flash Boundary



WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

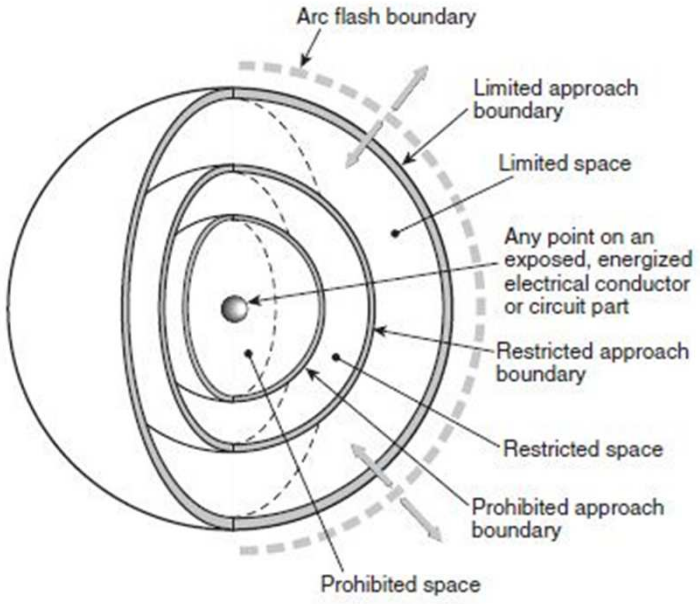
ARC FLASH PROTECTION		SHOCK PROTECTION	
Working distance:	**46 cm (18 in)**	Shock hazard when cover is removed:	**600 VAC**
Incident energy:	**5.0 cal/cm²**	Limited approach:	**107 cm (42 in)**
Arc flash prot. boundary:	**109 cm (43 in)**	Restricted approach:	**30 cm (12 in)**
Hazard/Risk Category:	**# 2**	Prohibited approach:	**2.54 cm (1 in)**
Refer to CSA Z462 for requirements		Glove class:	**0**

Equipment Name: MCC#3
Arc Flash Analysis by: XYZ Consulting

March 26, 2008 Std. IEEE 1584
File: "ABC PLANT Rev X.xyz"

130.7(C)(5) Hearing Protection

(new) **Employees shall wear hearing protection whenever working within the arc flash boundary.**



130.7(C)(10) Arc Flash Protective Equipment

(b) Head Protection:

(1) An arc-rated balaclava shall be used with an arc-rated faceshield when the back of the head is within the arc flash boundary. An arc-rated hood shall be permitted to be used instead of an arc-rated face shield and balaclava.

(2) An arc-rated hood shall be used when the anticipated incident energy exposure exceeds 12 cal/cm^2.

130.7(C)(10) Arc Flash Protective Equipment

(c) Face Protection:

Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area shall be used.

Table 130.7(C)(15) Hazard/Risk Category Classifications

- **Moves the maximum short circuit current, fault clearing time from the Specific Notes 1 to 4 into the appropriate section(s) of Table 130.7(C)(15)(a).**
- **Adds the Arc Flash Protection Boundaries to Table 130.7(C)(15)(a) and (b).**

Table 130.7(C)(15) Hazard/Risk Category Classifications

Tasks Performed on Energized Equipment	Hazard/Risk Category	Rubber Insulating Gloves	Insulated and Insulating Hand Tools
Panelboards or other equipment rated > 240 V and up to 600 V Parameters: Maximum of 25 kA short circuit current available; maximum of 0.03 sec (2 cycle) fault clearing time; minimum 18 in. working distance Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 30 in.			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	1	N	N
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	1	Y	N
Work on energized electrical conductors and circuit parts, including voltage testing	2	Y	Y

Table 130.7(C)(16)
Protective Clothing and PPE

- **Includes the requirement for a balaclava in hazard/risk category 2.**
- **Deletes hazard/risk category 2* and note 10.**
- **Revises all tasks currently listed as hazard/risk category 2* in Table 130.7(C)10 to hazard/risk category 2.**

Table 130.7(C)(16)
Protective Clothing and PPE

2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm² *(See Note 3.)***
	Arc-rated long-sleeve shirt and pants or 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 1.)*
	Leather work shoes

Electrical Safety Statistics

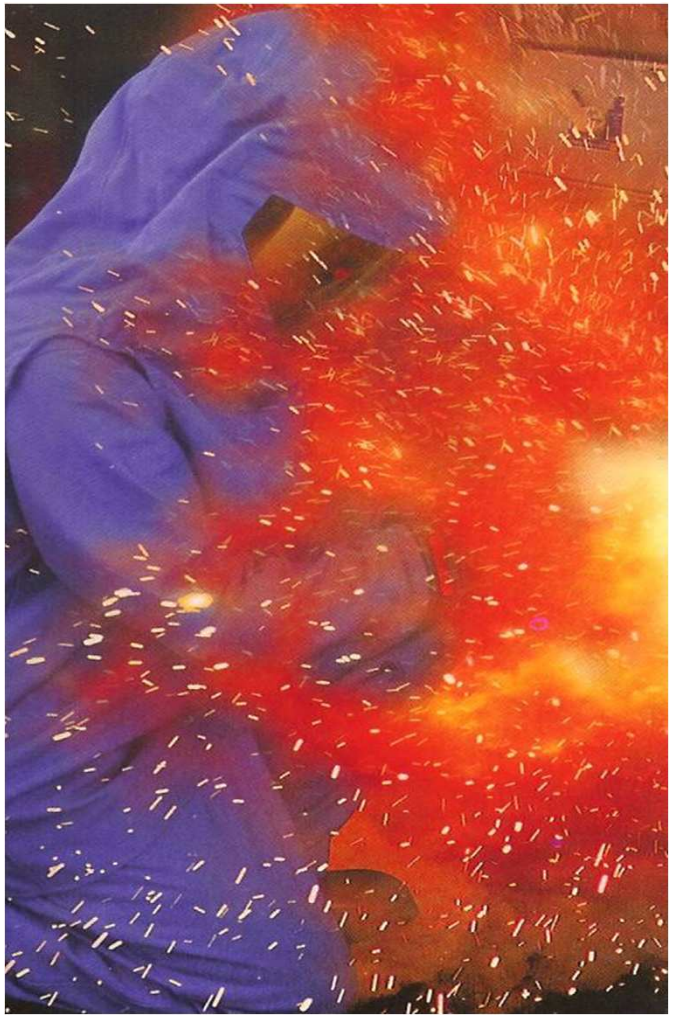
According to the Department of Labor's Bureau of Labor Statistics

- About 8,000 electrical contact injuries are referred to emergency rooms each year in U.S.

