FR PPE Fabric Choice Criteria and End User Importance

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FR PPE Fabric Choice Criteria

Webinar Overview

Introduction

Bainbridge Industry Research
- Credentials
- Study Parameters

Research Results - FR PPE Choice Criteria
- Order of Importance
- Choice Criteria/Characteristic Details
- Impact of Ordered Criteria on Performance

Choice Criteria Application
- Application of Fabric Data to Determine PPE Performance

General Study Conclusions

Choice Criteria Summary
Introduction
FR PPE Fabric Choice Criteria

Introduction

New 3rd party research has uncovered some interesting statistics on the importance of fabric choice for FR Garments.

FR PPE Garment Programs

- Many choices and considerations.
- Each application is different.
- End user may need to consider one fabric characteristic over another.
- Importance of different fabric characteristics may vary by application.
- Some fabric characteristics resonate universally across most applications.

Questions

- What performance criteria are most meaningful for choosing a FR PPE garment program?
- What fabric characteristics are the most important?
- What tradeoffs are wearers forced or willing to make?

Discussion

- End users view of available choices
- Fabric characteristics – Fabric dictates many garment properties
- Trade offs

Identify and Discuss Key FR Fabric Criteria for End Users
For decades, Bainbridge has acted as a strategy development partner for organizations ranging from the small-cap to the Global 500. With foundations out of MIT, our proven methodology coupled with our multi-faceted team helps clients drive their corporate initiatives forward at home and abroad.
Project Objectives
Better understanding of current market needs at an end-user level
Determine the best product offering and end-user influences

Methodologies Employed
Primary source research

Scope
Industry End Users
Safety Managers

Results
The key objective of this research is to generate reliable data to increase understanding of end-user perceptions, usage, and requirements in industries where FR PPE is used:
- Oil & Gas
- Chemical & Petrochemical
- Utilities
- General Manufacturing
Interviewees Purchasing FR PPE

Primary Research – 157 Interviews

- Chemicals (28)
- Utilities (47)
- Oil & Gas (40)
- Manufacturing (28)

How do you source your protective clothing?

Approximately how many employees are affected by you or your organization's purchasing decision?

- 17% 25-50 employees
- 31% 51-100 employees
- 27% 101-500 employees
- 17% 501+ employees

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Research Results - FR PPE Choice Criteria
Please rank in order, the importance of the following criteria to you in buying protective apparel. The items of importance are Durability, Comfort, Protection, Appearance, and Cost.

<table>
<thead>
<tr>
<th>Value</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.15</td>
<td>Protection</td>
</tr>
<tr>
<td>3.50</td>
<td>Durability</td>
</tr>
<tr>
<td>3.15</td>
<td>Comfort</td>
</tr>
<tr>
<td>2.8</td>
<td>Cost</td>
</tr>
<tr>
<td>1.4</td>
<td>Appearance</td>
</tr>
</tbody>
</table>

Values expressed are the average of respondents' ranking of criteria from 1 to 5; 1 being least important and 5 being most important.

- Protection is the most important aspect of protective apparel.
- Durability is second.
- Appearance is the least important aspect
- Cost is the second least important.

Fabric Characteristics Impact FR PPE Garment Performance Criteria
Ranked Choice Criteria

- Protection
- Durability
- Comfort
- Cost
Ranked Choice Criteria

- Protection
- Durability
- Comfort
- Cost
Many interviewees consider compliance with NFPA standards and dual/multi-hazard protection when evaluating a garment’s level of protection.

The features considered in “Other” primarily included “Duration of Protection” and “Ratings.”
FR PPE Fabric Choice Criteria

Regulations, especially NFPA 2112 and 70-E, are one of the most important factors driving the market.

