Battling Human Error: How NFPA 70E Changes and PPE Program Best Practices Improve Your Company’s Safety Culture and Bottom Line

NECA Safety Professionals Conference

May 2019
Agenda

- NFPA 70E Risk Assessment Procedure – Human Error
- Annex Q – Human Performance and Improved Safety Culture
- PPE Program Types and Best Practices
- NFPA 70E – key PPE changes
- Burn Injury and Cost
- Comfort and Heat Stress
- Summary
- Questions
Changes to NFPA 70E

2018 edition released in Fall 2017

• Several significant changes related to the risk assessment procedure and AR/FR clothing that affect PPE Best Practices

Changes affecting arc flash PPE
New: (2) Human Error

“The risk assessment procedure shall address the potential for human error and its negative consequences on people, processes, the work environment, and equipment.”

“Informational Note: the potential for human error varies with factors such as tasks and the work environment. See Informative Annex Q.”
New: (3) Hierarchy of Risk Control Methods.

- The risk assessment procedure shall require that preventive and protective risk control methods be implemented in accordance with the following hierarchy:
  - (1) Elimination
  - (2) Substitution
  - (3) Engineering controls
  - (4) Awareness
  - (5) Administrative controls
  - (6) PPE

No control is infallible. All of the risk controls are subject to errors in human performance.
• Human Performance: Aspect of Risk Management that addresses organizational and individual performance as factors that either lead to or prevent errors.
• High Risk Industries-Human Error-Root Cause

• Human performance addresses human error as a unique control that is complementary to the hierarchy of risk controls.

Principles of Human Performance

1) People are fallible, even best people make mistakes.
2) Error-Likely situations/conditions are predictable, manageable and preventable.
3) Individual performance is influenced by organizational processes and values.
4) People achieve high levels of performance from encouragement from leaders and peers.
5) Incidents can be avoided by understanding reasons mistakes occur and lessons learned.
Human Performance Modes – 3 modes

• Rule Based Mode: Person trained to use, covered by a procedure

Follows, IF (symptom X), THEN (situation Y) logic, most desirable human performance mode, since person can think, challenge proposed solution as appropriate. Conscious thinking/challenging can add to error prevention.

Common Error in Rule Based Mode: Misinterpretation

Since using IF-THEN logic; misinterpretation can happen, errors involve deviation from approved procedure, applying incorrect response to a work situation
Human Performance Modes – 3 modes

• Knowledge Based Mode - worker operates in mode when there is uncertainty about what to do, no rule or skill based mode identifiable.
  Phrases - “I think”, “I am pretty sure”

Person relies on their understanding and knowledge of the situation.
The uncertainty creates need for more information, forces individual attentional resources to become more focused, takes more time and energy to respond.

Common Error: Inaccurate mental picture of situation.

Stress, unfamiliar situations without rules and procedures lead people to use only readily available information and focus on only one aspect of problem. Incomplete or inaccurate info.= Erroneous decision making!
Human Performance Modes – 3 modes

• **Skill Based Mode** – person in this mode is usually executing a task that has been practiced, in a very familiar, common situation/environment.
  
  Time devoted to processing information is usually milliseconds.
  
  Example: writing one’s signature, doing a very familiar workplace task

Common Errors: Inattention- execution errors involving omissions and/or not recognizing changes in task requirements or work conditions

Perceived reduction in risk, Over confidence, complacency
Error Precursors

• Error Precursors are situations when the demands of the task environment exceed the capabilities of the worker or the limitations of human nature.

• Also, precursors can be unfavorable conditions that increase the probability for error during a specific work task

• Grouped in four broad Categories
<table>
<thead>
<tr>
<th>Error Precursors</th>
<th>Optimal Tool(s)</th>
<th>Human Performance Tool(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Demands</td>
<td>Time Pressure (In a Hurry)</td>
<td>Pre-Job Briefing</td>
</tr>
<tr>
<td>Work Environment</td>
<td>Distractions / Interruptions</td>
<td>Self Check with Verbalization (STAR)</td>
</tr>
<tr>
<td>Individual Capabilities</td>
<td>Lack of knowledge (Faulty Mental Model)</td>
<td>Stop when unsure</td>
</tr>
<tr>
<td>Human Nature</td>
<td>Complacency / Overconfidence</td>
<td>Job site review</td>
</tr>
</tbody>
</table>
Human Performance Warning Flags

Warning flags: Program, workers, supervisors, organizations

Organizational Performance Flags

• Engage in consensus or group thinking, without counter view pts.
• Personnel overly defer to managers and perceived experts
• Activities with high risk are not assigned clear owners
• The organization assumes risk mgmt. is healthy because a program or process was established (i.e. complacency exists)

