FR GARMENT COMFORT

Explaining the mystery

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AGENDA

- Why Comfort is Increasingly More Important
- Fundamentals of Comfort
- Thermal Comfort and Moisture Management
- Fabric Touch and Feel
- Garment Design
- Summary / Closing Remarks
GETTING COMFORTABLE WITH THE TOPIC OF COMFORT
Flame-Resistant (FR) Garment Selection Criteria

Many variables to consider, but protection is key

- Many factors influence the purchasing decision of an FR garment
- The best protection based on your hazard assessment should be the primary concern
- FR protection does not mean you have to be uncomfortable
- Discomfort can lead to PPE shortcuts, increased risk, and discontent
Why Comfort Is Important

Being uncomfortable can put you at risk

- Comfort can impact whether workers wear their FR PPE
  - 87% of workers have observed other workers failing to wear PPE*
  - Top reasons failed to wear PPE: Uncomfortable and too hot

- Why should the comfort of your FR be a consideration?
  - Increase compliance to FR safety regulations
  - More likely to wear FR PPE and wear appropriately
  - Increase productivity and reduce breaks
  - Reduce heat related illnesses
  - Increase wearer morale and reduce discontent

*Per 2006 National Safety Council Study, Kimberly Clark
Comfort – A Key FR Garment Consideration

What FR garment wearers say about comfort

Wearers indicated the top 3 qualities in an **ideal** FR garment*
1. **Comfortable** (breathable, cool, flexible, soft)
2. Protective
3. Lightweight

The most important garment comfort features*
1. **Breathability**
2. Lightweight
3. Garment Fit
4. Softness
5. Moisture Management

*Per 2014 3rd Party Bainbridge market research study
Understanding The Real Story Behind Comfort

FR comfort misconceptions

*Myths In the Market – What Is Not True*

- Comfort is the same for everyone
- In order to be comfortable, you have to sacrifice protection
- FR clothing is the primary contributor to thermal comfort and heat stress
- Synthetic fibers do not make comfortable FR garments
- My FR clothing should be comfortable in any environment / condition
- Garment weight does not impact my comfort level

*Per 2006 National Safety Council Study, Kimberly Clark*
Comfort Is Subjective

A wear trial is the best way to test comfort

- Comfort is the combination of the garment properties and each individual’s perception / preference

- In addition to fabric/garment properties, the region, individual, and work environment all have significant influence in their comfort perception

- There is no better comfort test than a personalized wear trial
  - Since wear trials can be time intensive, use data as directional indicators of comfort
  - Understand what key attributes to look for in a garment before wear testing
The Basics of Comfort

3 Pillars: Thermal Comfort, Hand, Garment Fit / Design

Comfort – According to the Textbook

- The state of physical ease and freedom of pain or constraint*
- Pleasant state of psychological, physiological and physical harmony between the human being and the environment**

3 Key Factors That Influence Comfort

Thermal Comfort & Moisture Management
- Ability to transport heat and moisture away from the body

Tactile & Hand Properties
- Perception of fabric touch and feel

Garment Fit / Design
- Closeness, tightness, and compression of garment

*Per Oxford Dictionary
What Is All This Talk About Comfort?

Industry is trending towards comfortable FR PPE

- FR industry moving towards protection and comfort all in one garment
- Comfort can be confusing……understanding what to look for

Keywords:
- Lightweight
- Air Permeability
- Thermal Comfort
- Cellulosic
- Moisture Management
- Moisture Regain
- Drying Rate
- Wicking
- Fabric Hand
- Hydrophilic
- Hydrophobic
- Heat Stress
- Absorption
What Comfort Attributes to Look For In A FR Garment

What to look for - key comfort criteria

- Lightweight (meeting protection requirements)
- Breathable
- Absorbs / wicks moisture, while drying quickly
- Appealing touch & feel: soft, smooth, supple
- Appropriate fit before and after laundering
- Comfortable for your work environment

Poor Performance In Any One Characteristic Can Make A Garment Undesirable
THERMAL COMFORT & MOISTURE MANAGEMENT
How Our Body Cools Down

