Changes in Arc Flash-2018

hood patterson & dewar

Agenda

David Rewitzer, PE, CEM

- IEEE-1584 review and meeting update
  - DC
  - Expected Date of new Standard
- Standards Changes
  - 70E
  - NEC
- Electrical Safety Workshop (ESW)
  - Statistics Analysis

IEEE-1584 Review and Meeting Update

Theory in Practice

Turn of the Century

- IEEE-1584 was born in early 2000's
  - Decided on wide range of currents and voltages
  - Raised ~$75,000 in funding
  - Used 20 cubic inch box
  - Tested MCC's using a smaller size box
  - Testing facilities – Square D in Cedar Rapids & Ontario Hydro in Toronto
  - Bussmann played a big roll as well
- Navy got involved
  - Wanted to see how an arc flash would damage ship
  - Built a 15' cube
  - Obtained funding for 13.8kV testing
- Completed document went through a robust approval process
  - Three rounds of 100s of questions
  - Approved June 2002 (2 year cycle)

IEEE 1584-2002

Developing the 2002 Revision

- Based on the results of > 300 arc flash tests
- Four calculation criteria:
  1. Systems less than 1000 V
  2. Systems from 1000 to 15,000 V
  3. Incident energy (cal/cm^2)
  4. Flash hazard boundary (AKA arc flash boundary)
- 85% rule
  - Slow burn vs. Rapid Energy Release
- 125kVA transformer rule
  - Based on data, would not sustain an arc
- 2-second rule
  - Would leave the arc with-in two seconds

IEEE 1584

Revision Process Begins

Questions immediately arose

1. What if the electrodes were horizontal instead of vertical?
2. What about difference size enclosures?
3. What about DC arc flash?

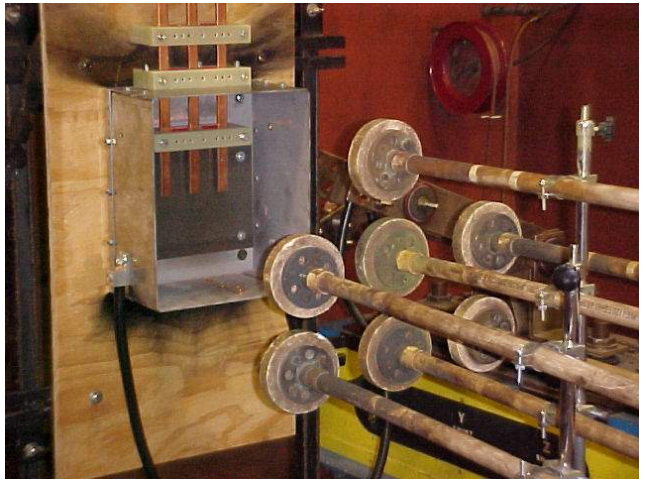
PCIC established a collaboration committee between IEEE and NFPA

- 6.5 Million Requested
- 3.5 Million Received
- Recommended 10-year Project Authorization Request (PAR)
- PAR extension was granted until 12/31/17

IEEE 1584

1700 Tests Conducted

Voltage	~ Number of tests
208V (3ph) 240V (1ph)	195
480V	400
600V	340
2700V	320
4160V	180
14.3kV	270



IEEE 1584

Study Complexity

- New standard makes modeling more complex
- Proposed variables
  - Configurations (VCB, VCBB, HCB, VOA, HOA)
  - V_{oc}
  - I_{bf}
  - Working Distance
  - Duration (Breaker or fuse curve)
  - Gap
  - Enclosure Size
    - Box Size & Gap defaults to conservative NEMA size and gap distance