Past success without adverse outcomes becomes the basis for continuing current practices. (i.e. complacency)
Workplace Culture

• Promote open communication

• Foster a culture that values error prevention and the use of human performance tools

• Identify and prevent the formation of error-likely conditions

• Support continuous improvement and learning across organization

• Establish a blame-free culture that supports incident reporting and proactively identifies and reacts appropriately to risk
• Forgetfulness: “I just forgot”

• Misunderstanding: “I didn’t know”

• Fearlessness, Overconfidence, Complacency: “I won’t get in an accident”, I’ve gone my entire career without an accident”, “that only happens to other people”

• Time Constraints: “I didn’t have time”, “it takes too much time”

• Discomfort: “It doesn’t fit right”, “it’s not comfortable”
Types of AR/FR Clothing/PPE Programs

“Task Based”
• Proper AR/FR clothing is put on to perform a specific task

“Daily Wear”
• Proper AR/FR clothing is worn at all times during work hours
A significant amount of arc flash incidents occur involving either brand new employees or the most experience employees.
Task based PPE Cultural Risk

Low Energy Tasks and Complacency

• PPE Category 1 and 2 type tasks-Will workers consistently don PPE at the appropriate time? Complacency!

• Normalization of Deviance- The gradual process through which unacceptable practices and standards become acceptable. As the deviant behavior is repeated without catastrophic results, it becomes the social norm of the organization.

• Complacency is usually one of the root causes of electrical incidents at 480V. Considered low voltage, but it is the #1 killer in the electrical industry in terms of fatal incidents.

• AR/FR clothing is a SEAT BELT!
Task based vs. Daily wear: Upfront Cost Comparison

(number of employees) X (cost of the garments per employee) = total initial cost of program

Daily Wear

Task Based

Non-FR uniforms
Cost Comparison

Upfront Cost

Long term cost
- effected by potential liability, medical costs and decreased productivity
Task based programs have less upfront cost but may have significantly higher long term costs.
Task based program increases risk of catastrophic burn injury due to human error.
### Risks Associated with Daily Wear FR Clothing Programs

<table>
<thead>
<tr>
<th>improper wear</th>
<th>Liability Concern</th>
<th>Productivity Inhibitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-FR clothing overtop AR/FR clothing</td>
<td>❌</td>
<td>❌</td>
</tr>
<tr>
<td>Question</td>
<td>Liability Concern</td>
<td>Productivity Inhibitor</td>
</tr>
<tr>
<td>----------</td>
<td>------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Will the employee recognize the hazard? Complacency?</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Do they have the clothing they are supposed to have with them? Will they put it on? Put on over natural fiber clothing? Comfort = Protection = Productivity</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>If the clothing is out in the truck or in their locker, will they take the time necessary to go get it? Inconvenient?</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Do other people who are assisting with electrical maintenance or working near where combustible dust is being cleaned up have the proper AR/FR clothing on?</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Is the employee in a hurry because it is lunch time, the end of the day or they are on a tight job schedule? If so will they take the extra time to put on their AR/FR clothing?</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Level of Risk Recap

- Risk associated with both types of FR clothing programs
- Significantly larger amount of risk associated with task based because of possibility of human error

Task based FR clothing programs = chance of exposing flammable clothing to thermal hazard which can result in significant burn injury or even death
Dangers of Non-FR Clothing

100% Cotton Shirt and Pants

TEST PARAMETERS
Voltage = 480
Amperage = 200

Arc Flash 8.4 cal/cm²

Incident Energy
8.4 cal/cm²
(Fractional per IEEE 1584)

Acs created with 70E Solutions

Presented by WESTEX INC

westex.com
AR/FR Clothing - Westex UltraSoft®

Westex UltraSoft® 7 oz. Shirt and 9 oz. Pants

Arc Flash 7.4 cal/cm²

TEST PARAMETERS
Voltage = 480
Amperage = 200

Incident Energy
7.4 cal/cm²
Calculated per IEEE1584

A arcs created with 7OE Solutions

Westex UltraSoft® 7 oz. Shirt and 9 oz. Pants
Changes to NFPA 70E

2018 edition released in Fall 2017

• Several significant changes related to risk assessment procedure and AR/FR clothing

Changes affecting arc flash PPE
Employer and Employee Responsibilities

**Employer Responsibility**
- Requires safety related work practices and procedures - established, documented, and implemented and shall provide training in these practices.