- Over 2,000 workers are sent to burn centers each year with electrical-related burn injuries.

- Electrical workplace injuries cause about one fatality every day.

Arc Flash Research



Arc flash accidents cause

- **Injuries**
- **Fatalities**

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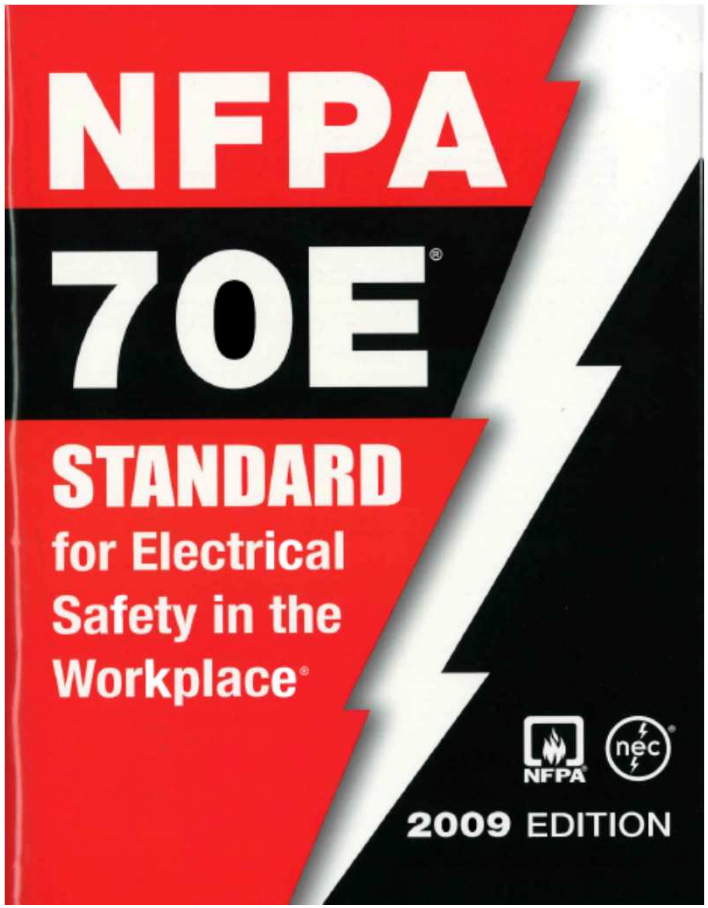

Informative Annex D Incident Energy and Arc Flash Boundary Calculation Methods

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$$P = [\text{maximum bolted fault, in } MVA_{bf}] \times 0.707^2 \quad \text{[D.2(b)]}$$

$$P = 1.732 \times V \times I_a \times 10^{-6} \times 0.707^2 \quad \text{[D.2(c)]}$$

The arc flash boundary distance is calculated in accordance with the following formulae:

$$D_c = [2.65 \times MVA_{bf} \times t]^{1/2} \quad \text{[D.2(d)]}$$

$$D_c = [53 \times MVA \times t]^{1/2} \quad \text{[D.2(e)]}$$

where:

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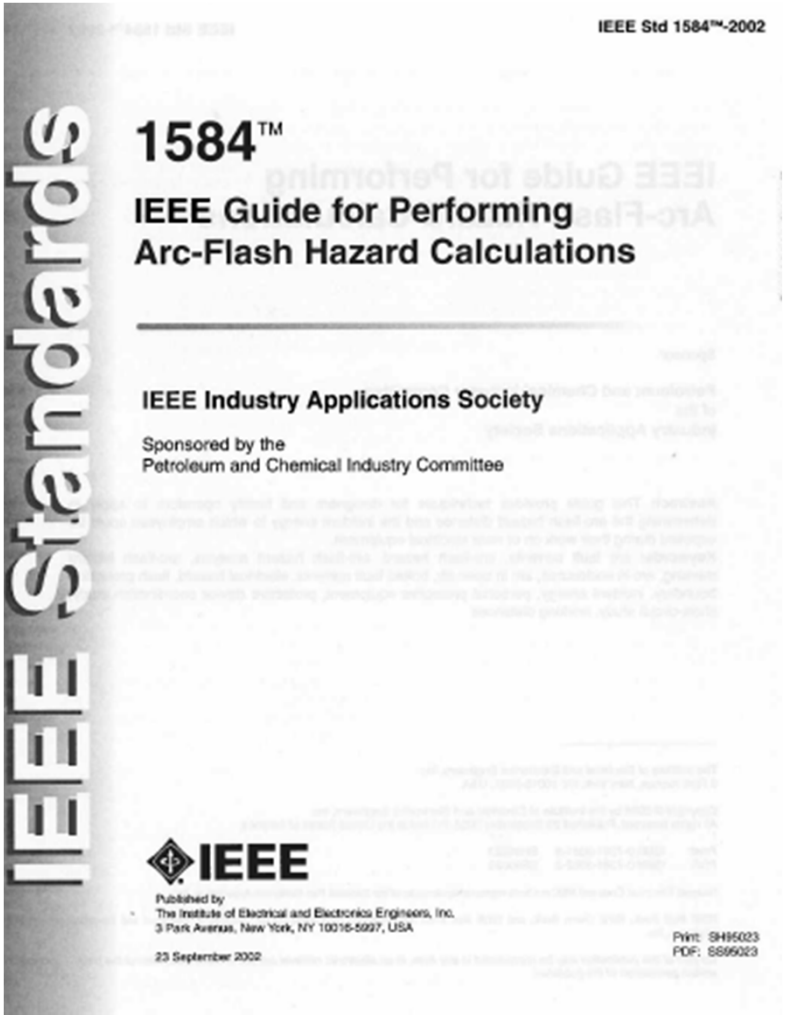
D.3 Single-Line Diagram of a Typical Petrochemical