NFPA 2112: Standard on Flame Resistant Garments for Protection of Industrial Personnel Against Flash Fire

- Standard **Primarily for Manufacturers**, not End-Users
- Provides **Minimum** Requirements for Design, Construction, Evaluation, and Certification of FR Garments
- Qualified Garment must exhibit 50% or Less Total Predicted Burn Injury (TPBI)
- Required Tests (3rd Party Certified)
  - **Instrumented Thermal Manikin** (ASTM F 1930)
  - Vertical Flammability (New and 100x IL)
  - Heat Transfer Performance (HTP)
  - Thermal Shrinkage Resistance
  - Heat Resistance
  - Sewing Thread Melting

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Regulations, especially NFPA 2112 and 70-E, are one of the most important factors driving the market.

NFPA 70e: Standard For Electrical Safety In the Workplace

- Standard encompasses guidance for making hazard identification and risk assessments
- PPE and Clothing Selection
- Assists in complying with OSHA 1910 Subpart S and OSHA 1926 Subpart K
- Establishes Arc flash boundaries
- Establishes Arc flash PPE categories
  - Arc PPE categories range from 1 to 4.
  - Arc PPE category is used to determine the necessary arc rating of a garment for a specific job task
# Dual Hazard Protection

Differentiation – Hazard Risk Types

<table>
<thead>
<tr>
<th>NFPA 2112 - ASTM F-1930</th>
<th>NFPA 70E – ASTM F-1959</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finished Garment Subjected to ‘Jet’ Fire – Engulfment Fireball</td>
<td>Fabric Sample Subjected to Arc Flash</td>
</tr>
<tr>
<td>2 cal/cm²s Heat Flux at 3 seconds duration</td>
<td>&lt; 1 second Arc of Intense Energy</td>
</tr>
<tr>
<td>6 cal/cm² total Energy Exposure</td>
<td>&gt; 1.5 cal/cm²</td>
</tr>
<tr>
<td>TPBI – Total Predicted Body Injury</td>
<td>ATPV – Arc Thermal Performance Value</td>
</tr>
<tr>
<td>Minimum Performance Standard Pass/Fail</td>
<td>EBT – Energy Break Open Threshold</td>
</tr>
<tr>
<td>Garment Must Not Exhibit &gt; 50% TPBI</td>
<td>Energy that results in second degree burns or break open</td>
</tr>
<tr>
<td></td>
<td>Does Not Predict a TPBI</td>
</tr>
</tbody>
</table>
**Dual Hazard Protection**

Cannot Infer short duration fire protection based on ATPV or arc categories

<table>
<thead>
<tr>
<th>Hazards</th>
<th>Key End-Users</th>
<th>Exposures</th>
<th>Temp Limits</th>
<th>Exposure Time</th>
<th>Key Performance / Attribute Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire</strong></td>
<td>Industrial Workers</td>
<td>Convective Energy</td>
<td>~1000 °C</td>
<td>Seconds</td>
<td>NFPA 2112 / 2113</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exposure Time</td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td>Smoke / Fumes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Re-Ignition Potential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Arc</strong></td>
<td>Electricians</td>
<td>High Radiant Energy</td>
<td>~6000 °C</td>
<td>&lt;&lt; 1 sec</td>
<td>NFPA 70E / NESC</td>
</tr>
<tr>
<td></td>
<td>Utility Workers</td>
<td>Concussive Forces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smoke / Fumes</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Molten Metal Splatter</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Are your current PPE choices the BEST fit for your risk assessment?

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FR PPE Fabric Choice Criteria

What features do you consider when evaluating a garment’s level of Protection?

The features considered in “Other” primarily included “Duration of Protection” and “Ratings.”

“Duration of Protection”

- Protective Performance Assurances
- Performance should not diminish through normal use
- Inherent vs Post-Treated Fabrics

“Ratings”

- Thermo-Man ASTM F-1930 TPBI
- Intensity Matters – Duration & Heat Flux
- ASTM F-1959 ATPV values

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Ranked Choice Criteria

- Protection
- Durability
- Comfort
- Cost
• Tear and rip performance is markedly the most considered in evaluating garments’ durability.
Break Strength – Grab Method

Breaking Strength and Elongation of Textile Fabrics - ASTM D5034
- **Force required to elongate or break a fabric sample**
- **Measures relative strength of a fabric**
- **Evaluate as new and after laundering**

Stronger and More Durable Fabric or Garment Can Provide a Longer Service Life, and Reduce Replacement Costs.
Trap Tear

- Trapezoidal Tear Strength ASTM D5587
  - Measures force required to tear a fabric
  - Indication of a fabric’s relative resistance to tearing.