**Employee Responsibility**
- Need to comply with the practices and procedures provided by employer

105.4 Priority in implementation - hazard elimination! De-energize!
Work energized only if de-energizing is
1) Infeasible, not inconvenient.
2) Creates greater hazards, more risk
110.3 Host Employer and Contractor Employer Responsibilities

Examples of host employer in informational note helps provide clarity of who is truly responsible

Informational note:

Examples of a host employer can include owner or their designee, construction manager, general contractor or employer
Article 130.5 Arc Flash Risk Assessment

New 130.5 (A) General

1) Identify arc flash hazards
2) Estimate the Likelihood of occurrence of injury and potential severity of injury
3) Determine if additional protective measures are required, including the use of PPE

Use of Table 130.5 (C) which was formerly Table 130.7 (C) (15) (A) (a)
Table 130.7 (C)(15)(A)(a) Now Table 130.5(C)

2015 Edition
- Table 130.7 (C)(15)(A)(a)
- Arc Flash Hazard Identification

2018 Edition
- Table 130.5(C)
- Estimate of the Likelihood of Occurrence of an Arc Flash Incident for ac and dc systems
Table 130.5 (C) Likelihood of Occurrence of an Arc Flash

- Changes From Table 130.7 (C)(15)(A)(a) To Table 130.5(C)
  - Last column Heading changed:
    - Arc Flash PPE Required is now Likelihood of Occurrence
    - Still in Yes/No format
    - Task and Equipment Conditions Columns remain
  - Yes answer for Likelihood of Occurrence, means additional protective measures required, likely to include PPE.
    - Use Arc Flash PPE Category and PPE Tables as before.
      - Tables 130.7 (C) (15) a,b,and c, if using PPE Category method
Arc Flash PPE

- Incident Energy Method

- Annex H.3(b) PPE for Incident Energy Method
  - Has moved to body of NFPA 70E in Table 130.5 (G) in 2018 Edition
    
Selection of AR Clothing & Other PPE When the Incident Energy Analysis Method is Used

- **Annex H-PPE Category Method**-Single layer PPE 2 daily wear and PPE 4 flash gear (Annex H.2) – remains in Annex H
Article 130 Work Involving Electrical Hazards

• Specific requirements for industry PPE standards, Table 130.7(C)(14) have been replaced with “PPE shall conform to applicable state, federal, or local codes and standards” and Table 130 (C) (14) is now an informational note, to conform with NFPA standard format and style.

• Responsibility is on the user — due-diligence is needed
• Info. Note Table 130.7 (C) (14) will likely continue to be used, due to lack of other PPE standards
Conformity assessment requiring “All suppliers and manufactures of PPE shall demonstrate conformity with an appropriate product standard by one of the following methods.”

3 ways to comply:

1. Self declaration with supplier’s declaration of conformity - used today by PPE mfg. primarily
2. Self declaration under a registered quality management system, with accredited testing
3. Accredited, independent, third-party organization
<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier testing</td>
<td>Supplier testing, ISO 17025-accredited lab</td>
<td>Independent third-party testing and certification</td>
</tr>
<tr>
<td>Quality management system tied to manufacture of the specified product</td>
<td>ISO 9001 registered quality management system tied to manufacture of the specified product</td>
<td>Quality management system as determined by the third-party certifier</td>
</tr>
<tr>
<td>Supplier declaration of conformity</td>
<td>Supplier declaration of conformity</td>
<td>Third-party mark, certification</td>
</tr>
</tbody>
</table>
The ATPV (Arc Thermal Performance Value) of arc rated clothing is the incident energy (cal/cm²) that produces a 50% of a 2\textsuperscript{nd} degree burn through the fabric.

**FIRST-DEGREE BURNS**
- **DEPTH:** Includes only outermost layer of skin, the epidermis
- **HOW IT LOOKS:** No blisters, very pink or red
- **HOW IT FEELS:** Very painful, tender and sore
- **TIME IT TAKES TO HEAL:** 2–5 days with skin peeling
- **SCARRING:** No major scarring, may have discoloration

**SECOND-DEGREE BURNS**
- **DEPTH:** Includes entire epidermis, upper layers of the dermis
- **HOW IT LOOKS:** Pink or red in color; moist, oozing blisters
- **HOW IT FEELS:** Painful
- **TIME IT TAKES TO HEAL:** Less severe second-degree wound, 5–21 days; severe wound, 21–35 days
- **SCARRING:** Minimal scarring, may have discoloration

**THIRD-DEGREE BURNS**
- **DEPTH:** Includes entire epidermis, dermis and extends into subcutaneous tissues
- **HOW IT LOOKS:** Charred, leathery appearance
- **HOW IT FEELS:** Very little pain or no pain
- **TIME IT TAKES TO HEAL:** Small wounds, several months; large wounds may require skin grafting
- **SCARRING:** Scarring present

**FOURTH-DEGREE BURNS**
- **DEPTH:** Includes all skin layers and subcutaneous tissues, extends into muscle and bone
- **HOW IT LOOKS:** Black, charred, dry, crisp
- **HOW IT FEELS:** Painless (nerve endings are destroyed)
- **TIME IT TAKES TO HEAL:** Function in the affected area is lost or severely limited
- **SCARRING:** Excision or amputation is typically needed

References
- hospitals.unm.edu/burn/classification.shtml
- healthresearchfunding.org/difference-between-3rd-and-4th-degree-burns/
What Is Important?