IEEE 1584


IEEE Std 1584™-2002
IEEE Standards
1584™
IEEE Guide for Performing
Arc-Flash Hazard Calculations
IEEE Industry Applications Society
Sponsored by the
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IEEE
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23 September 2002
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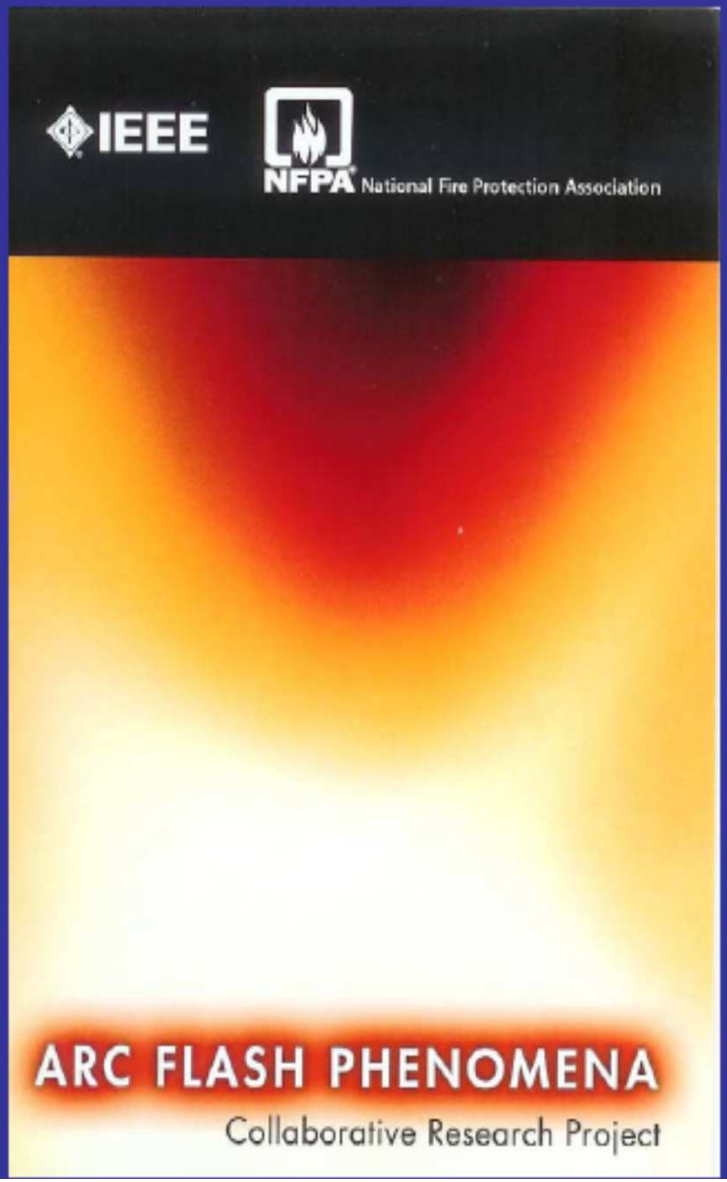
Introduction



- This Collaborative Initiative supports Research and Testing to increase the understanding of various aspects of Arc Flash Phenomena.
- The effort brings together two organizations (IEEE and NFPA) that have been instrumental in the advancement of the Electrical Safety culture.

- **Research Areas**
  - Heat and Thermal Effects
  - Blast Pressure
  - Sound
  - Toxicity
  - Electromagnetic Radiation

Present Research Project Goals

- Because of the complexity of the arc flash phenomena and the number of variables and unknowns involved in testing, one of the major goals of the present research effort is to properly design the experiments and clearly define the test protocols for uniformity and future reference.
- The other major goal is to develop engineering and/or physics based models which verify the experimental test results.

Project Sponsors

PLATINUM LEVEL CONTRIBUTORS ($500k)

Underwriters Laboratories

Bruce Power

Ferraz Shawmut

Square D/Schneider Electric

Eaton Corporation

GOLD LEVEL CONTRIBUTORS ($250k)

Hydro One Networks, Inc.

Procter & Gamble, Inc.

SILVER LEVEL CONTRIBUTORS ($50k +/-)

Duke Energy Foundation

SKM Systems Analysis

National Fire Protection Association

e-Hazard, In memorium of Don Bauman

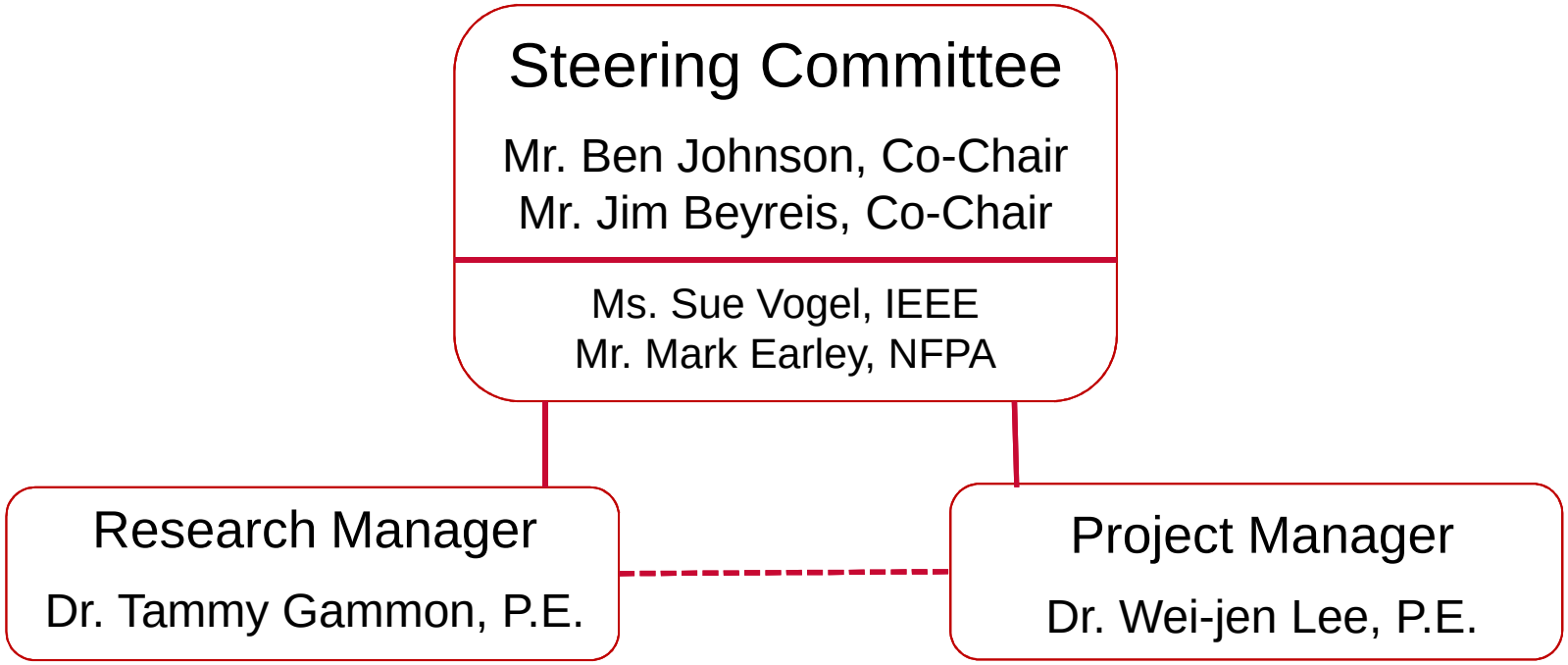
Salisbury Electrical Safety L.L.C.

