

DC Systems & Battery Safety

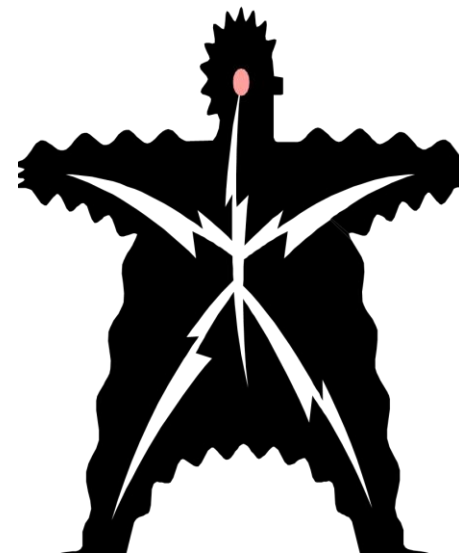
Evolution through Codes & Government Regulations

Stephen McCluer
Schneider Electric

NFPA 70E – dc Electrical Safety

Today we will cover:

- Battery systems in NFPA 70E
 - Background; current state of affairs
 - Future
 - Harmony with the National Electrical Code
- Battery system in NFPA 70 (National Electrical Code)
- DC electrical shock & arc flash protection
 - Electrical hazards & associated boundaries
 - PPE



Disclaimer



Most of the slides in the presentation have been borrowed or adapted from previous presentations to the BATTCON Battery Conference by Steve McCluer &/or Bill Cantor (with permission)

What is NFPA 70E?

The Standard for Electrical Safety in the Workplace

- *SCOPE of NFPA 70E:*

“Electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees during activities such as the...

- **installation***

- **operation,**
- **maintenance,**
- **demolition,** and
- **inspection** *

...of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways”

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Note: Scope does not include “DESIGN.”
- 70E-2012 also eliminated “installation” requirements, which are the domain of the NEC, but it added “INSPECTION”
- *Work safety practices* associated with installation procedures remain.

...of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways”

NFPA 70E

- Has grown to prominence in the past few years for rules on the hazards of “live work”
 - Traditionally it has been based on ac
- **NFPA 70E includes:**
 - definitions
 - approach boundaries
 - calculations of incident energy
 - flash protection boundaries
 - hazard evaluation procedures
 - personal protective clothing & equipment (PPE)

The NFPA 70E Conundrum

- **Premise: Live work (i.e., work on energized equipment) should be avoided whenever possible**
 - “Business continuity is not justification for work on energized equipment”
- BUT**
- **Battery systems are *always* energized**
 - You cannot de-energize stored electrical energy

Batteries in NFPA 70E

- “Live work” is unavoidable on certain portions of battery systems
- Most batteries are covered in Article 320
 - NFPA 70E-2009 was full of installation requirements
 - Some contradicted the National Electrical Code (NEC)
- IEEE StaBatt Committee Codes Working Group participated in an NFPA Task Group to clean up the battery section
 - Submitted over **70 PROPOSALS** and over **30 comments** to 70E-2012
 - Mostly installation requirements, many of which reappeared in NEC-2014

Deleted Installation Requirements

(Partial List)

- rating of cables, busbars, or busways for short circuit withstand
- insulation of cables & busbars
- cable connection and support methods
- placement of busbars
- dc switching equipment installation
- intercell and battery terminal connector construction
- shrouds & physical barriers over terminals
- dc circuit protection
- location of batteries
- separate rooms for batteries rated over 24 volts and 10 ampere-hours (at 1-hour rate)
- arrangement and accessibility of cells
- battery ventilation
- physical installation requirements
- overcurrent protection
- ground fault detection*

Added, Deleted, & Rejected

- ADDED: Definitions harmonized with IEEE Stationary Battery Committee Standards
 - Battery
 - Cell
 - Electrolyte
 - Nominal voltage
 - Pilot cell
 - VRLA cell
- MOVED: References to IEEE Battery Installation Standards to the NEC
- REJECTED: NIOSH lifting standards



-- Considered “non-electrical”

NFPA 70E Present Status

- **NFPA 70E-2015 to be published in August 2014**
- **Separates “hazard” and “risk”**
 - **Hazard identification** spots a hazard: electrical, chemical, etc.
 - **Risk assessment** identifies the potential for injury depending upon the type of work being performed
 - Leads to appropriate selection of PPE
(Personal Protective Equipment)
- **Raises the dc electric shock safety threshold**
 - 100 Vdc
 - 50 VAC
- **Identifies tasks specific to battery installation/maintenance in tables**

NFPA 70E-2015

- Batteries are primarily addressed in **Article 320**
 - work practices associated with installation and maintenance of batteries containing many cells
- DC Arc Flash/Shock addressed in **Article 130** and **Annex D**
- Companion Document: NFPA 70E Handbook
 - To be published Fall of 2014

Art 320 - Minor changes

- 320.2 **DEFINITIONS**

- “Prospective *Fault* Current” changed to

- “Prospective *Short Circuit* Current”

- Aligns with terminology used throughout the standard
 - “...highest level of fault current that could theoretically occur...”

- 320.3(A)(5): New **WARNING SIGNS** required to be posted :

- **thermal hazards** added to list of electrical warnings
 - Notice prohibiting access to **unauthorized personnel**
 - **Additional information concerning arc flash hazard signage**
 - **Arc flash hazard needs to be determined and posted**

- 320.3(D): **cell flame arresters**
to be replaced when necessary

Minor changes (Cont'd)

- **DELETED:**

~~320.3(C)(1) Battery Short Circuit Current. The battery manufacturer shall be consulted regarding the sizing of the battery short circuit protections and for battery short circuit current values.~~

- **SIGNIFICANCE:** Short circuit current rating for an individual cell or multi-cell unit can be available from the battery mfr
 - The short circuit current rating for an entire battery string or system should be calculated by an engineer or a qualified person based on how the battery system is designed at a particular facility.