IEEE 1584

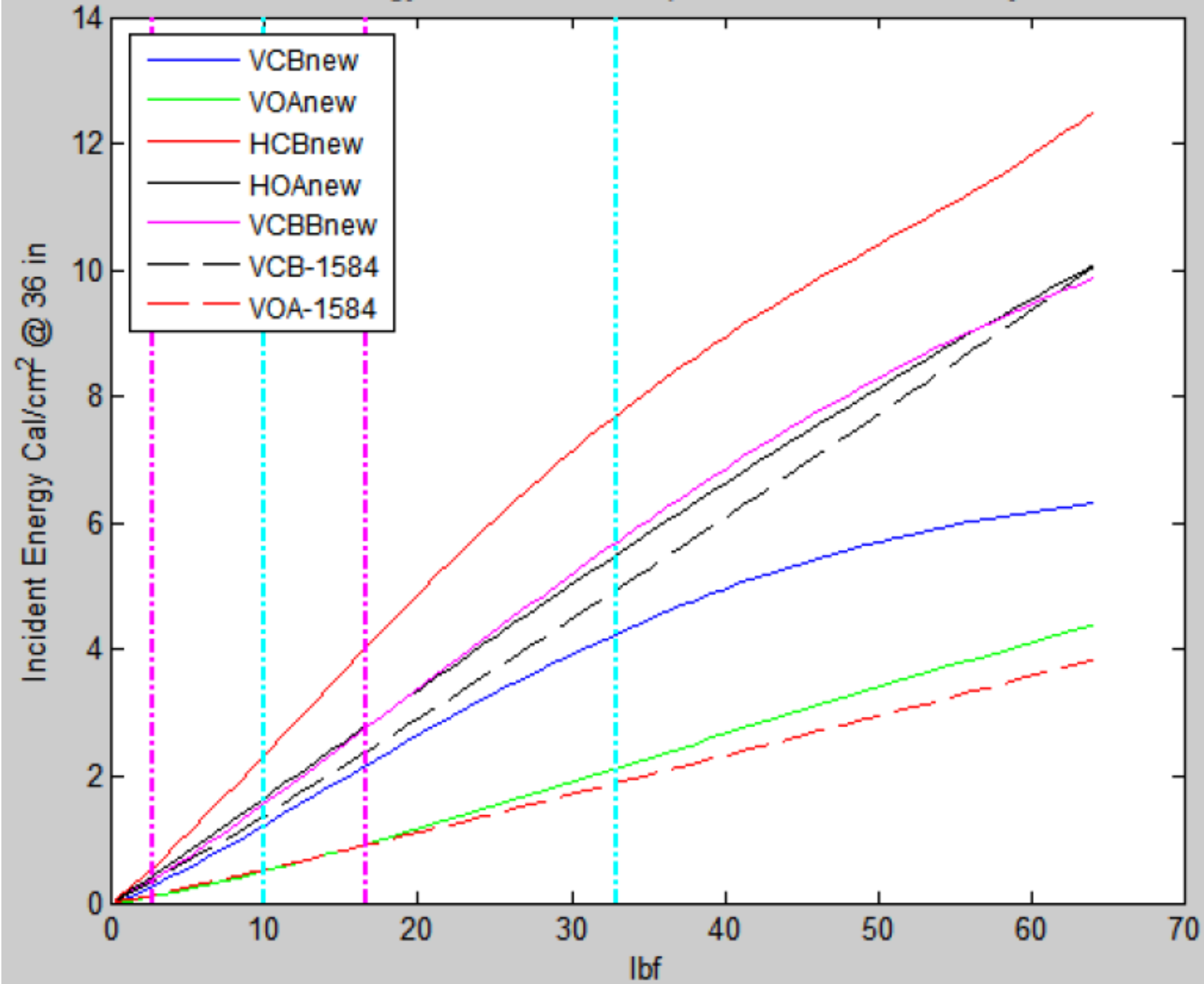
Test Configurations

The 1584 Committee decided to conduct tests using five configurations

- VCB – Vertical electrodes in a Cubic Box (IEEE 2002)
  - Load side of BKR
- VCBB – Vertical electrodes in a Cubic Box terminated in a “Barrier”
  - line side of BKR
- VOA – Vertical electrodes in Open Air (IEEE 2002)
- HOA – Horizontal electrodes in Open Air
- HCB – Horizontal electrodes in a Cubic Box
  - Busbar
  - HCBB was considered but HCB was considered worst case

IEEE 1584

Comparison of Results



IEEE 1584

Other Parameters

- Blast Pressure
  - Injury potential based on fault level
    - Slow burn vs. Rapid Energy Release
- Sound Pressure
  - Risk of severe hearing damage
  - Tests at 4,160 volts have produced sound levels upwards of 160 dB at distances of more than 3-meters
- Light
  - Bright summer day is 100,000 lux (light intensity)
    - 1 lux= 1 lumen per square metre squared
  - Tens of millions of lux have been measured during arc flash testing
- Enclosure Size (now a variable)
  - Based on standard NEMA sizes