Cadick Corporation

InterNational Electrical Testing Association

ArcWear.com

Project Organizational Structure



Technical Advisory Committee (TAC)

- Project Manager
- Research Manager
- Platinum Member's Representatives
- Invited Experts

HRC #1 PPE - Arc-Rated Long Sleeve Shirt and Pants - 4 cal/cm^2

ASTM 1959/F

Designation: F 1959/F 1959M – 06a$^{\epsilon 1}$

Standard Test Method for Determining the Arc Rating of Materials for Clothing[1]

This standard is issued under the fixed designation F 1959/F 1959M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ϵ^1 NOTE—Reference to a research report was added to 14.1 in April 2007.

1. Scope

1.1 This test method is used to measure the arc rating of materials intended for use as flame resistant clothing for workers exposed to electric arcs that would generate heat flux rates from 84 to 25 120 kW/m^2 [2 to 600 cal/cm^{2}s].

1.2 This test method will measure the arc rating of materials which meet the following requirements: less than 150 mm [6 in.] char length and less than 2 s afterflame when tested in accordance with Test Method D 6413.

1.2.1 It is not the intent of this test method to evaluate non flame-resistant materials except where used as under layers in multiple-layer specimens.

1.3 The materials used in this test method are in the form of flat specimens.

1.4 This test method shall be used to measure and describe the properties of materials, products, or assemblies in response to convective and radiant energy generated by an electric arc under controlled laboratory conditions.

priate safety and health practices and determine the applicability of regulatory requirements prior to use. For specific precautions, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 123 Terminology Relating to Textiles

D 1776 Practice for Conditioning and Testing Textiles

D 4391 Terminology Relating to The Burning Behavior of Textiles

D 6413 Test Method for Flame Resistance of Textiles (Vertical Test)

E 457 Test Method for Measuring Heat-Transfer Rate Using a Thermal Capacitance (Slug) Calorimeter

F 1494 Terminology Relating to Protective Clothing

2.2 *ANSI/IEEE Standard:*[3]

Standard Dictionary of Electrical and Electronics Terms

2.3 *AATCC Standard:*[4]

Calorimeter Research

To verify existing or generate new test protocols used to measure the thermal effects of an arc fault event. These may include calorimeter comparisons, the alternate placement of calorimeters, radiometer research, low fault currents, and plasma cloud issues.

Calorimeter Research

Calorimetry – *The science of measuring the heat of chemical reactions or physical changes.*

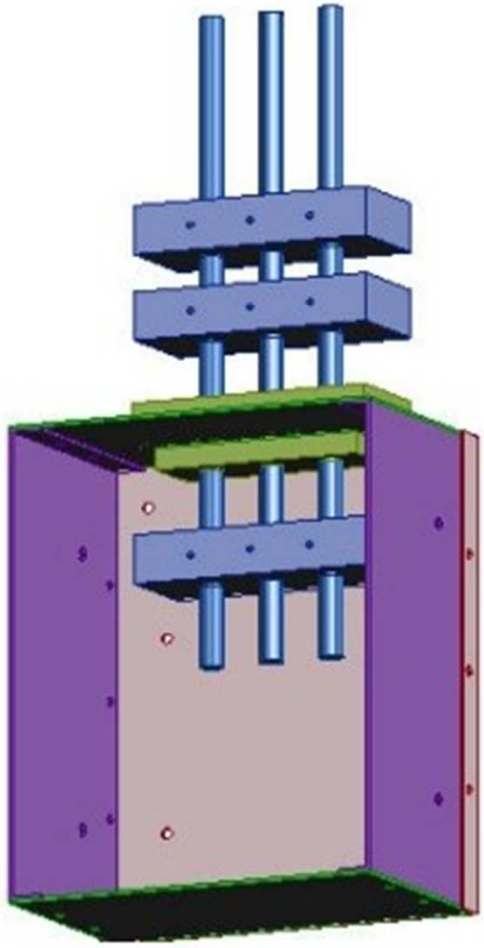
Multiplying the temperature change by the mass and specific heat capacities of the substances gives a value for the energy given off or absorbed during the reaction.