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

Primarily **Dry** Heat Transfer

Primarily **Wet** Heat Transfer
The Difference In The Cooling Mechanisms

Heat stress occurs when the body can no longer cool itself

**Dry Heat Transfer – Cooler Environments**
- In cooler environments heat loss through radiation, convection, and conduction are more prominent

**Wet Heat Transfer – Hot Environments**
- In hot environments when the temperature is greater than that of your body (~90 to 95°F), the primary method of cooling is wet heat transfer or evaporation
Environment conditions impact heat stress

Need very high activity levels (metabolic rate) to induce heat stress in standard room condition environments for single layer garments.

- Fabric characterization was done at North Carolina State University.
Independent 3rd Party Study* – Thermal Comfort

Environment conditions impact heat stress

- In hot environments, heat stress can occur at **lower** activity levels
- Heat stress less likely when wearing light weight fabrics

* Fabric characterization was done at North Carolina State University

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Heat Stress Factors

External conditions, activity level, and body conditions

- Primary factors contributing to heat stress for single layer FR garments
  - Heat & Humidity
  - Activity level
  - Personal body condition

- Single layer FR garments may not be the primary contributor to heat stress
Wet / Evaporative Heat Transfer - Cooling In Hot Climates

Managing sweat / moisture is a critical part of thermal comfort

**FR clothing’s role in moisture management**

- Moisture travels in both vapor and liquid forms away from the body.

- Moisture vapor can pass between fibers and through openings in the fabric.

- Liquid / sweat is transmitted from the skin to the fiber’s surface before evaporating into the air.

- Poor moisture management can make a garment feel clammy*, clingy*, sticky, and heavy.

Fibers Role in Moisture Management

Fiber type is a differentiator in moisture management

**Fibers with high moisture absorbency – hydrophilic**
- Increased ability to absorb moisture and sweat
- Saturated fibers swell, decreasing the fabrics ability to breath
- Can take longer to dry and can feel wet and heavy
- Cellulosic (i.e. Lyocell) / “natural” fibers (i.e. cotton, wool, silk)

**Fibers with lower moisture absorbency - hydrophobic**
- Absorbs less moisture than hydrophilic fibers
- Dries faster due to lower moisture content
- Synthetic fibers (i.e. polyester, modacrylic, aramid – Nomex®)

**Innovative fabric blends now can have both fiber types**
- Engineered fabric blends, like New Nomex® MHP incorporate both fiber types to optimize moisture management
Measuring Thermal Comfort & Moisture Management

Accepted industry methods for measuring comfort

One Dimensional Fabric Testing
- Vertical Wicking *(AATCC 197)*
- Moisture Regain / Absorption *(ASTM D1576)*
- Drying Rate / Time *(AATCC 199-201)*
- Air Permeability *(ASTM D737)*
- Fabric Weight *(ASTM D3776)*

Innovative Comprehensive Garment Testing
- Sweating Manikin *(ASTM F 1291 / F 2370)*

Sweat Management
- Effective Cooling
- Quick-Drying
- Breathable
- Lightweight
Measuring Thermal Comfort & Moisture Management

Wicking is a critical indicator of thermal comfort

**Wicking**
- Movement and dispersion of liquid through the fabric
- High wicking can lead to feeling dry, increasing evaporative cooling
- 3rd party research
  - Wicking is the most effective process to maintain a comfort feel*
  - Garments which do not wick are normally perceived as very hot**
- Naturally wicking fibers – cellulosic
- Synthetics can be engineered to wick – DuPont™ Nomex®

**100% cotton moisture management” NC State University Journal of Textile and Apparel, Technology and Management, Vol. 2, Issue 3, Summer 2002
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Vertical wicking is a simple and effective wicking test

**Vertical Wicking Test**
- Test method illustrating the movement of water on a vertical fabric
- The further/faster the water is transported, the greater the wicking ability
- Effective Wicking:
  - Water wicks quickly in first few minutes
  - Water should travel at least 4 inches in 10 minutes

![Graph showing wicking performance of different materials](image_url)
Too much moisture absorption is not always a good thing

**Moisture Regain %**

- Measures how much moisture is absorbed by a fabric from its surroundings.