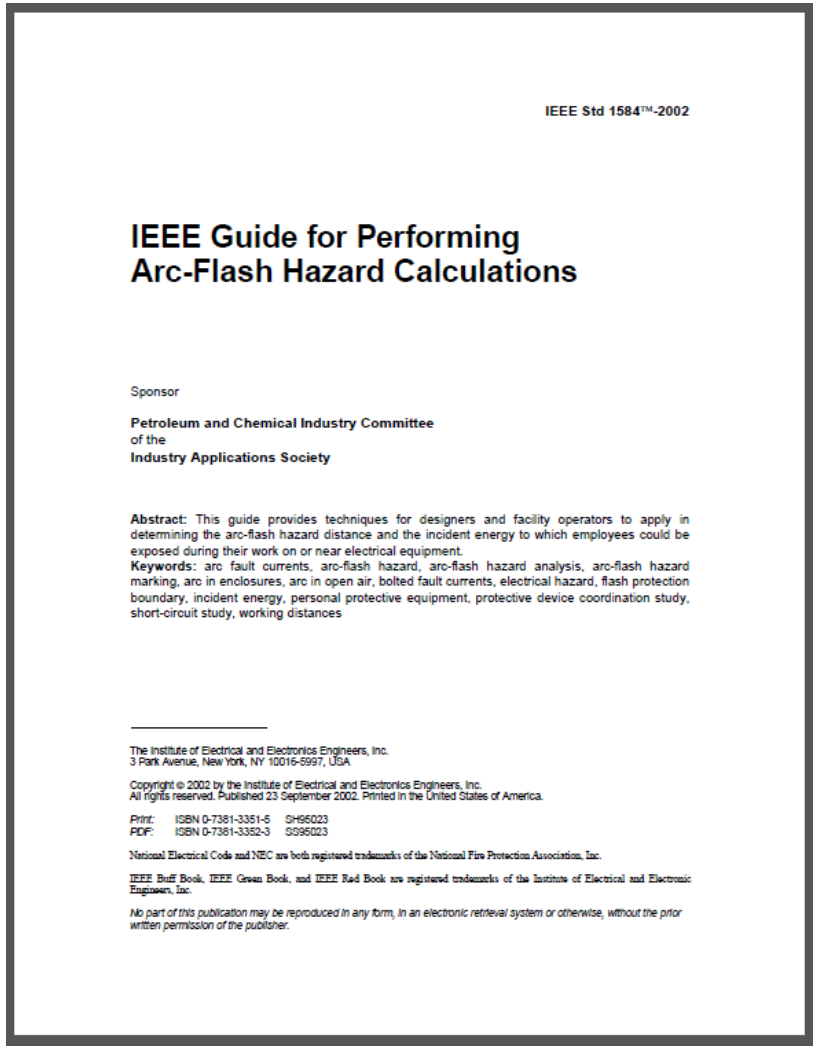
Study Complexity

Standard practices taken out

- 125kVA Rule will not be in the new text
  - Instead a proposal was made – *"No tests were done at 208V and less than 2500A, therefore should not be considered."*
- 85% rule will not be in new text
  - Statistical deviation was such that confidence in formulas
  - So no need to have this rule
- 2 second rule will not be in new text

IEEE 1584 and 1584.1

Two Documents



IEEE Std 1584™-2002

IEEE Guide for Performing Arc-Flash Hazard Calculations

Sponsor

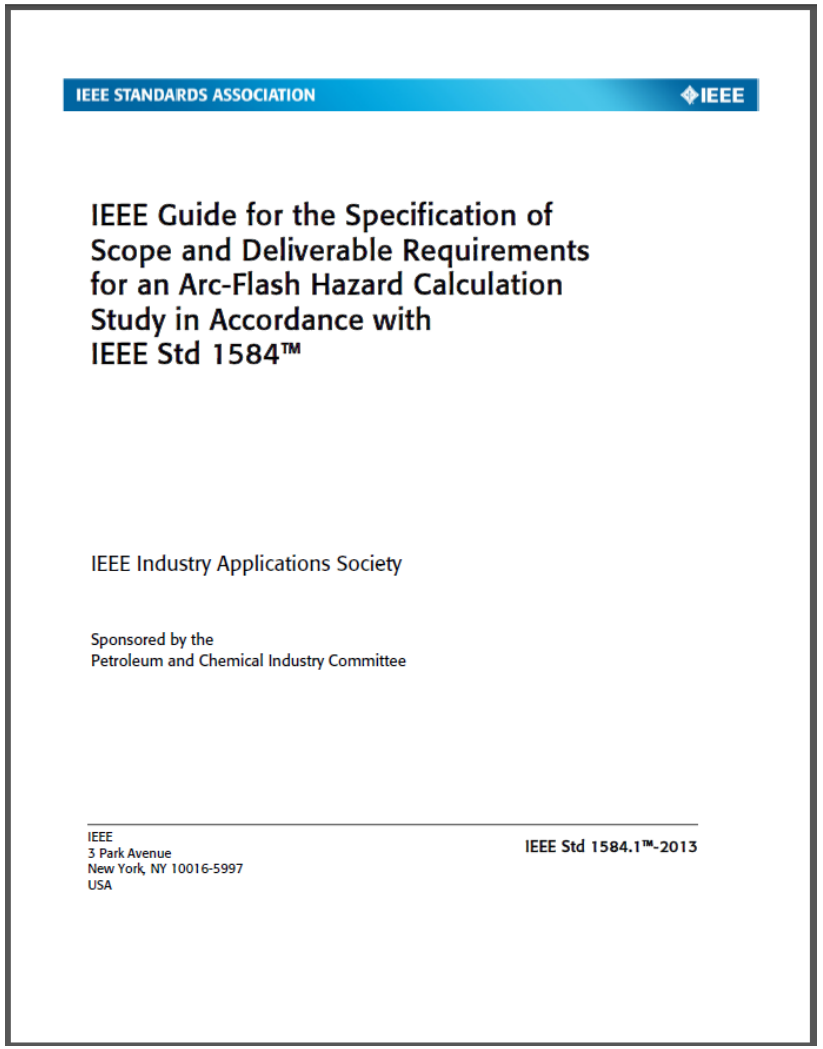
Petroleum and Chemical Industry Committee
of the
Industry Applications Society