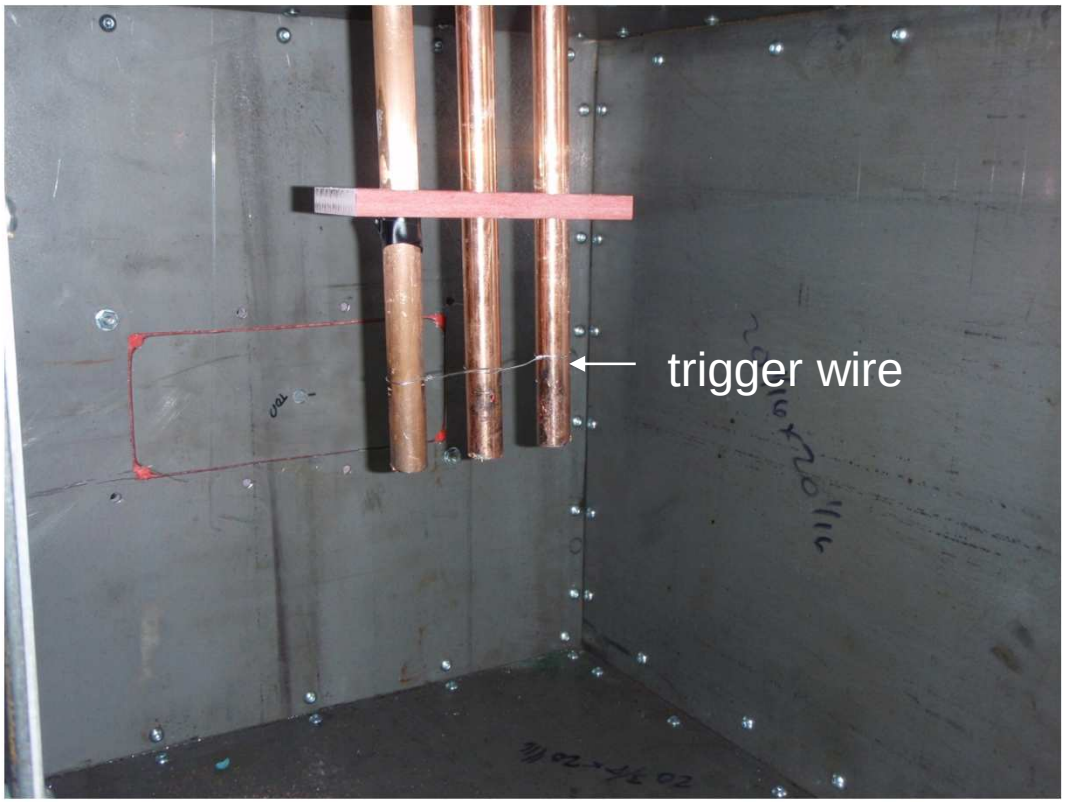
$$q = mc\Delta T$$

where

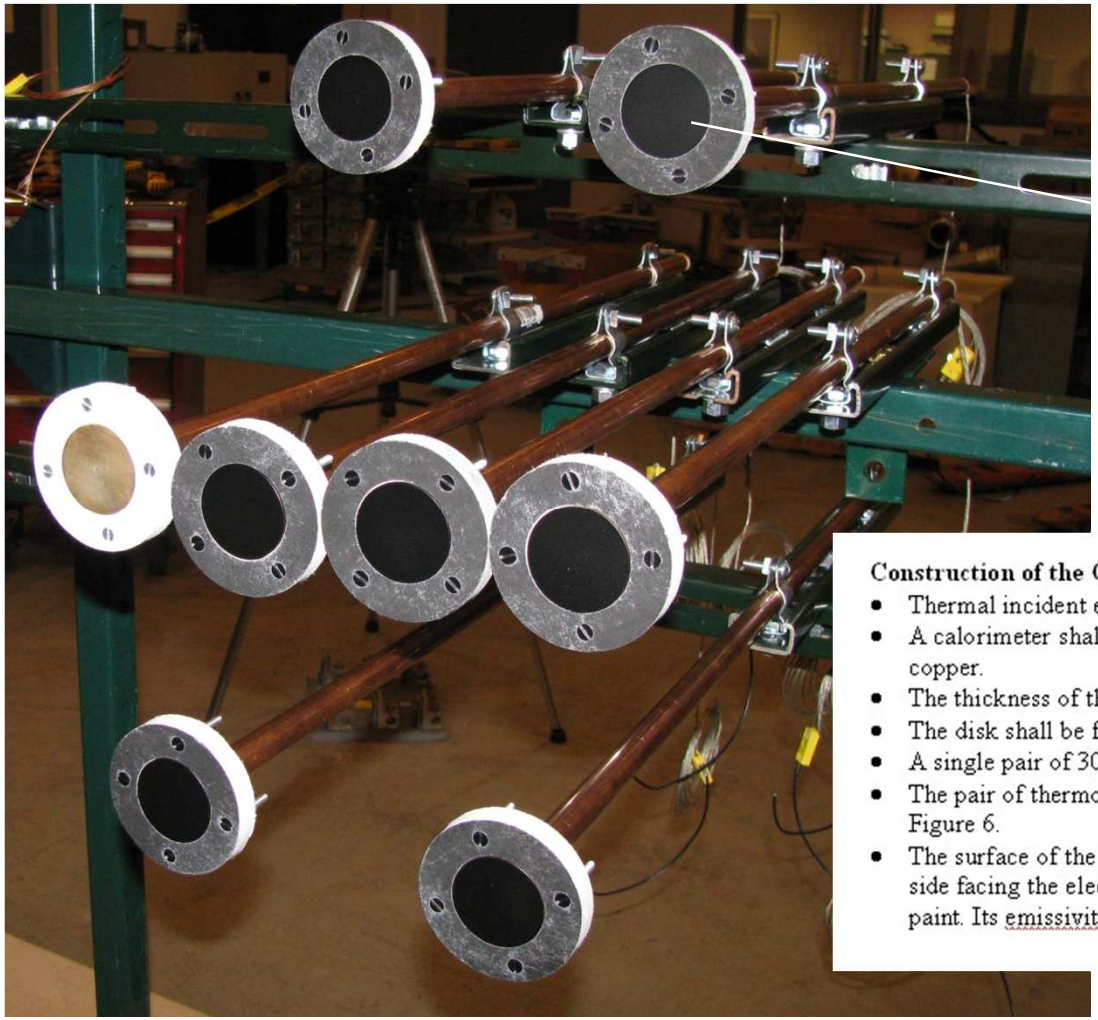
q is energy, or heat,
m is mass,
c is specific heat,
ΔT is change in temperature.