Stronger and More Durable Fabric or Garment Can Provide a Longer Service Life, and Reduce Replacement Costs.
**Abrasion Resistance**

Taber Abrasion ASTM D3884

- Abrasive discs rubbing against a fabric sample with a known pressure
- Indication of a fabric’s relative resistance to weakening and wear through.

**Stronger and More Durable Fabric or Garment Can Provide a Longer Service Life, and Reduce Replacement Costs.**
Ease of Care

Ease of Laundering
- Soil Release Properties
- Contaminate Removal vs. Redistribution

Special Laundering Procedures
- Bleach
- Hard Water
- Others

Effect of Laundering on Garment Properties
- Wear Durability
- Replacement and Repairs
Ranked Choice Criteria

Protection

Durability

Comfort

Cost
What features do you consider when evaluating a garment’s level of **Comfort**?

- **Breathability of Garment**
- **Lightweight garment**
- **Other**
- **Garment fit**
- **Softness**
- **Moisture Management (Wicks moisture from skin, absorbs)**
- **Reduces risk of heat stress**
- **Insulates in cold weather**
- **Smoothness of Fabric**
- **Anti-Microbial**
- **Drape**

- **Breathability and weight of garment are the most considered in evaluating garments’ comfort.**
- **Of garment comfort category “Other,” most commonly considered aspects are flexibility and employee feedback.**
3 Pillars of Comfort

- Thermal Comfort
- Moisture Management
- Fabric Hand
- Garment Fit Design

Balance of Properties
**Light Weight**
- Fabric weight has significant impact on thermal comfort and heat stress

**Breathability**
- Air flow improves evaporative and convective cooling.
- Lower likelihood of heat stress

**Fabrics Which Absorb and Repel Moisture**
- Aids with evaporative cooling. Push-Pull effect

**Moisture Dissipates Across Fabric Surface**
- Can enable faster drying. Key factor in feeling cool and dry

**How to Measure?**

- **Fabric Weight (Actual)**
- **Air Permeability**
- **Drying Rate**
- **Moisture Regain**
- **Sweating Manikin**
- **Vertical Wicking**
FR PPE Fabric Choice Criteria

**Tactile (Touch / Feel)**

- **Material “Hand” / Feel**
  - How a Fabric/Garment Feels to the human touch (sensory perception)

- **Garment Fit**
  - Impacts the wearer’s perception of comfort

**How to Measure?**

- **Human Wear Trials**
  - Expert Panel Study

- **Laundry Shrinkage**

*Data can provide comfort guidance, but always conduct a wear trial*

**The Key: All Factors Must Be In Balance!**
Fabric Weight Has Significant Influence on Thermal Comfort

**Fabric Weight**
- Fabric weight has more influence than fiber type on heat regulation and heat stress, per 3rd party study*
  
  * North Carolina State Textile Study
- Heavier fabric weight can influence durability, style, and protection (depending on material)

On A Hot Summer Day, Do You Choose To Wear A Heavy Shirt to Stay Cool and Dry?
4 primary ways our bodies release and regulate heat

**Radiation**
- Heat and energy from a warmer body “radiates” into a cooler atmosphere (think infrared)

**Convection**
- Lose heat through the movement of air around our body

**Conduction**
- Heat flows from your body through direct contact with a cooler object

**Evaporation**
- As the amount of heat being removed from the body decreases, sweat is created.
- As the sweat evaporates into the atmosphere, heat is removed and the body cools

**Goal:** Maximize moisture management and thermal comfort while minimizing any negative impact clothing has on how our bodies cool

Primarily **Dry**
Heat Transfer

Primarily **Wet**
Heat Transfer
Sweating Manikin is designed to evaluate heat and moisture management properties of clothing systems.