Abstract: This guide provides techniques for designers and facility operators to apply in determining the arc-flash hazard distance and the incident energy to which employees could be exposed during their work on or near electrical equipment.
Keywords: arc fault currents, arc-flash hazard, arc-flash hazard analysis, arc-flash hazard marking, arc in enclosures, arc in open air, bolted fault currents, electrical hazard, flash protection boundary, incident energy, personal protective equipment, protective device coordination study, short-circuit study, working distances

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Print: ISBN 0-7381-3351-5 SH95023
PDF: ISBN 0-7381-3352-3 SS95023

IEEE-1584-2018
Technical Information



IEEE STANDARDS ASSOCIATION IEEE

IEEE Guide for the Specification of Scope and Deliverable Requirements for an Arc-Flash Hazard Calculation Study in Accordance with IEEE Std 1584™

IEEE Industry Applications Society

Sponsored by the
Petroleum and Chemical Industry Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1584.1™-2013

IEEE-1584.1-2018
Deliverable Requirements

So What Does This Mean to Me?

- Design Engineers / Owners
  - Arc flash analysis per 1584.1
  - Engineers to collect data?
- Study Engineers
  - Consistency within your own group
  - Plan the data collection
- Manufacturers
  - Make data visible so we can collect it without taking energized equipment apart

Direct Current

IEEE 1584

Two landmark technical papers changed the understanding of DC arc flash

- Used same methodology as AC for now
- "Arc Flash Calculations of Exposures to DC Systems" Doan, D.R., IEEE Transactions on Industry Applications, Vol. 46 No.6.
  - Equations included in the informative annex of the 2012 Edition of NFPA 70E and remain in Annex D of the 2015 edition
  - Helped elevate the discussion of DC arc flash calculations
- "DC Arc Models and Incident-Energy Calculations," R.F. Ammerman, T. Gammon, J.P. Nelson and P.K. Sen, IEEE Transactions on industry Applications, Vol. 46, No. 5
  - Introduced Gap variable

IEEE 1584

DC Arc Flash Formula in 70E

$$I_{arc}=0.5*I_{bf}$$

$$IE_M=0.01*V_{sys}*I_{arc}*T_{arc}/D^2$$

Where:

IE_m = Estimated DC arc flash incident energy at the maximum power point – *cal/cm²*

I_{arc} = Arcing current - *Amps*

I_{bf} = System bolted fault current - *Amps*

V_{sys} = System voltage – *Volts*

T_{arc} = Arcing time - *Seconds*

D = Working distance – *cm*

- *Assume that the maximum available short-circuit current is 10* the 1 minute ampere rating*
- *"For exposures where the arc is in a box or enclosure, it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b)"*

IEEE 1584

DC Arc Flash

- DOE Funding 3-yr DC arc flash research with EPRI and Sandia Labs
  - Sent out DC arc flash problem with same variables
  - Got back results anywhere between 7-124 cal/cm^2
- Any Documented Cases DC arc flash burns?
  - Not Many

IEEE 1584

DC Arc Flash

- Preliminary model shows promise
  - Testing shows that consistent arcs can be reproduced.
  - Need more testing to verify model
- Preliminary results
  - Is arc sustainable? Yes- However, depends on inductance in circuit
  - Current formulas including 70E seems conservative
  - Current-Energy remains constant
  - Arcs vs. Arc Flash

IEEE 1584

DC Hazards for Batteries

- New Research on Hazards of DC
  - Chemical
    - Lead Acid
  - Shock
  - Arc Flash
  - Thermal
  - Poisonous Gas
    - Hydrogen

NFPA-70E & NEC

NFPA-70E 2018

Global Changes

- New Terminology – Replaced
  - “accident” with “incident”
  - “accidental” with “unintentional”
  - “accidentally” with “unintentionally”
  - “short circuit current” with “available fault current”

- Reduced DC threshold from 100vdc to 50vdc
  - Aligns with OSHA CFR 1910.303 – 50vdc
  - NFPA 70E Table 130.4(D)(b)- DC shock boundaries

NFPA 70E

History

- Tenth Edition 2015
  - Emphasis on risk
    - From arc flash hazard analysis to arc flash risk assessment
  - Prohibited approach deleted
  - Category 0 removed from PPE table
  - Electrical Safety Program to include maintenance conditions
  - Arc flash label to include IE or table category BUT NOT BOTH
- Eleventh Edition 2018
  - Aligned LOTO with OSHA 1910.147
  - Electrical Safety Program to include
    - Inspection
    - Human factor/Human error
    - Incident Investigation
    - Job Planning
    - Risk Assessment Procedure
    - Hierarchy of risk controls
  - Removal 40cal/cm2 reference

70E – 105.3

Responsibilities

A. Employer Responsibility

1. Establish, document, and implement practices and procedures
   - MOPs, SOPs, PPE, etc
2. Provided employees with training in practices and procedures
   - On-the-Job, Classroom