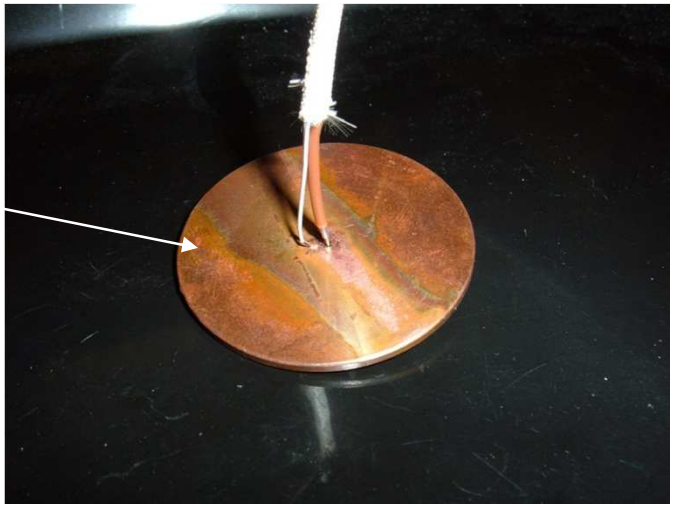
Calorimeter Research





Calorimeter Research

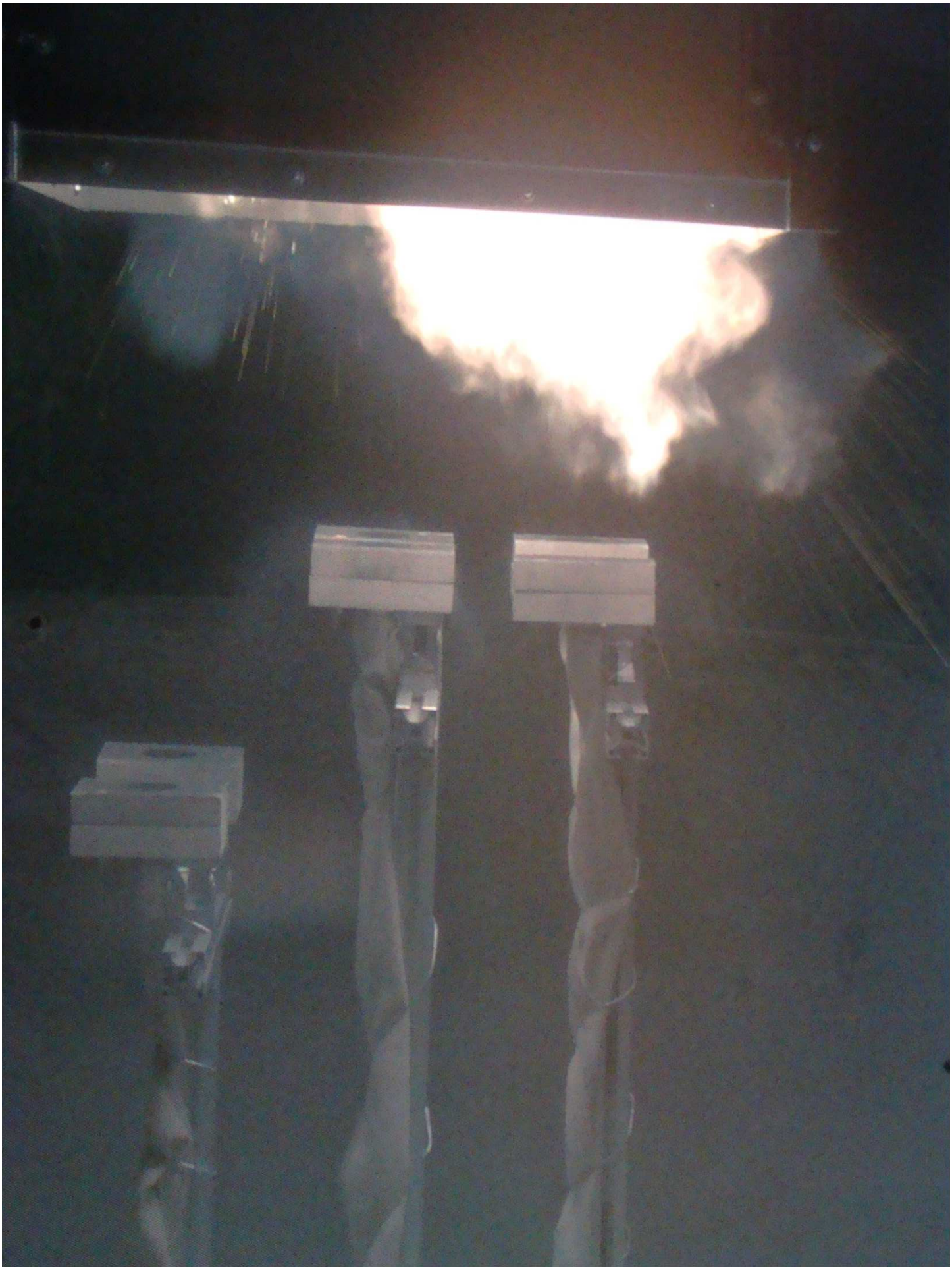




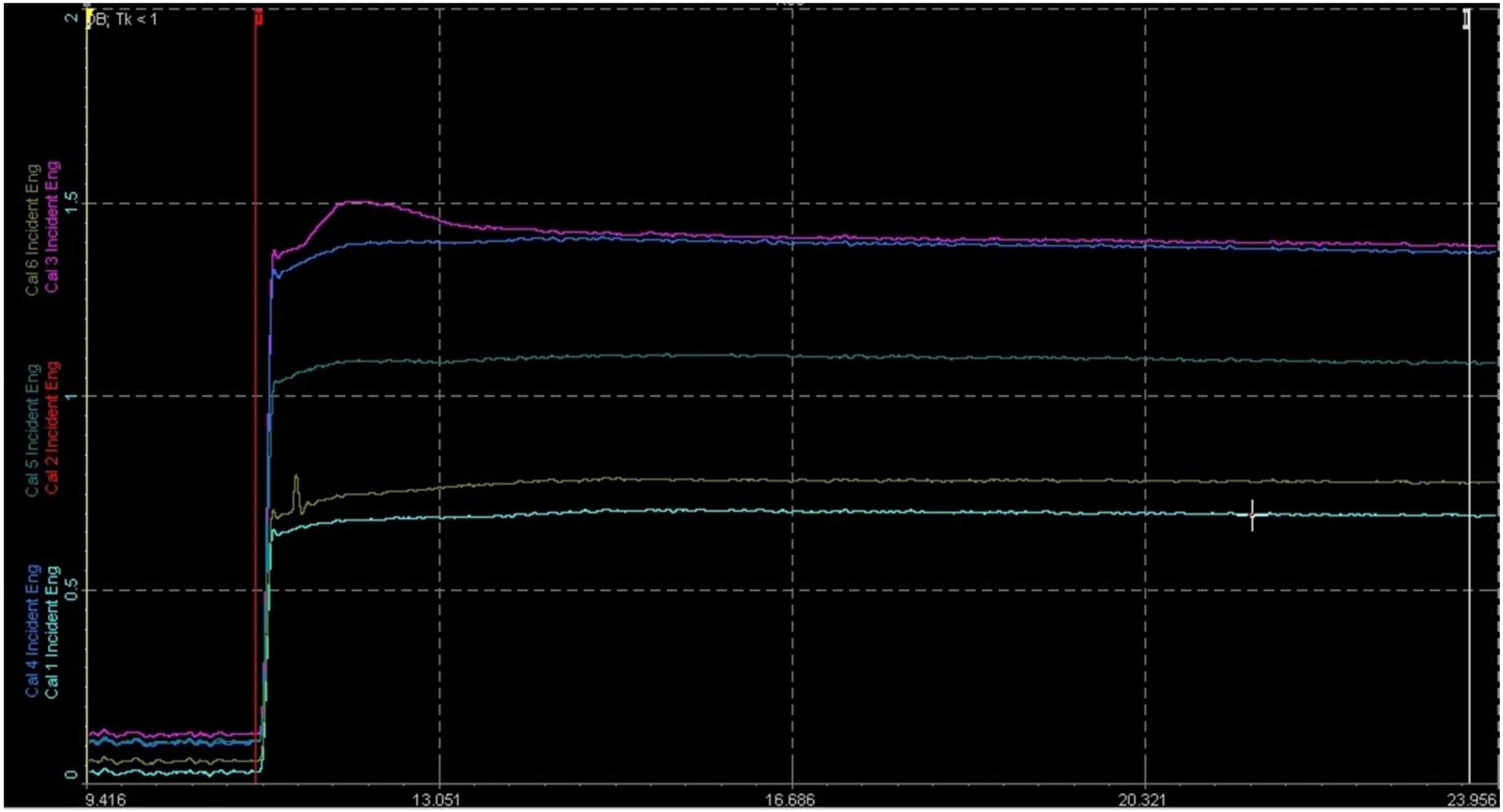
Construction of the Calorimeters (Figures 5, 6, & 7) [4]