Significant changes

- 320.3(A)(1): adds a new requirement for a **risk assessment** associated with battery work.
 - Prior to any work on a battery system, a risk assessment must identify the hazards associated with the type of tasks to be performed and assess the risks associated with the type of tasks to be performed
 - Electric shock
 - Chemical
 - Arc flash
 - Thermal;
 - Light;
 - sound;
 - pressure
- 320.3(A)(3) revised to simplify the requirement for annual testing of **battery alarm functionality**.
(see next slide)

Significant changes (Cont'd)

320.3(A) General Safety Hazards

320.3(A)(3) Abnormal battery conditions

[moves list of alarms for VLA & VRLA to a **new informational note**]:

Battery monitoring systems typically include alarms for such conditions as

- overvoltage
- undervoltage
- overcurrent
- ground fault, and
- overtemperature

The type of conditions monitored will vary depending upon the battery technology.

Reference: IEE 1481, *Battery Monitoring Equipment in Stationary Applications*

Significant changes (Cont'd)

320.3(B)(1): “Batteries with *Liquid Electrolyte*” changed to
“**Battery Activities** That Include Handling of Liquid Electrolyte.”

Handling electrolyte requires portable or stationary
eye wash facilities
within the work area
capable of drenching or flushing of eyes and body
for the duration necessary for the hazard

Capacity of eye wash facilities and **duration** of the flushing
should be specified by the battery or electrolyte manufacturer.

Reference: ANSI/ISEA Z358.1, *Emergency Eye Wash & Shower
Equipment*

Significant changes (Cont'd)

- 320.3(B)(1): “Batteries with *Solid or Immobilized Electrolyte*”
changed to
“Activities That Do Not Include Handling of Electrolyte.”
- Wearing of safety glasses is required at all times
- New Informational Note:
.... Batteries with solid electrolyte (such as most lithium batteries) or immobilized electrolyte(such as VRLA batteries) present little or no electrolyte hazard.

Most modern density meters expose a worker to a quantity of electrolyte too minute to be considered hazardous, if at all.

... If specific gravity readings are taken using a bulb hydrometer, the risk of exposure is higher – this could be considered to be handling electrolyte.

Significant changes (Cont'd)

SIGNIFICANCE of Activities That Do Not Include Handling of Electrolyte.”

- Battery maintenance activities usually do not involve handling electrolyte.
- Even with VLA* batteries, if the user is not handling electrolyte, only safety glasses are required....
- (B)(1) states that Goggles/face shield shall be available BUT are only required when handling electrolyte

*VLA = Vented Lead-Acid (a.k.a. “flooded” or “wet cell”)

Significant changes (Cont'd)

- 320.3(C)(2)(c):
“*hazard identification and risk assessment*”
changed to
“*risk assessment*”.
- Recognizing that:
Hazards are there or they are not there
Risk varies depending upon the activity
 - how close are you?
 - and what are you doing?

Article 130 Changes

As they Relate to
DC Shock and Arc Flash

Arc-Flash Hazard

- An **arcing fault** is current flowing through air.
 - Temperatures up to 35,000 F
(4x times the surface temperature of the sun)
 - All known materials are vaporized at this temperature.
When vaporized they expand in volume
Copper: 67,000 X; Water: 1670 X
 - The air blast can spread molten metal to great distances with force.
- **Incident energy** is the energy dissipated during an arc fault, or arc flash event.
 - Arcs [“arc blasts”] produce intense heat, IR/UV radiation, sound blast and pressure waves (i.e. an explosion), and intense light.

* IR/UV = Infrared/Ultraviolet



(a) **Arc blast in a box** (b) **Arcing fault in an ac electrical panel**

Incident energy is multiplied 3X for “arc in a box”

Photo: Siemens Energy & Automation

An Arc-Flash Event

Although no one was electrocuted in this particular event, the closest worker was pronounced dead on the scene and another was badly injured and ended up in the burn unit for five days.

A third person, 10 feet away, also suffered burns when his shirt ignited.



Photo: Siemens Energy & Automation

Practical DC guidance (new)

- Table 130.7(C)(15)(A)(a)
- **Arc Flash PPE is not required*** for:
 - Voltage testing on individual battery cells or individual multi-cell units
 - Removing battery intercell connector covers
 - Performing infrared thermography and other noncontact inspections outside the restricted approach boundary.

***...When this activity does not include opening of doors or covers.**

Practical DC guidance (continued)

- Arc Flash **PPE is not required** on dc systems for:
 - Insertion or removal of individual cells or multi-cell units of a battery system in an open rack
 - Maintenance on a single cell of a battery system or multi-cell units in an open rack

Practical DC guidance (continued)