B. Employee Responsibility

- Shall comply with the practices and procedures provided by the employer

The Arc-Flash Hazard Warning Label

The Final Product…

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

Arc Flash Hazard Boundary	5 ft 5 in
Working Distance	1 ft 6 in
Shock Hazard Exposure	480 VAC
Glove Class	00
Limited Approach	3 ft 6 in
Restricted Approach	1 ft

Incident Energy in cal/cm^2

9.8

PPE Requirements
Arc-rated shirt & pants + arc-rated coverall + arc-rated arc flash suit

Equipment ID: **ATS-CH1**

Hood-Patterson & Dewar, Inc

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

Incident Energy in cal/cm^2	1.2
Arc Flash Hazard Boundary	1 ft 6 in
Working Distance	1 ft 6 in
Shock Hazard Exposure	208 VAC
Glove Class	00
Limited Approach	3 ft 6 in
Restricted Approach	Avoid Contact

Hill Brands PPE Level

1

PPE Requirements
Natural Fiber Shirt, Pants, and Safety Glasses

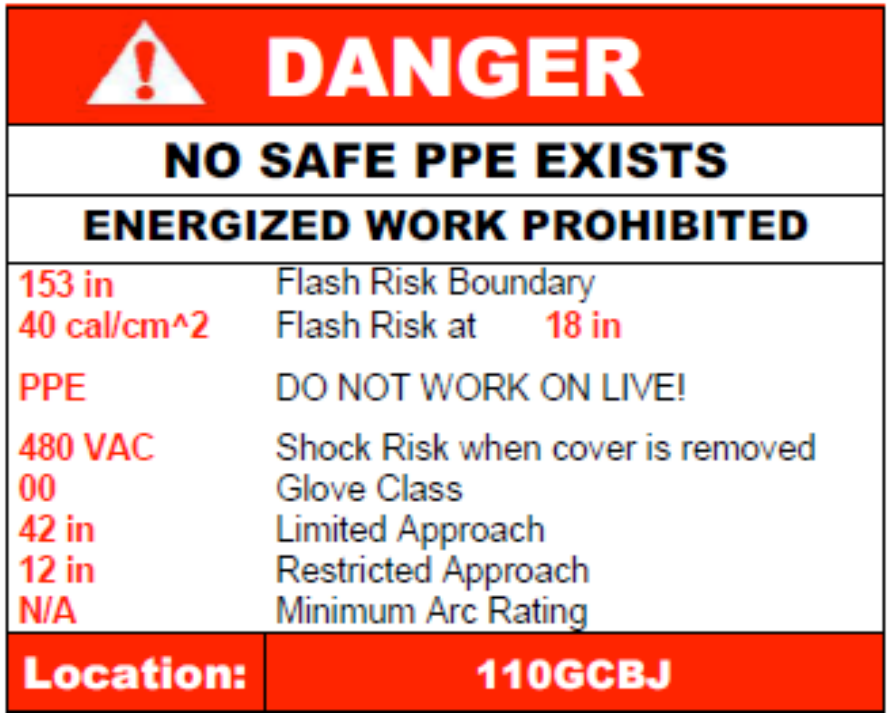
Equipment ID: **PANEL A** Date: **02/13/16**

Hood Patterson & Dewar hoodpd.com | 850 Center Way, Norcross, GA 30071

NFPA -70E 2018

Changes

- 40 cal/cm2 Restriction Removed
- 130.7 (A) Informational Note 3 – removed from 2018 version
  - Used to warn that “greater emphasis may be necessary with respect to de-energizing” equipment that exceeds 40 cal/cm2



NFPA -70E 2018

Is it required that I relabel my facility?

130.5(H) Exception 1

- *“…..Labels applied prior to the effective date of this edition (2018) shall be acceptable if they complied with the requirements for equipment labels in the standard in effect at the time the labels were applied.”*

Electrical Safety Program (ESP)

Risk Assessment Procedure

(Performed before work is started)

- Identify hazards
- Assess risks
- Implement risk control according to a hierarchy of methods
  - Elimination
  - Substitution
  - Engineering controls
  - Awareness
  - Administrative controls
  - PPE

*Example of Risk Assessment – Annex F

NFPA 70E 2018

Risk Assessment Terminology

- Hazard
  - Source of harm – injury, damage or death
- Risk
  - Combination of the likelihood of harm occurring and the severity of that harm
- Risk Assessment
  - A process of hazard identification, risk analysis and risk evaluation