- Fabrics which absorb moisture easier can be prone to slowly releasing *more water to dry*.

- Goal is to find optimized fabrics which absorb *and* also effectively release moisture.

![Moisture Regain Chart]

<table>
<thead>
<tr>
<th>Material</th>
<th>Moisture Regain %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomex® IIIA</td>
<td>4%</td>
</tr>
<tr>
<td>Nomex® MHP</td>
<td>8%</td>
</tr>
<tr>
<td>88/12 FR Treated Cotton</td>
<td>9%</td>
</tr>
</tbody>
</table>
Measuring Thermal Comfort & Moisture Management

Quick drying fabrics and fibers are critical for cooling

**Drying Rate**

- Thicker and heavier fabrics can be prone to retaining moisture

- General rule: The more moisture absorbed, the longer it takes to dry

- After 30 minutes, Nomex® IIIA is 50% drier than FR cotton

![Drying Rate Graph](image-url)
Measuring Thermal Comfort & Moisture Management

**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*

- Heavier fabric weight can influence durability, style, and protection (depending on material)

- Nomex® is available in the lightest weight NFPA 2112 FR fabric – 4.5 oz/sy

* North Carolina State Textile Study

On A Hot Summer Day, Do You Choose To Wear A Heavy Shirt to Stay Cool and Dry?
What is the weight of your FR fabric / garment?

**Fabric Weight**

- Actual weights can be much different than as advertised
- Comparing different fiber/fabric types, more weight does not always equal more protection
- Lower weight fabrics can exceed NFPA standards
  - Inherent FR performance
  - Strong fibers

![Fabric Weight Chart]

<table>
<thead>
<tr>
<th>Material</th>
<th>Advertised (oz/sq yd)</th>
<th>Actual (oz/sq yd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomex® IIIA</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Nomex® IIIA</td>
<td>4.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Nomex® MHP</td>
<td>5.0</td>
<td>6.0</td>
</tr>
<tr>
<td>FR Modacrylic Blend</td>
<td>6.0</td>
<td>7.0</td>
</tr>
<tr>
<td>88/12 FR Treated Cotton</td>
<td>7.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>
Air permeability is critical in influencing thermal comfort*

- Lighter weight fabrics and more open fabric weaves increase air permeability (breathability)

- More air permeability helps cool a wearer through radiative, convective, and evaporative heat loss

- Increasing air permeability, increases moisture movement through the fabric, leading to being dry and cool

- Higher air permeability enables higher sustainable work rates and is less likely to cause heat stress**


Air permeability enables heat and moisture vapor transmission and increases cooling, which increases breathability.
Measuring Thermal Comfort of Entire Garment

Innovative & comprehensive sweating manikin testing

**Sweating Manikin – 3\textsuperscript{rd} Party Testing***

- Evaluates heat and moisture management properties
- Simulates heat and sweat production
- Assesses influence of clothing on thermal comfort

**ASTM Test Standards**

- Thermal Resistance (ASTM F 1291)
  - Air Temp < Dry Skin Temp
- Evaporative Resistance (ASTM F 2370)
  - Air Temp = Wet Skin Temp

*Note: Values can vary depending on the construction, weave or finish of the fabric*

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* Fabric characterization was done at North Carolina State University

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Cooling capability influenced by thermal & evaporative resistance

Lower Resistance = More Heat Loss & Cooling Capability

Lower Resistance is Better

Higher is Better for Cooling
Measuring Thermal Comfort of Entire Garment

Conclusive sweating manikin testing results

**Visual Indicator**
- More Blue = Cooler
- Manikin has 34 temperature controlled sensors / segments

**The Performance of Nomex® IIIA vs. Competition:**
- 61% lower thermal resistance
- 53% lower evaporative resistance
- 24% more predicted heat loss

Nomex® cools more effectively due to lower thermal and evaporative resistance
FABRIC HAND

Touch and Feel
Fabric Hand – The Touch and Feel

Fabric hand is the feeling of the garment on your skin

What Does Fabric “Hand” Mean?