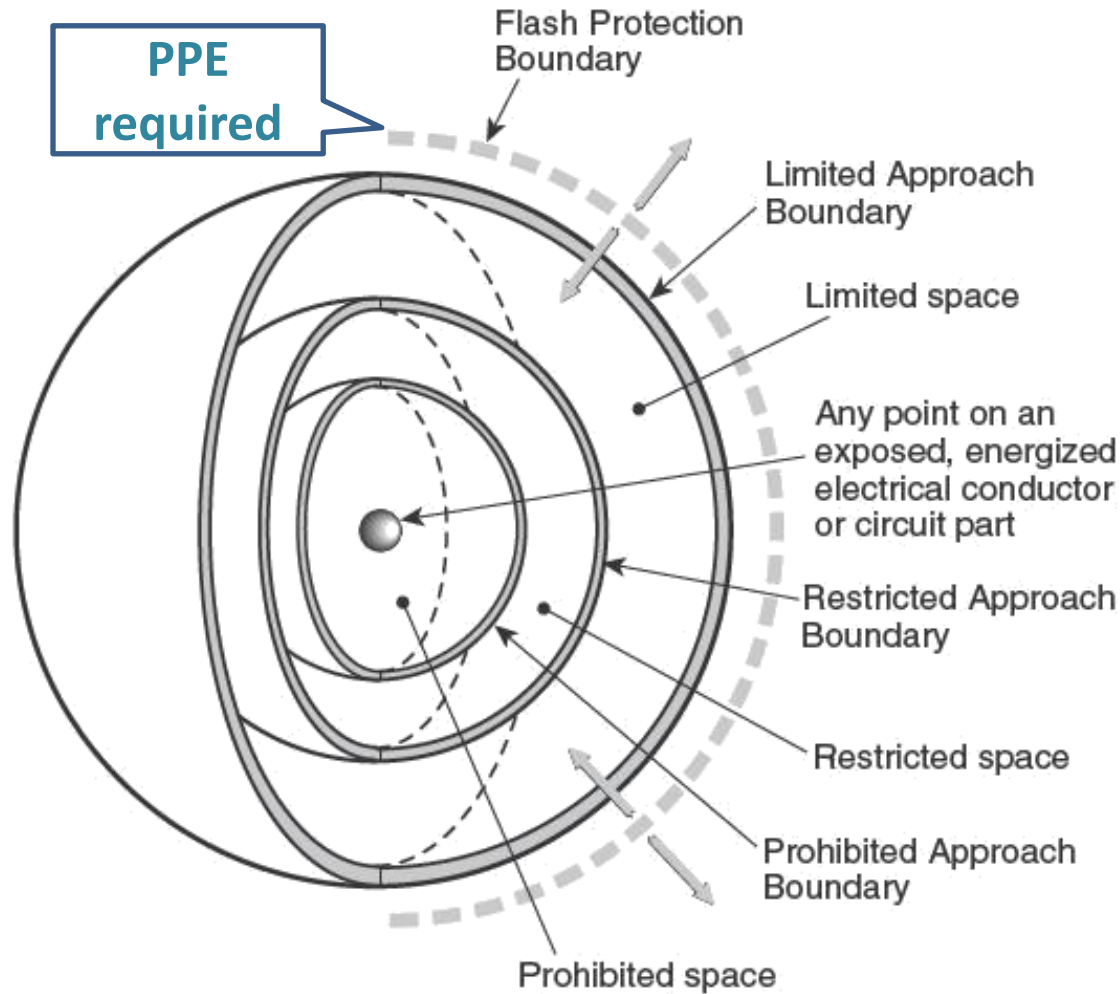
- **Arc Flash PPE IS required on DC Systems for:**
 - Work on energized electrical conductors and circuit parts of series-connected battery cells, including voltage testing
 - *Such as measuring overall voltage on a string*
 - Removal of bolted covers (to expose bare energized electrical conductors and circuit parts)
 - this includes bolted covers, such as battery terminal covers

Practical DC guidance (continued)

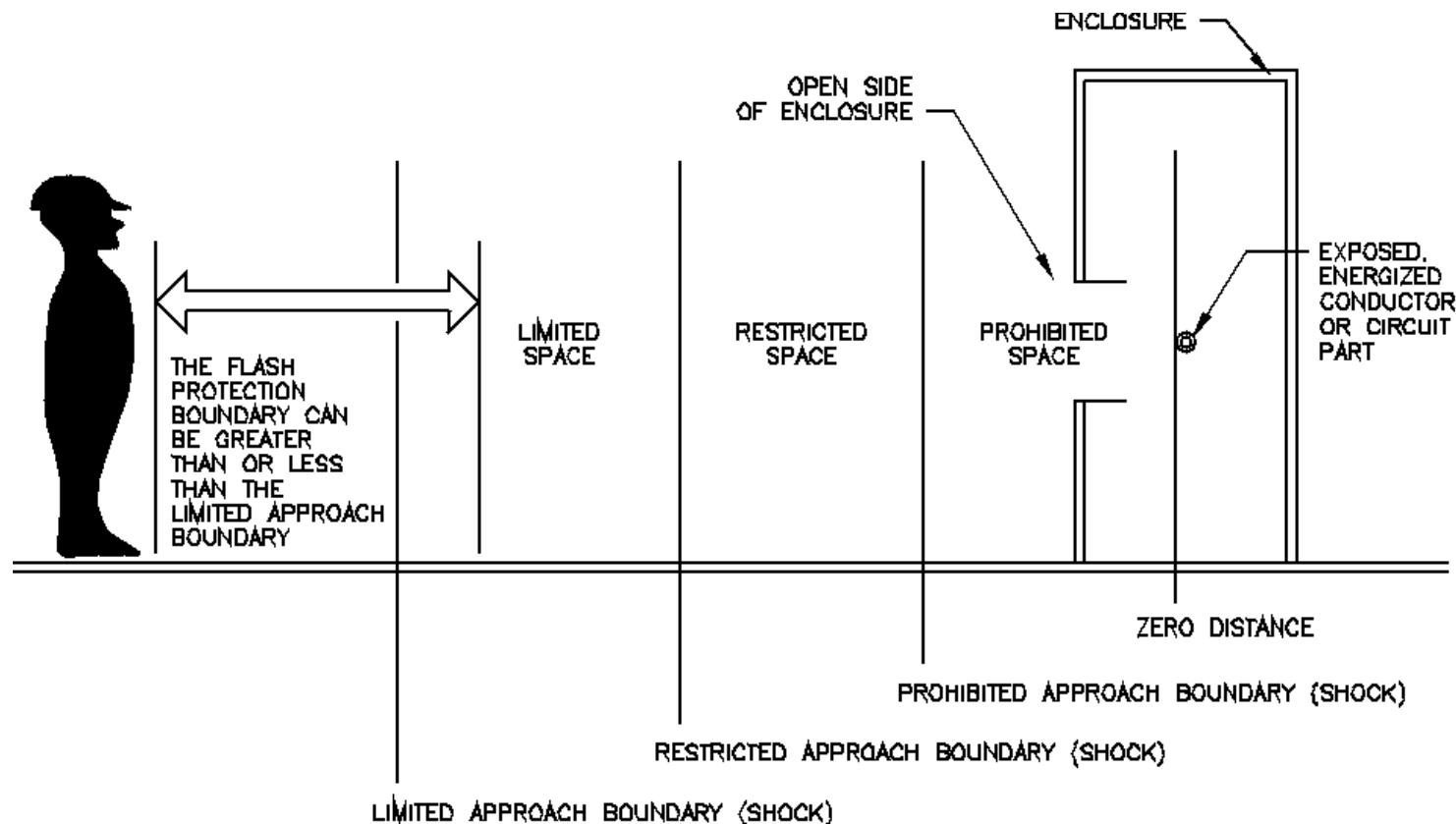
- **Arc Flash PPE IS Required on DC Systems For:**
 - Insertion or removal of individual cells or multi-cell units of a battery system **in an enclosure**
 - Work **on exposed energized electrical conductors and circuit parts** of utilization equipment directly supplied by a dc source