*Example of Risk Assessment – Annex F

NFPA 70E 2018 Example

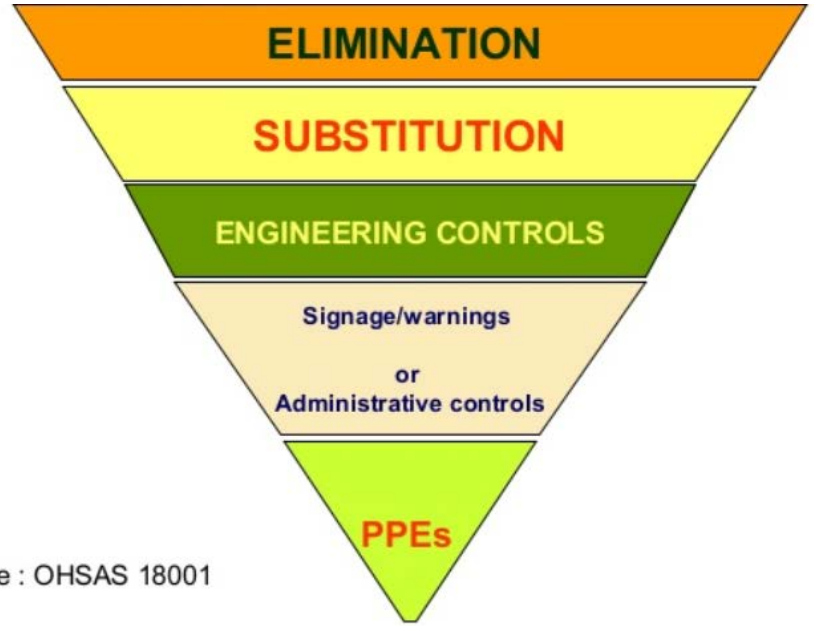
What is a Risk Assessment for Shock?

- Likelihood of making electrical contact
  - Is electrical contact possible when crossing the restricted approach?
    - Not: Can the worker be careful enough to avoid the electrical shock?
- Severity of harm
  - Could electrical contact result in harm (e.g. burns, loss of body parts, or death)?
    - Not: It’s ok since I've been shocked before with no lasting effect

*Example of Risk Assessment – Annex F

Hierarchy of Controls

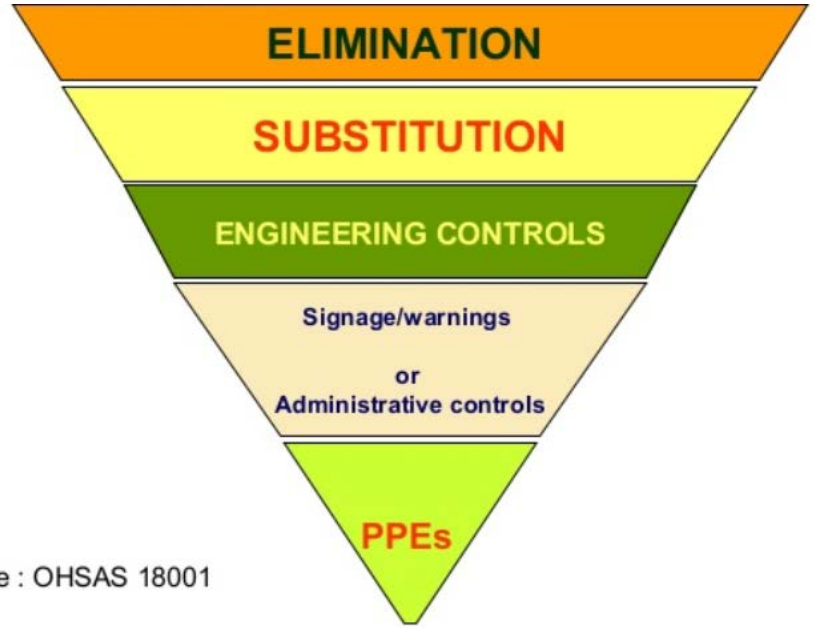
1. Elimination-
    - Physically removing the hazard – TURN IT OFF
2. Substitution-
    - Replace with non-hazard equipment – ARC-RESISTANT SWITCHGEAR
3. Engineering controls-
    - Isolate workers from hazard – REMOTE RACKING DEVICE



Source : OHSAS 18001

Hierarchy of Controls

4. Warning/Awareness
   - Making workers award of hazards and risks – SIGNS, WARNING LIGHTS
5. Administrative Controls
   - Standardize the way to perform task – DEVELOP POLICIES, TRAINING
6. Personal Protective Equipment (PPE)
   - Reduces the effects in attempt to make injury survivable – AR CLOTHING, SAFETY GLASSES etc.



Source : OHSAS 18001

Hierarchy of Controls

IV AWARENESS

NFPA 70E 2018

Safety Planning

110.1(I)

I. Job Safety Planning and Job Briefing

1. **Job Safety Planning**
    1. Be completed by a qualified person
    2. Be documented
    3. Include the following information
        a) Job and task description
        b) Identify hazards
        c) Shock assessment
        d) Arc flash assessment
        e) Work procedures, special precautions, and energy source controls
2. **Job Briefing –** Shall cover the job safety plan
3. **Change in Scope –** Additional planning to occur if changes occur

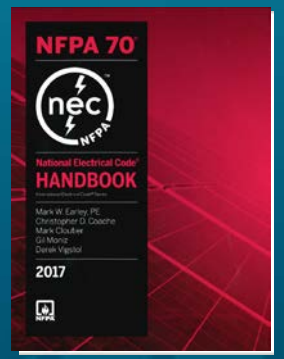
NFPA 70E 2018

Article 120: Lockout/Tagout

- Additions to 120.5 (7) regarding “adequately rated” portable test instruments
  - **Exception 1** added to allow operators to use permanently installed meters rather than handheld meters to test conductors and circuit parts
  - **Exception 2** added to allow non-contact test instruments for electrical systems over 1000V