- Senses perception when touching and feeling a fabric
- Common approach - rub fabric between fingers
- Large differences are often noticeable and at times visible, but individual preference can vary
- Fabric hand is arguably the most subjective and secondary to thermal comfort and garment fit in rating overall garment comfort
New Independent 3rd Party FR Fabric Hand Study

Leading textile institute on comfort conducts FR industry test

Test Methodology

- Conducted by French Institute for Textile and Clothing, based on international standards (ISO, AFNOR cert.)
- Trained panel of experts provide reliable, calibrated, and reproducible results
- Consumer perception results reported on a 1-10 scale
  - Softness, Smoothness, Drape, Supple
- Fabric hand can change after washing / wearing
  - Doesn’t always improve - Do a wear trial
- Wash FR garments before wearing the first time
New Independent 3rd Party FR Fabric Hand Study

The consensus of fabric hand experts

- Nomex® MHP was overall comfort winner: soft, smooth, supple, drape
- The superior soft touch and feel of Nomex® MHP remained unchanged after laundering

![Bar chart showing comparison of softest, smoothest, most drape, most supple fabric hand properties between Nomex® MHP, FR Modacrylic Blend, and 88/12 FR Treated Cotton. ](chart.png)
New Independent 3rd Party FR Fabric Hand Study – Impact of Laundering

Laundering can greatly impact the hand of a FR fabric

- After just 5 launderings, fabric properties can change dramatically
- The hand of Nomex® IIIA improved significantly in softness and smoothness, while FR treated cotton declined significantly

![Bar chart showing the impact of laundering on fabric properties]

- Nomex® IIIA
- 88/12 FR Treated Cotton

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GARMENT DESIGN
FR Garment Design / Fit Can Impact Your Comfort

Garment fit needs to be monitored over time

Key Considerations
- Garment fit will vary slightly between manufacturers
- Personalized sizing and wear trial is important
- How does the garment fit after laundering several times?
  - Watch for physique changes over time

Impact of Improper Garment Fit
- Increases contact points between the garment and skin
- Garment may create unnecessary compression on body
- Garment may feel more clingy / clammy / sticky
- Tighter garments will also provide less FR protection

Nomex® Image: http://www.lakeland.com/
Laundry shrinkage can impact garment fit, comfort, and appearance.

Improper garment fit may lead to incorrectly wearing and limited movement ability, potentially increasing a wearer’s risk.

Higher levels of shrinkage can lead to a frequent FR re-purchasing, increasing the overall cost of an FR program.
The Importance of Laundry Shrinkage

Laundry shrinkage can vary depending on fabric type

- Nomex® IIIA and MHP shrink less than the majority of the competition, even after 100 launderings.
- Garments with higher levels of shrinkage may lead to increased levels of discomfort and replacement cost.

![Chart showing laundry shrinkage comparison between Nomex® IIIA, MHP, FR Modacrylic Blend, and 88/12 FR Treated Cotton after 25 and 100 launderings.](chart.png)
Summarizing Comfort – Key Considerations

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

- 3 Pillars of comfort: thermal comfort / moisture management, fabric hand, garment fit / design
- Higher air permeability increases moisture movement, leading to feeling cool and dry with a lower likelihood of heat stress
- Lightweight fabrics have more impact than the type of fiber on keeping wearers cool and comfortable
- Moisture management is a key factor in feeling cool and dry
  - Wick and dry quickly
- Fabrics which absorb more moisture will take longer to dry
- Fabric touch & feel can change after laundering
- Improper garment fit and laundry shrinkage can lead to discomfort and re-purchasing costs
- Poor performance in any one comfort attribute can make a garment undesirable
The Sure Bet Is A Wear Trial

No risk wear trial, so you can decide for yourself

- Contact DuPont to discuss a free garment wear trial with one of our trademark brand licensee partners
- Personalized garment sizing and trial for your worksite
- Experienced field wear testing sales and technical professionals
- Lab testing can only say so much, you be the judge
Thank You for Attending!

For additional questions, please visit www.nomex.com

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