- Thermal incident energy shall be determined by use of calorimeters.
- A calorimeter shall be a 1.6 in. (4 cm) diameter disk constructed from electrical grade copper.
- The thickness of the calorimeter shall be 1/16 in. (1.6 mm).
- The disk shall be flat.
- A single pair of 30 AWG thermocouple wires shall be installed as shown in Figure 5.[5]
- The pair of thermocouple wires shall be installed in the center of the disk as shown in Figure 6.
- The surface of the disk opposite the pair of thermocouple wires exiting therefrom (the side facing the electrodes) shall be painted flat black with a high temperature spray paint. Its emissivity shall be >0.9. The coating shall be thin with no defects.


1
18.14
2
4
3
18.15
5
18.15



Calorimeter Research



Non-Thermal Effects

Another goal of this work is to define other mechanisms of energy transfer from the arc to the surrounding area and their relationship to potential injury. These may include measurements of blast and pressure, shrapnel, sound, and toxic by-products.

Blast Pressure

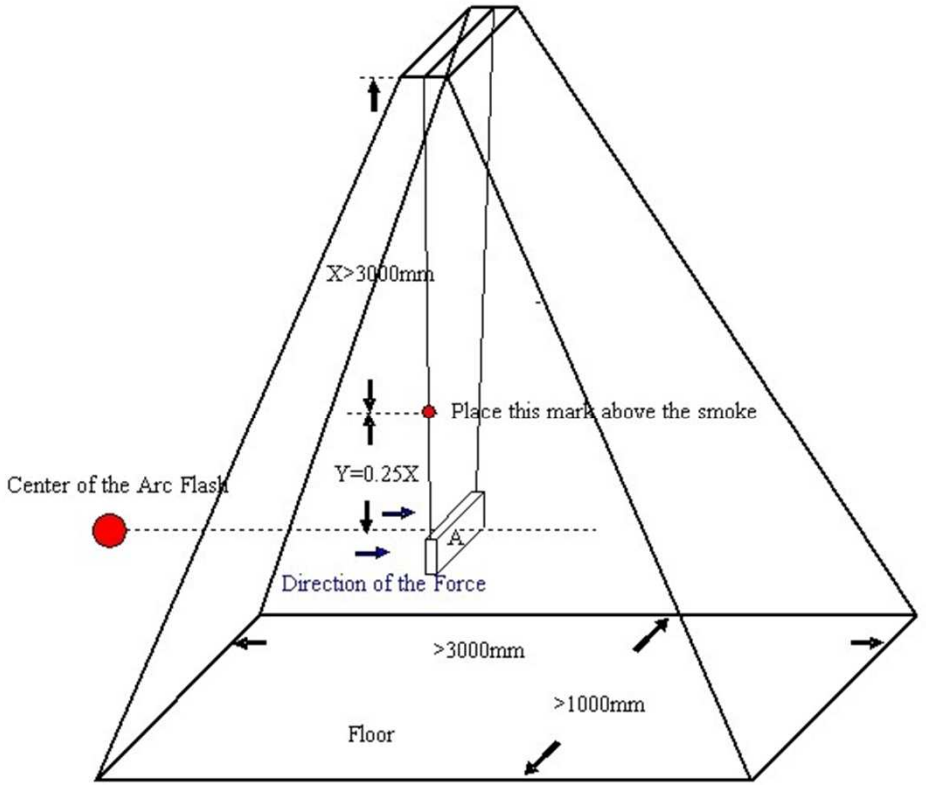
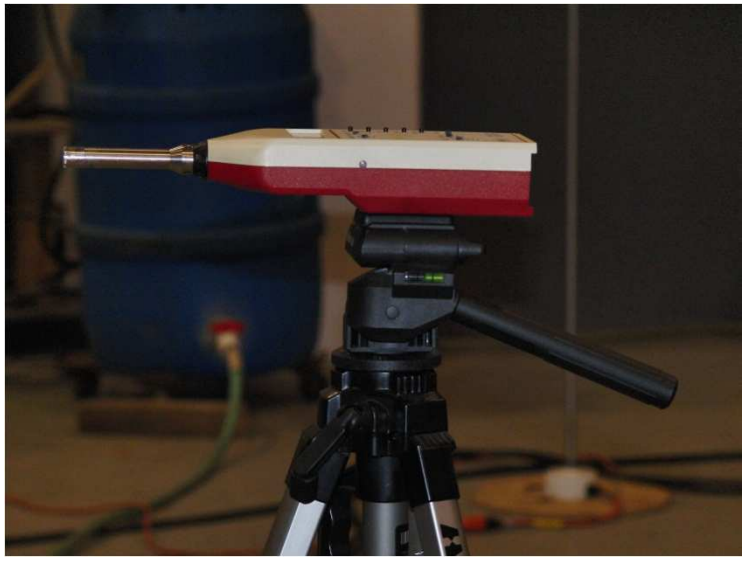