NEC 2017 (NFPA 70) Article 240.87

Arc Flash Reduction



- Where installed overcurrent device is rated or adjustable to a continuous current trip setting of 1200 A or higher, 240.87 A and B apply
  A. Circuit breaker location must be documented and available to authorized personnel
  B. Methods to reduce clearing time:
     1. Zone-selective interlocking (ZSI)
     2. Differential relaying
     3. Energy-reducing maintenance switching with local status indicator
     4. Energy-reducing arc flash mitigation system
     5. *An instantaneous trip setting that is less than the available arcing current*
     6. *An instantaneous override that is less than the available arcing current*
     7. An approved equivalent means

Stastistics

Electrical Fatalities since the 1990s

Workplace fatalities declined 41%

Electrical Shocks

By the Numbers

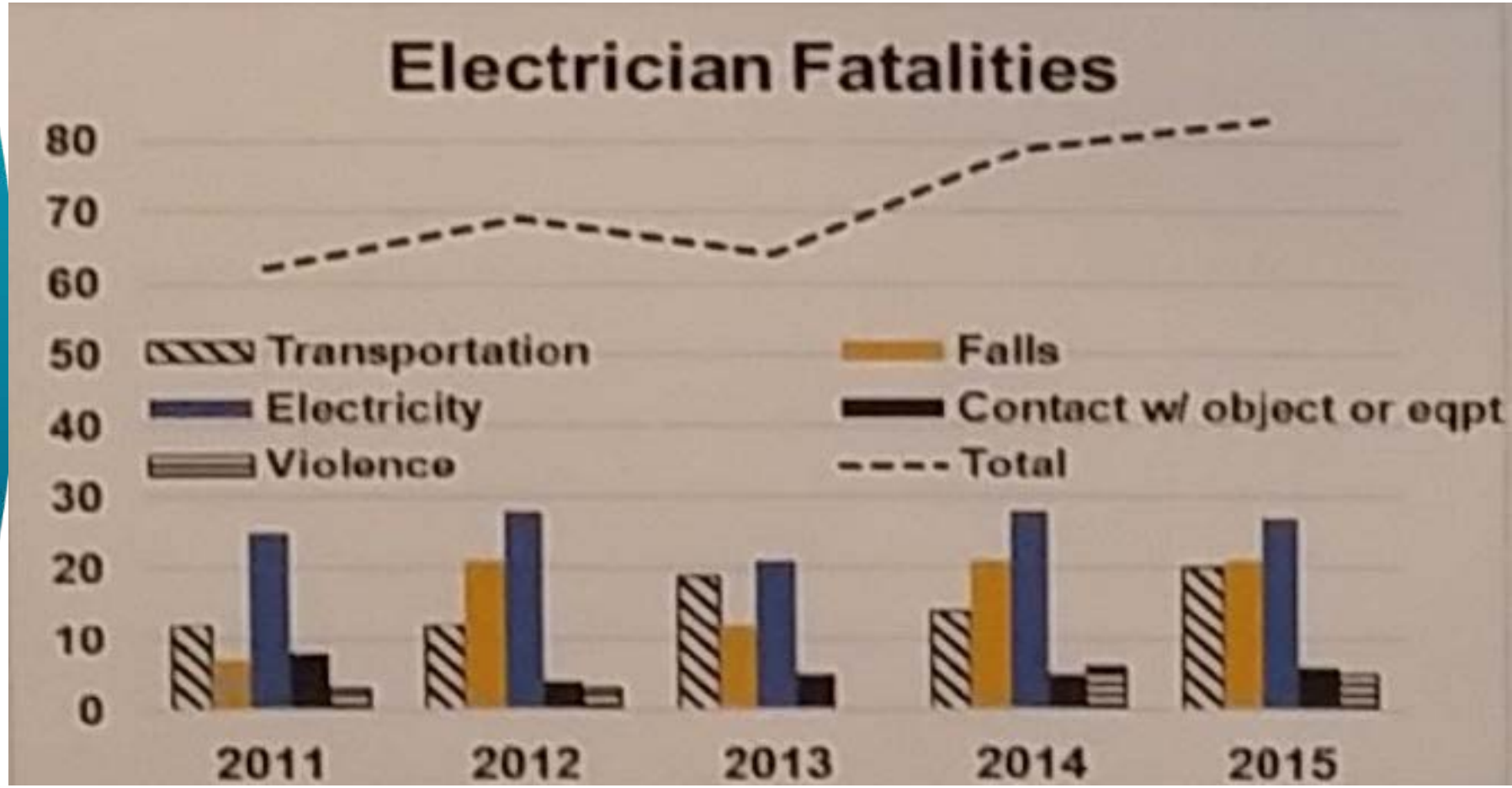
- Nearly 6000 fatalities from 1992-2012
  - 98% involve electrocutions
  - About 40% involve voltages under 600V
  - About 40% involve overhead power line contact