Simulates heat and sweat production making it possible to assess the influence of clothing on the thermal comfort process for a given environment.

Test Methodologies

- Thermal Resistance (ASTM F 1291)
- Evaporative Resistance (ASTM F 2370)
Ranked Choice Criteria

- Protection
- Durability
- Comfort
- Cost
What features or attributes do you consider when evaluating a garment’s level of Cost Effectiveness?

Long-term care considerations are the most considered in evaluating garments’ cost effectiveness.
Pressure to save money on the front end decision for short term gains
The cheaper alternative is not always the least expensive to own.

Identify key fabric considerations to choose a FR PPE program with the best long term value; save more money over time than is possible through initial purchase price considerations alone.

Value – the material or monetary worth of something…the worth of something compared to the price paid or asked for it.

Conditioned to Look at Initial Procurement Cost

Must Consider

Quality
Cost Effectiveness
Total Life Cycle Costs
Long Term Performance
Wearer Safety
Cost Effectiveness can be gauged by Garment Life Cycle

Key Considerations

- Durability
  - FR Protection Durability
  - Fabric and Garment Wear Durability
  - Repair/Replacement Frequency
- Launderability
  - Soil Release Properties
  - Ease of Care
- Appearance

Attribute Measurements

- Field Trials and Actual Use
- Fabric/Garment Testing

Garment Life Cycle is a Result of the Fabric Long Term Care Characteristics

Repair and Replacement Costs Are Significant
A key factor in Total Cost of Ownership is **Garment Life Cycle**

**Repair and Replacement Costs Are Significant**

*Value* — *the material or monetary worth of something... the worth of something compared to the price paid or asked for it.*

By choosing a garment with a higher initial cost but lower replacement costs, you can potentially save close to 27% over the life of the program.

**Key assumption:** 200 wearer program
Choice Criteria Application
## FR PPE Fabric Choice Criteria

<table>
<thead>
<tr>
<th>Fabric Type</th>
<th>Nomex® IIIA</th>
<th>Nomex® IIIA</th>
<th>FRTC 88/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection</td>
<td>4.15</td>
<td>3.50</td>
<td>3.15</td>
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<tr>
<td>Durability</td>
<td>2.8</td>
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<tr>
<td>Comfort</td>
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<td>Cost</td>
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### Values in red denote lowest performance for the category

<table>
<thead>
<tr>
<th>ASTM F-1930</th>
<th>Duration</th>
<th>TPBI %</th>
<th>ATPV</th>
<th>Break Strength (Grab)</th>
<th>Warp (lbf)</th>
<th>Fill (lbf)</th>
<th>Category</th>
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</thead>
<tbody>
<tr>
<td>Thermal Manikin</td>
<td>4s</td>
<td>34.7</td>
<td>6.4</td>
<td>225.76</td>
<td>160.55</td>
<td>1</td>
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<tr>
<td>2 cal/cm²/s</td>
<td>cal/cm²</td>
<td>Category</td>
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<thead>
<tr>
<th>ATPV</th>
<th>Duration</th>
<th>TPBI %</th>
<th>Break Strength (Grab)</th>
<th>Warp (lbf)</th>
<th>Fill (lbf)</th>
<th>Category</th>
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<td>6.4</td>
<td>4s</td>
<td>49.2</td>
<td>171.63</td>
<td>113.72</td>
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<td>4.9</td>
<td>cal/cm²</td>
<td>Category</td>
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<tr>
<td>8.7</td>
<td>4s</td>
<td>65.3</td>
<td>114.2</td>
<td>74.82</td>
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<td></td>
<td>cal/cm²</td>
<td>Category</td>
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### Trap Tear