Fig. 5 Proposed Arrangement for Pressure Measurement

Sound Pressure

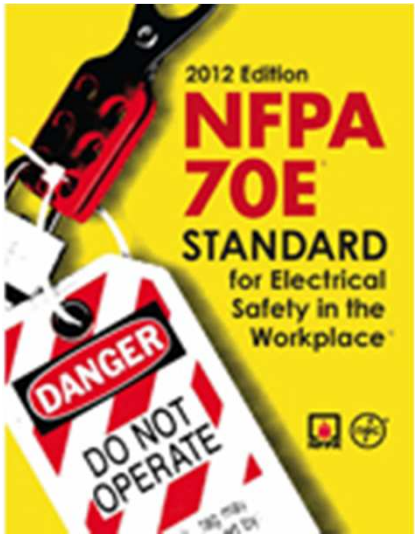


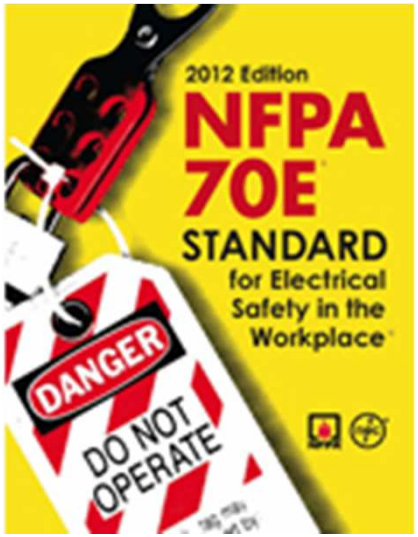
Phase II (2011 – 2012)

Voltage	Ibf (kA)	Gap Width (in)
480V	10, 40, 65, 100, 150	0.5, 1.25, 2.5
600V	5, 20, 40, 65, 100, 150	0.5, 1.5, 2.5, 4
2.4kV	5, 20, 40, 65	0.5, 4, 6, 8, 12
4.16kV	5, 20, 40, 65	0.5, 4, 6, 8, 12
13.8kV	5, 20, 40, 65	0.5, 4, 8, 12, 24

- **Perform Light Intensity and Spectrum Measurements**
- **Shrapnel Damage**
- **Toxicity**


DANGER


2012 Edition
NFPA
70E
STANDARD
for Electrical
Safety in the
Workplace
DANGER
DO NOT
OPERATE



WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

ARC FLASH PROTECTION		SHOCK PROTECTION	
Working distance:	46 cm (18 in)	Shock hazard when cover is removed:	600 VAC
Incident energy:	5.0 cal/cm²	Limited approach:	107 cm (42 in)
Arc flash prot. boundary:	109 cm (43 in)	Restricted approach:	30 cm (12 in)
Hazard/Risk Category:	# 2	Prohibited approach:	2.54 cm (1 in)
Refer to CSA Z462 for requirements		Glove class:	0

Equipment Name: MCC#3
Arc Flash Analysis by: XYZ Consulting

March 26, 2008 Std. IEEE 1584
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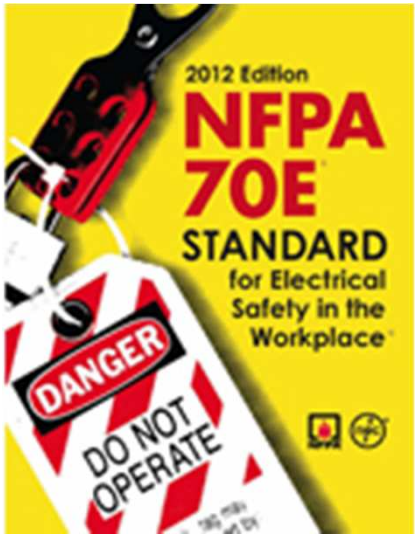

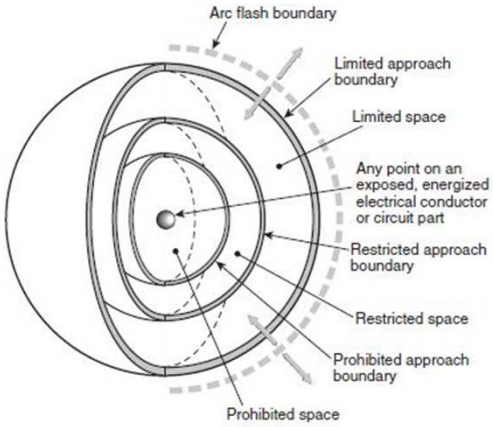

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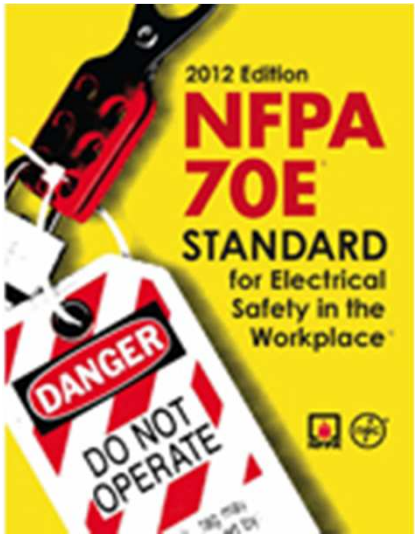

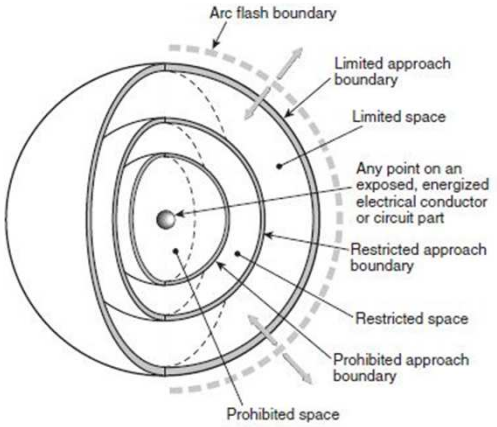

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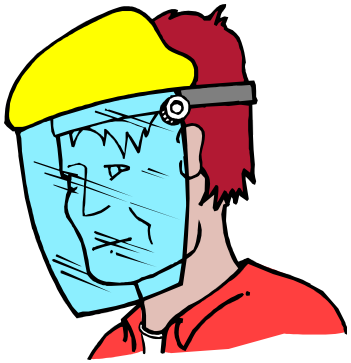

Electrical Safety Statistics

According to the Department of Labor's Bureau of Labor Statistics

- About 8,000 electrical contact injuries are referred to emergency rooms each year in U.S.

- Over 2,000 workers are sent to burn centers each year with electrical-related burn injuries.

- Electrical workplace injuries cause about one fatality every day.

WORK SAFE!

THANK YOU