Source-NFPA-70E Annex K

Fatalities Between 2011 and 2015

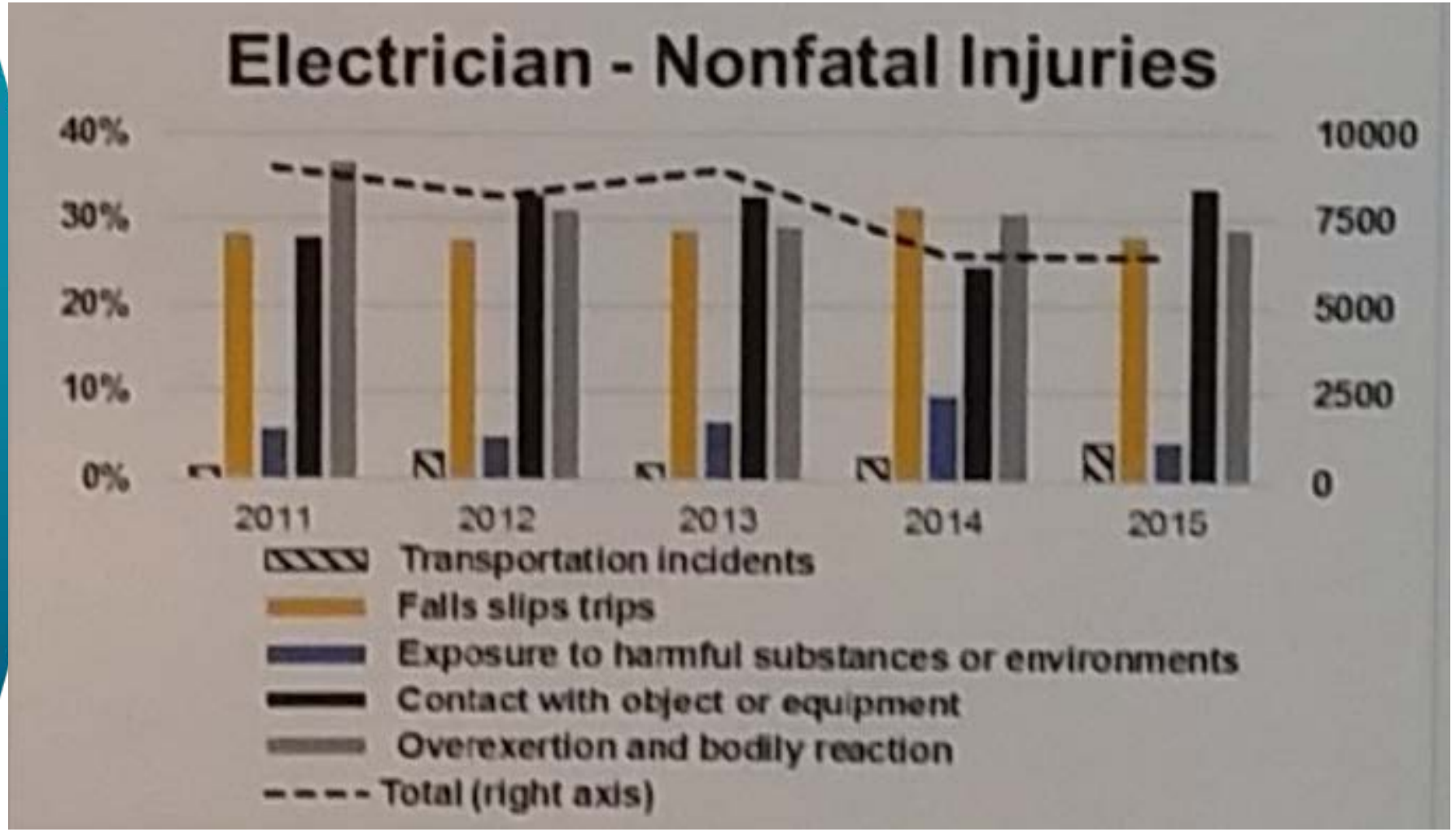
FATAL OCCUPATIONAL INJURIES						
2011-2015 Occupational Fatalities by Event/Type						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Total Occupational Fatalities	4,693	4,628	4,585	4,821	4,836	**23,563**
Type of Event of Exposure						
Transportation Incidents	1,937	1,923	1,865	1,984	2,054	**9,763**
Slips, Trips, and Falls	681	704	724	818	800	**3,727**
Violence/Injuries by Persons/Animals	791	603	773	765	703	**3,635**
Contact with Objects and Equipment	710	723	721	715	722	**3,591**
Exposure to Electricity	174	156	141	154	134	**759**
Fire or Explosion	144	122	149	137	121	**673**

Electrical Fatalities Between 2011 and 2015



ESW 2018-39-Reframing our view of workplace electrical injuries

Non-Electrical Fatalities Between 2011 and 2015



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Thank You

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