APPROACH BOUNDARIES

Article 130



Flash Protection Boundary and Limits of Approach



Source:
Extension Service
West Virginia University
Safety & Health Extension

Approach/Flash Protection Boundaries

Arc Flash PPE – DC table (changed)

Table 130.7(C)(15)(B)

- Applicable for 100 – 600 volts
- Changed from “arcing current” to “short circuit current”
 - (arcing current = 50% of short circuit current)
- Existing table (70E-2012) is incorrect
 - Corrected one now requires even higher PPE
- No minimum short circuit current is identified
 - **PPE 1 is always required** (Level 0 no longer exists)
- Changed
 - From: “if acid exposure is possible”
 - To: apparel “that can be expected to be exposed”
(needs to be acid resistant)

Arc Flash PPE – DC table (continued)

Notes that:

- Short-circuit current includes effects of cables and other circuit impedances
- Battery unit short-circuit currents can be obtained from the manufacturer
- The values in the table are for open air
 - battery enclosures can increase incident energy as much as 3 times
 - i.e., “arc in a box”

Equipment Labeling for Arc Flash

130.5(C) Equipment Labeling [NEW]

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 of the following information:

- (1) Nominal system voltage
- (2) Arc flash boundary
- (3) At least one of the following:
 - (a) Available incident energy & the corresponding working distance
 - (b) Minimum arc rating of clothing
 - (c) Required level of PPE
 - (d) Highest Hazard/Risk Category (HRC) for the equipment

Arc Flash Information	
Category 1	Use this information in accordance with applicable OSHA standards, NFPA 70E, and other required safe electrical work practices.
37 inches Flash Protection Boundary 4 cal/cm ² Max Incident Energy at 18" working distance Category 1 PPE Category (Per NFPA 70E-2004)	
480 VAC Shock hazard when cover is open	
42 inches Limited Approach	} Per NFPA 70E-2004
12 inches Restricted Approach	
1 inch Prohibited Approach	
Q2C: 21834068 Date: 10/30/07	
Values produced by a Square D® Engineering Services analysis. Any system modification, adjustment of protective device settings, or failure to properly maintain equipment will invalidate this label. For more information, contact Square D Engineering at 1-888-SQUARED. Copyright ©2007 Schneider Electric. All Rights Reserved.	

PPE

- **No Hazard - Risk Category 0**
- PPE Category 1
 - Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm²
 - 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
 - Leather footwear (AN)

(Note 2) Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

HOT ISSUES

(Common complaint)

BATTERY PPE



“If I do the calculations, the incident energy value goes off the chart. There is no level of PPE that would allow me to do any maintenance!”



“The PPE is so cumbersome and so hot inside that I cannot perform the work properly.”

“My visibility is so obstructed I can’t see what I’m doing.”

We would like to avoid for battery work

- Level 4 PPE



PPE Requirements

Category 1 - 2



Category 4



DC Shock Threshold

- Remains the same
- Lower DC threshold is 100 volts

TABLE 130.4(D)(b)

Approach Boundaries to Energized Electrical Conductors or
Circuit Parts for Shock Protection
Direct-Current Voltage Systems

(1)	(2)	(3)	(4)
	Limited Approach Boundary		Restricted Approach Boundary
Nominal Potential Difference	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes inadvertent Movement Adder
< 100V	Not Specified	Not Specified	Not Specified

Annex D

Incident Energy & Arc Flash Boundary Calculations

- Minor changes including relocating text
- Added note:

A conservative approach in determining the short-circuit current that the battery will deliver at 25°C is to assume that

the maximum available short-circuit current is 10 times the 1 minute ampere rating

- (to 1.75 volts per cell at 25°C and the specific gravity of 1.215) of the battery.

A more accurate value for the short-circuit current for the specific application can be obtained from the battery manufacturer.

National Electrical Code (NEC) – 2014

(NFPA 70)



Published September 2013
Public inputs:

- **3,700 proposals**
- **1,600 comments**

3 new Articles created

Direct Current (DC) Color coding 210.5(c)

Identification of branch circuit ungrounded conductors > 50 Vdc

6 AWG & smaller

(-) **NEGATIVE polarity** identified by

- continuous **black** outer finish; or
- continuous **black** stripe for entire length; or
- imprinted with minus signs (-) or the word NEGATIVE every 24"

(+) **POSITIVE polarity** identified by

- continuous **red** outer finish; or
- continuous **red** stripe for entire length; or
- imprinted with positive signs (+) or the word POSITIVE every 24"