<table>
<thead>
<tr>
<th>Break Strength (Grab)</th>
<th>Warp (lbf)</th>
<th>Fill (lbf)</th>
<th>ATPV</th>
<th>4s</th>
<th>23.3</th>
<th>7.9</th>
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<tbody>
<tr>
<td></td>
<td>50.4</td>
<td>38.5</td>
<td>5.4</td>
<td>13.6</td>
<td>19.5</td>
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</table>

### Taber Abrasion

<table>
<thead>
<tr>
<th>Break Strength (Grab)</th>
<th>Cycles (cs-10/1000g)</th>
<th>4s</th>
<th>581.4</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>327.4</td>
<td>550.4</td>
</tr>
</tbody>
</table>
## FR PPE Fabric Choice Criteria

### Fabric Type

<table>
<thead>
<tr>
<th>Fabric Type</th>
<th>Nomex® IIIA</th>
<th>Nomex® IIIA</th>
<th>FRTC 88/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (oz/sqyd)</td>
<td>6.0</td>
<td>4.5</td>
<td>~ 8.0</td>
</tr>
<tr>
<td>Air Permeability (cfm/ft²)</td>
<td>83.6</td>
<td>224</td>
<td>30.5</td>
</tr>
<tr>
<td>Thermal Resistance (°C*m²/W)</td>
<td>*</td>
<td>0.0553</td>
<td>0.0867</td>
</tr>
<tr>
<td>Evaporative Resistance (kPa*m²/W)</td>
<td>*</td>
<td>5.6 x 10⁻³</td>
<td>10.7 x 10⁻³</td>
</tr>
<tr>
<td>Total Heat Loss (W/m²)</td>
<td>*</td>
<td>438.4</td>
<td>305.1</td>
</tr>
</tbody>
</table>

* Data currently not available.

Values in red denote lowest performance for the category.
### FR PPE Fabric Choice Criteria

<table>
<thead>
<tr>
<th>Fabric Type</th>
<th>Protection</th>
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<tr>
<td>Nomex® IIIA</td>
<td>4.15</td>
<td>3.50</td>
<td>3.15</td>
<td>2.8</td>
</tr>
<tr>
<td>FRTC 88/12</td>
<td>2.8</td>
<td>3.15</td>
<td>3.50</td>
<td>4.15</td>
</tr>
</tbody>
</table>

#### Initial Cost

<table>
<thead>
<tr>
<th>Fabric Type</th>
<th>Cost (Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomex® IIIA</td>
<td>~ 120</td>
</tr>
<tr>
<td>FRTC 88/12</td>
<td>~ 70</td>
</tr>
</tbody>
</table>

#### Replacement Factor

<table>
<thead>
<tr>
<th>Fabric Type</th>
<th>Expected Re-purchases</th>
<th>Total Dollars (Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomex® IIIA</td>
<td>1</td>
<td>120</td>
</tr>
<tr>
<td>FRTC 88/12</td>
<td>2.0</td>
<td>140</td>
</tr>
</tbody>
</table>

### Total Cost of Ownership

<table>
<thead>
<tr>
<th>Fabric Type</th>
<th>Total Dollars (Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomex® IIIA</td>
<td>120</td>
</tr>
<tr>
<td>FRTC 88/12</td>
<td>140</td>
</tr>
</tbody>
</table>

Values in red denote lowest performance for the category.
General Study Conclusions
Please imagine your ideal protective garment. Consider all qualities and characteristics that may be relevant to your purchasing decision such as the look, feel, what it may protect against, etc. Please describe this ideal garment.
If have ever used Nomex®: What adjustments, if any, would you make to current Nomex® protective apparel products?

Many interviewees would not make any adjustments at all to Nomex® products.
Summary
Conclusions and Summary

- End Users Consider Protective Performance and Durability Top Priorities
- FR Garment Purchasing Decisions Need to Balance Multiple Criteria
- Fabric Properties Dictate Many of the Desirable Garment Properties
- Choose the Fabric First
Thank You
Disclaimer

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