- Three factors: extent, severity, location
- Extent expressed as % body surface reaching 2nd and 3rd degree. Closely linked to survivability
- Severity, location linked to quality of life
Survival

Extent: Burn percentage, more than severity, predicts survival because skin is infection barrier

• 2nd and 3rd degree break skin, providing an infection pathway

• Most hospital deaths 2-4 weeks post-exposure are infection (gram-neg staph)
Survival Factors

• Odds of survival fall with total % burn
• Odds of survival fall precipitously above 50% burn
• Odds of survival fall as age increases
The risk increases with smoke inhalation.

This does not include rehabilitation or reconstruction, which can be necessary years after injury.

For people over 50, the risk of morbidity (illness) and mortality (death) from their injury increases.

<table>
<thead>
<tr>
<th>Age</th>
<th>% of 2\textsuperscript{nd} &amp; 3\textsuperscript{rd} degree burns</th>
<th>Risk of death</th>
<th>Avg. hospital stay for survivor</th>
<th>Avg. cost per day</th>
<th>Total avg. cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>40- to 49 year old</td>
<td>50%</td>
<td>Almost 40%</td>
<td>3 days per % of body burn</td>
<td>$7,791</td>
<td>$1,168,650</td>
</tr>
</tbody>
</table>

Source: The University of Texas Medical Branch Blocker Burn Unit
PPE Culture: Top Reasons Employees Fail to Don PPE

• Forgetfulness: “I just forgot”

• Misunderstanding: “I didn’t know”

• Fearlessness, Overconfidence, Complacency: “I won’t get in an accident”, I’ve gone my entire career without an accident”, “that only happens to other people”

• Time Constraints: “I didn’t have time”, “it takes too much time”

• Discomfort: “It doesn’t fit right”, “it’s not comfortable”
Comfort

Innovative FR/AR fabrics

Daily wear is a single layer clothing

Task based is double layer clothing (layering AR/FR coverall over non-FR, natural fiber clothing)

The flame resistant engineering of AR/FR fabrics has advanced to make AR/FR clothing almost indistinguishable from regular street clothing
Comfort & Heat Stress

Comfort is inherently subjective

• Not linked to weight across fiber types
• Not linked to weight within fiber type until >30% delta
• Wear tests are the best way to judge
• Wears tests will help develop consensus on FR/AR clothing options
Heat Stress

No single layer, breathable woven/knit fabric (FR or not) causes heat illness

Heat illness causes:
- Poor hydration
- Lack of rest breaks
- Lack of shade
- Poor health
The Fabric Brand is Important

Specify the AR/ FR Fabric Brand

✓ Do Your Homework
  • Find fabrics that meet your performance needs
  • Review independent test reports, i.e. UL certified for NFPA 2112, Kinectrics arc rating test report
  • Ask: Does the fabric perform to all of your hazards?

✓ Evaluate viable options
  • Don’t settle for minimum performance, i.e. ASTM F1506
  • Because data does not exist to evaluate comfort, conduct wear trails to assess it
  • Look for market-proven performance

✓ Specify by brand name
  • Know what brand you are getting
  • For example, “88/12” is not a brand
  • There are large differences in how “similar” fabrics perform
Upfront and Long Term Cost Comparison

Task based programs have less upfront cost but may have significantly higher long term costs.
• Task based programs have less upfront cost but potential for significantly higher long term costs.

• Daily wear programs reduce the chance of human error exposing non-FR clothing (FUEL) to a thermal hazard and catastrophic burn injuries.

• The cost of treatment, length of recovery, and chances of mortality increase significantly with the increase in % of body burn (Extent).

• With both Daily Wear and Task Based programs, always make sure your AR/FR clothing provides the required level of protection against your specific hazard(s).

• There are many different options of AR/FR fabric on the market that all perform differently. Specifying the AR/FR fabric brand(s) is essential. Three Daily wear program decisions: Fabric(s), Garment design, Service Provider.
Summary

NFPA 70E consensus standard focus: how to reduce the likelihood of incident occurrence and mitigate the severity of burn injury from arc flash hazards and have shed new light on PPE program best practices.

The Daily wear programs, with innovations in fabric and garment technology, now provide a comfortable, “want to wear”, “best practice” program that further reduces the burn injury risk and increases an organization’s Safety Culture.
Potential Task based Scenario - Bank Arc Flash
Why FR/AR

Real Life Arc Flash Caught on Surveillance Camera: Daily wear - Westex UltraSoft®