4 AWG & larger: all conductors identified by polarity at all points of:

- termination
- connection
- splices

Identification methods must be documented & readily accessible

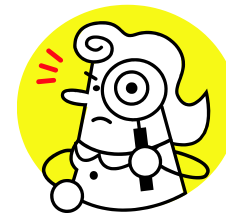
UPS BATTERIES – Article 480

- Large numbers of battery installation requirements were moved from NFPA 70E to the NEC, including:
 - battery disconnects required for battery 480.6(A)
 - OCPD not required for starting or control of prime movers <50 volts
 - Lock-out/tag-out (LOTO) for battery disconnects not in line-of-sight 480.6(B)
 - Disconnects can be plugged into busway 480.6(C)
 - Battery short circuit notification located on the battery 480.6(D)
 - Terminals of all cells readily accessible for reading, inspection & cleaning 480.8(C)
 - Wider aisles where spill containment barriers are used 480.9(C)
 - (“flooded” batteries only)
 - 1” clearance between a cell container and any wall
 - Top clearance for maintenance required for top terminal cells 480.9(D)
 - Doors w/ panic hardware required for battery rooms 480.9(E)
 - Gas piping prohibited in battery rooms 480.9(F)

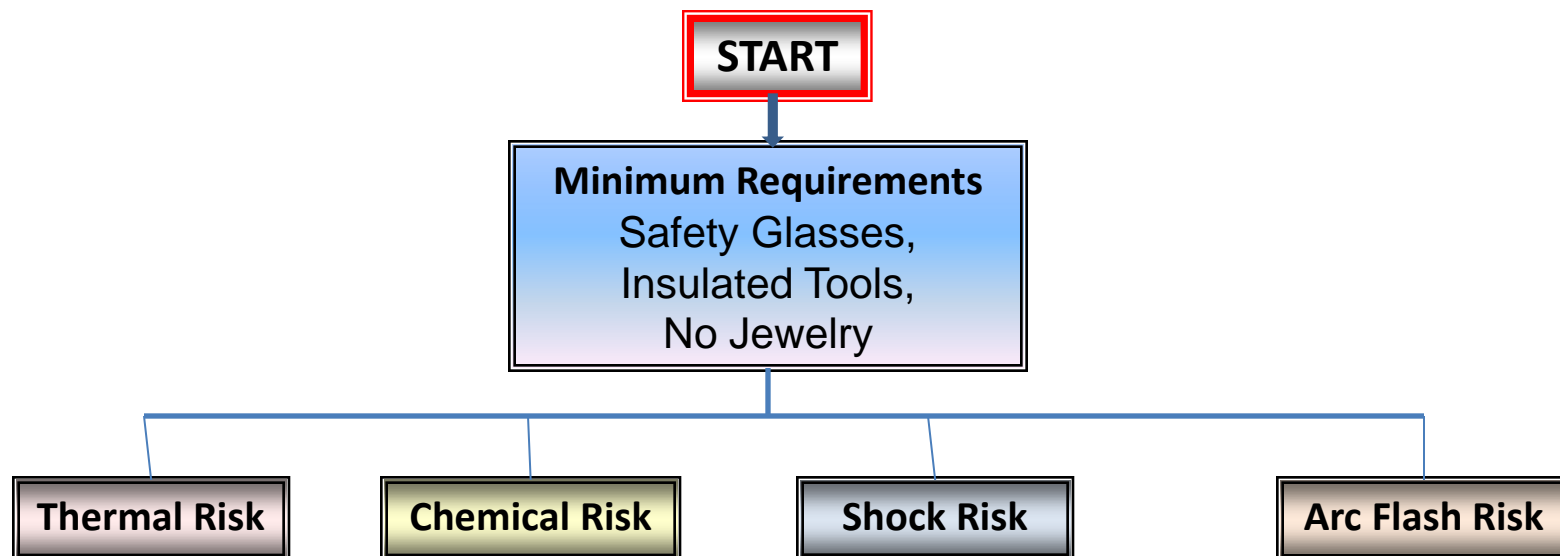
Battery Hazards

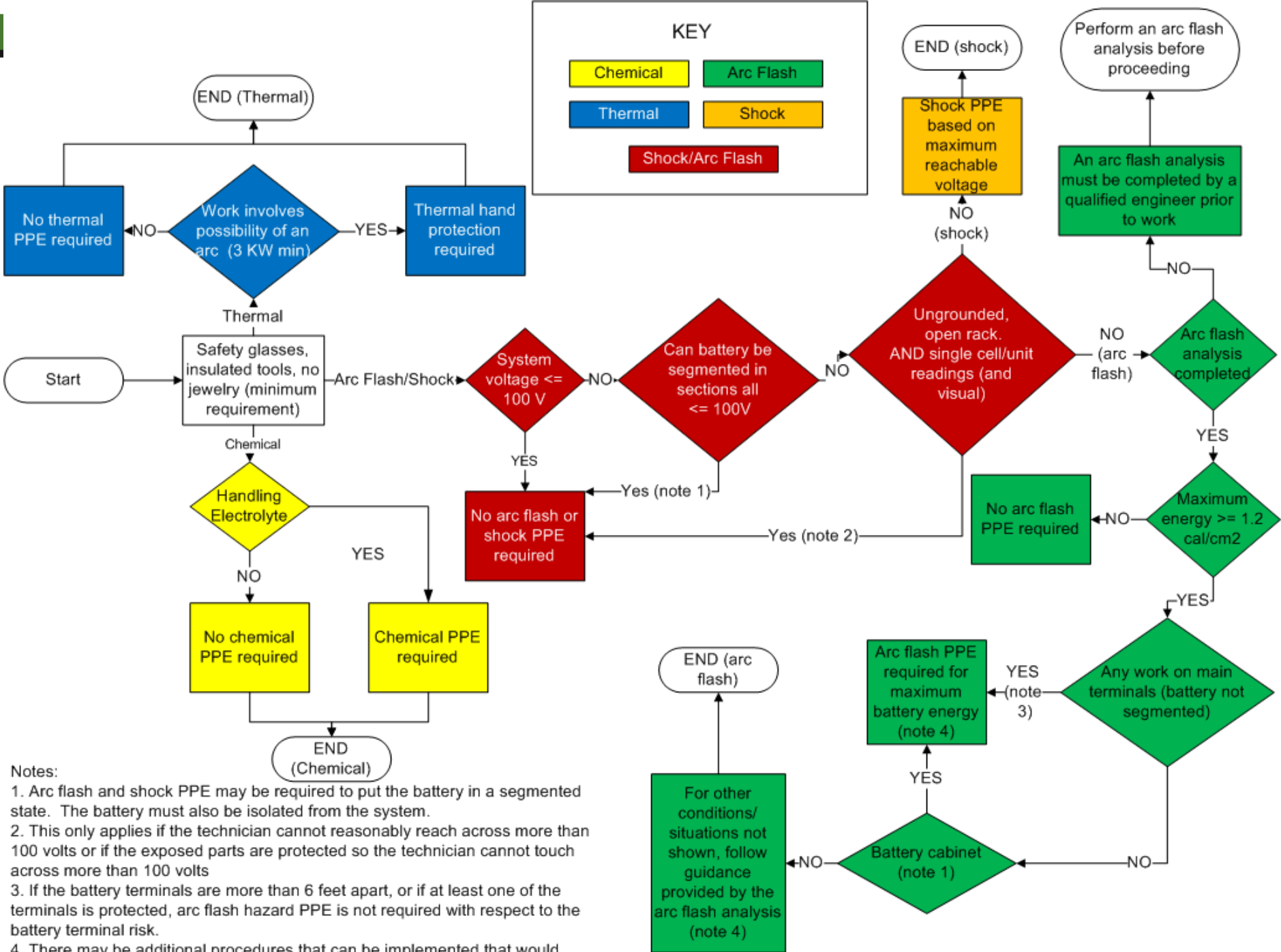
- **Chemical**
 - Electrolyte
- **Shock**
 - 100 Vdc per NFPA 70E
 - 50 Vdc per NFPA 70 (NEC)
- **Thermal**
 - Molten splatter
- **Arc Flash:** Heat, light, sound, pressure
 - Least information available
 - Greatest potential hazard

Battery Risk Assessment

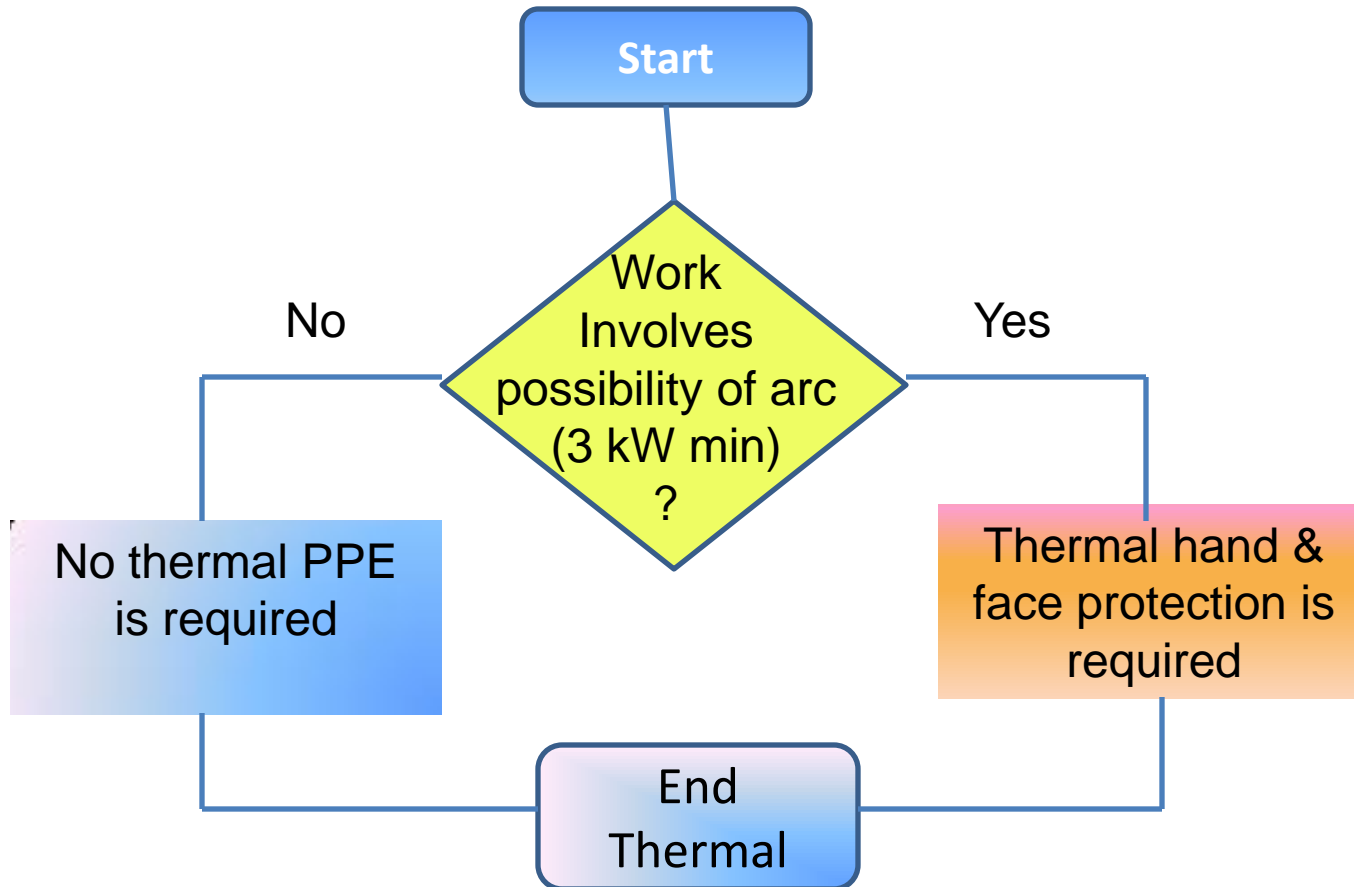


- The hazards exist
- Assess the risk of being exposed to a hazard

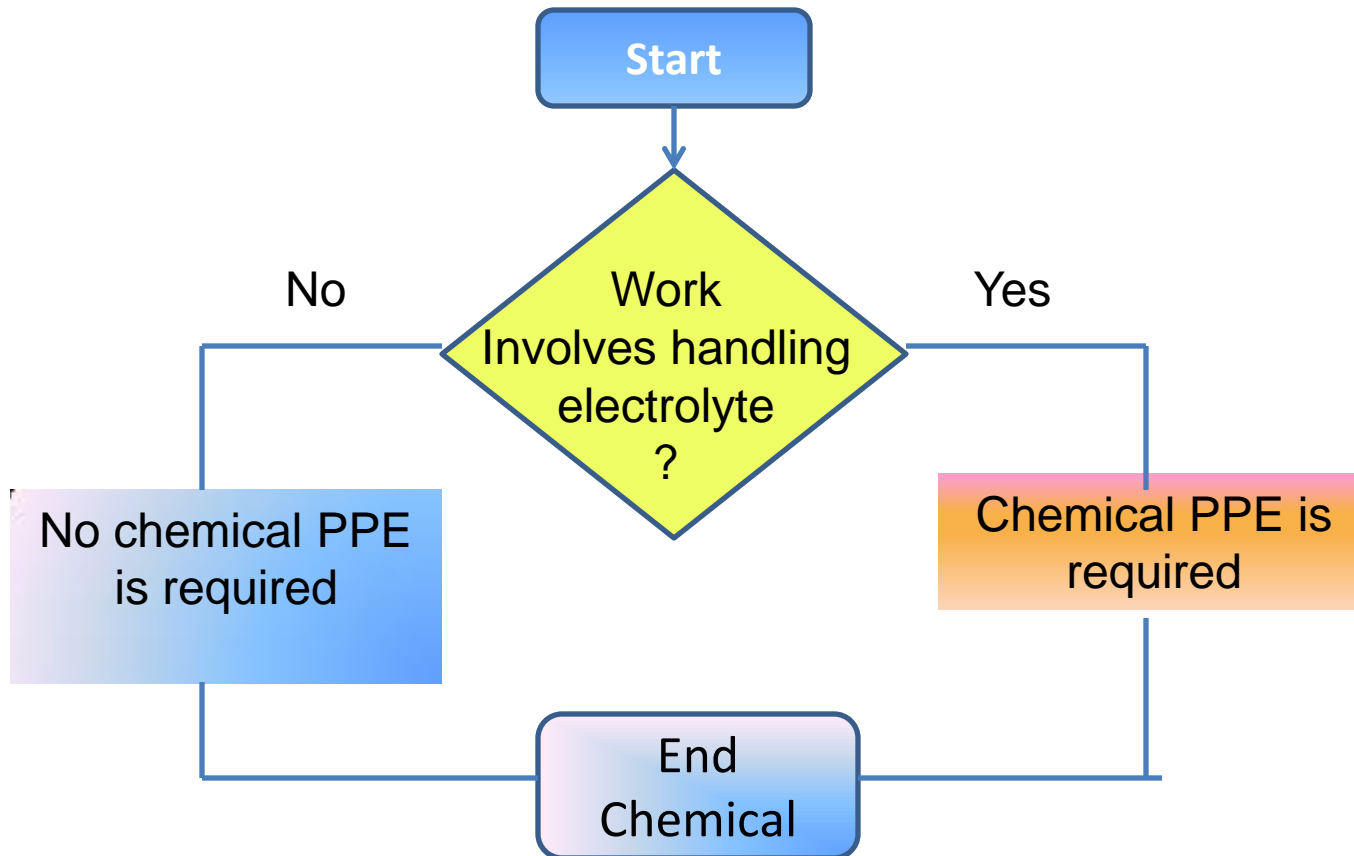




THERMAL Risk Assessment

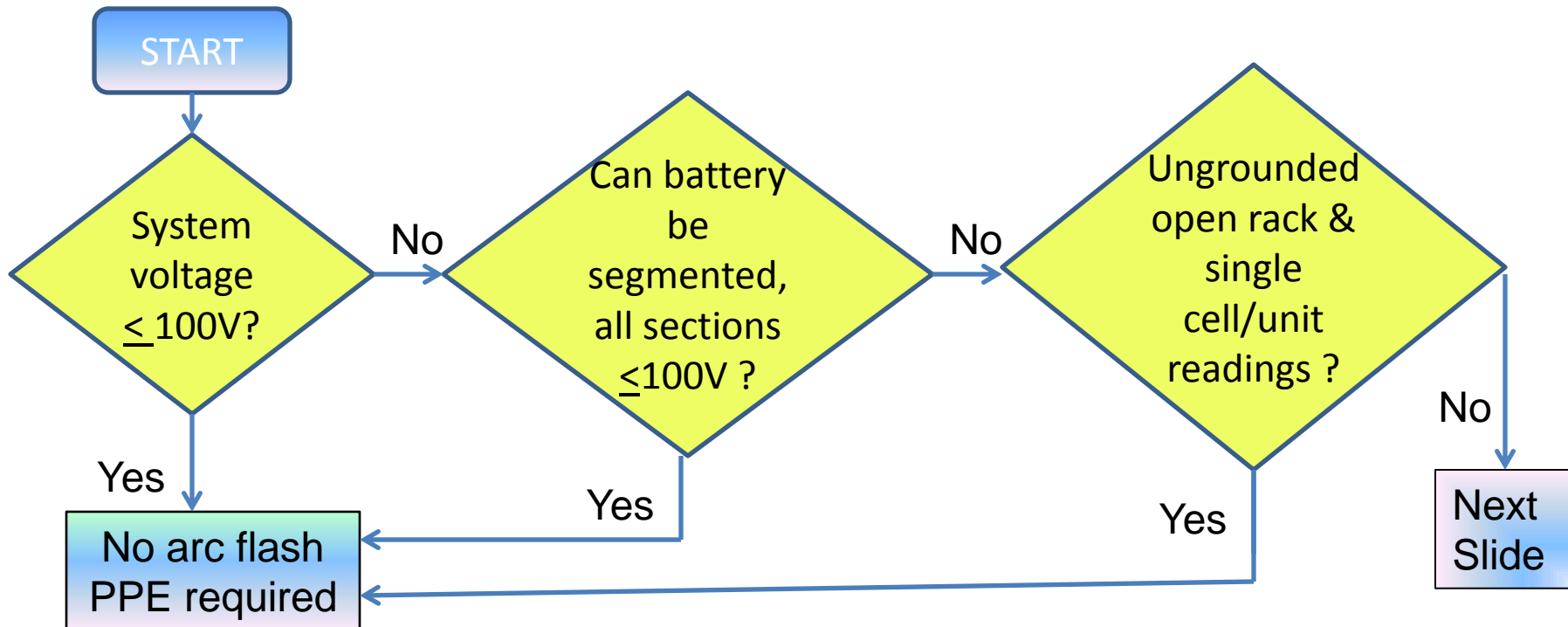


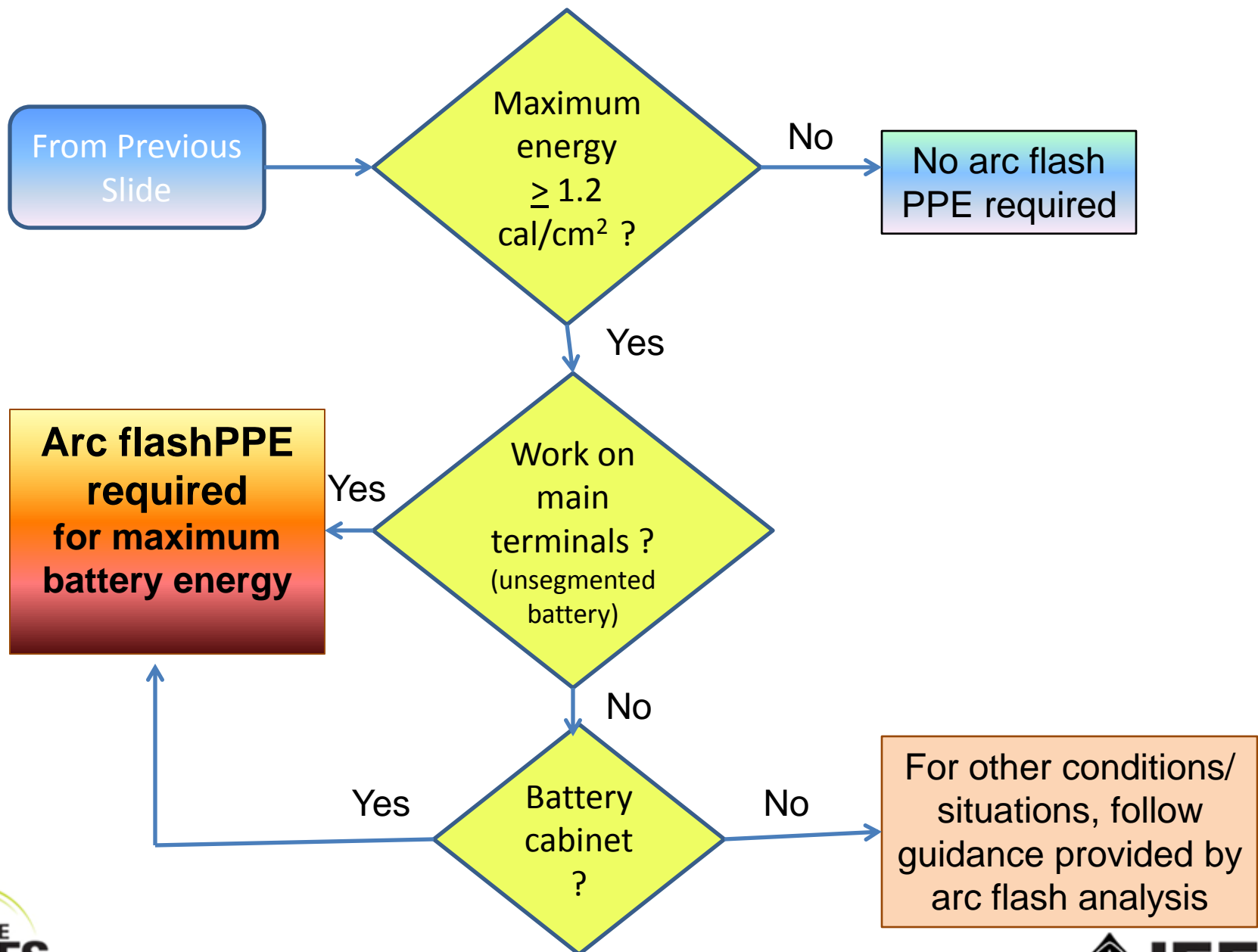
CHEMICAL Risk Assessment



Shock/Arc Flash Risk Assessment

An arc flash analysis must be performed by a qualified person before starting work on a battery system.





Why are rules so tough?

- Because we don't even know what we don't know.
- DC Arc Flash has not been characterized
 - In the absence of knowledge, code writers respond to fear
- IEEE & NFPA have conducted testing to characterize ac arc flash
 - No funding has been provided for dc
 - Our knowledge of dc arc flash is about where it was 20 years ago for ac arc flash



The End

