THE 3 SECOND MYTH

FR Compliance vs Protection
AGENDA

- Industrial fires and standards
- Why the focus on “flash fires”
- Where did the 3 second duration come from
- How FR fabrics work
- Why exposure duration matters
- Why exposure intensity matters
- Testing your FR garments
WHAT YOU SHOULD KNOW ABOUT INDUSTRIAL FIRES AND STANDARDS
INDUSTRIAL FIRE AND STANDARD MISCONCEPTIONS

Industry misconceptions may influence FR clothing selection

The purpose of flame resistant clothing is to only protect workers from **Flash Fire Hazards**

All, or most, fire hazards:
- Are **short duration** (3 seconds or less)
- Have the **same intensity** (2 cal/cm²)

To simplify the implementation of an FR clothing program, **only need to stipulate NFPA 2112** compliant/certified garments or fabrics
WHAT ARE INDUSTRIAL FIRES?

Types and Sources of Industrial Fires

- Flash - Rapid Burning of Vapor Cloud
- Jet - Burning of Pressurized Fuel Supply
- Pool - Burning of Flammable Liquid Spill
- BLEVE - Explosion & Fireball from Catastrophic Failure of Contained Liquid

Fuel Sources

- Flammable Liquids
- Flammable Gases
- Combustible Dusts

- Can Ignite / Melt Typical Work Clothing
- Burn Unprotected Skin
WHAT ARE TYPICAL INDUSTRIAL “FIRES”?  

There are no “typical” industrial fires

- Three (3) Main Variables \((\text{Duration} \times \text{Intensity} = \text{Magnitude})\)
  - Duration (Exposure Time, seconds) - 1 sec to “Time to Escape”
  - Intensity (Heat Flux) - <1 to >7 cal/cm\(^2 \cdot s\)
  - Magnitude (Total Exposure Energy) - <1 to >20 cal/cm\(^2\)

- It is the employer’s responsibility to assess the hazard and identify appropriate FR clothing to protect the workers

- NFPA 2113 has been developed to assist in the workplace FR clothing assessment process
INDUSTRIAL FIRES

Recent Industrial Incidents

May 4, 2009
Veolia Environmental Services
West Carrollton, OH

Flammable Release from Waste Recycling Process to Atmosphere
2 Workers Seriously Injured
20 Residences Damaged

Routine Excavation
Gas Line Ruptured
Operator & Rig Engulfed
INDUSTRIAL FIRES

Recent Industrial Incidents – Refer to Chemical Safety Board

July 19, 2009
Citgo HF Plant – Surveillance Camera
Corpus Christi, TX
Vapor Cloud + Jet Fire

October 6, 2005
Formosa Plastics
Point Comfort, TX
Propylene Explosion
SAFETY AND HEALTH PROGRAM

1. Culture
   - Attitudes, Beliefs, Understanding

2. Engineering
   - Technical solutions to make equipment safer

3. Work Practices
   - Proper Tools
   - Proper Procedures

4. PPE
   - Personal Protective Equipment
     - Clothing
     - Eye Protection
     - Foot Protection
     - Head Protection
     - Hand Protection
     - Hearing Protection
     - Respiratory Protection

PPE is the last line of defense

Leadership & Expectations
Accountability & Consequences
Right Metrics
Right Organization & Structure

Thermal Hazards & Flame Resistant Apparel
Personal Protective Equipment for General Industry

(d)(1) The employer shall **assess the workplace to determine if hazards are present**, or are likely to be present, which necessitate the use of personal protective equipment (PPE). If such hazards are present, or likely to be present, the employer shall:

(i) **Select, and have each affected employee use, the types of PPE that will protect the affected employee from the hazards** identified in the hazard assessment;
GENERAL PPE REQUIREMENTS FOR EMPLOYER

OSHA 3151 – Personal Protective Equipment Guide

- Perform a Hazard Assessment of the Workplace
- Identify & Control Physical and Health Hazards
- Identify & Provide Appropriate PPE for Employees
  - OSHA 3151-12R 2003, “…select PPE that will provide a level of protection greater than the minimum required to protect employees from hazards”.
- Train Employees in Use & Care of PPE
- Maintain PPE – Must Replace Worn / Damaged
- Periodically Review / Update / Evaluate PPE
NFPA 2112: Standard on Flame Resistant Garments for Protection of Industrial Personnel Against Flash Fire

- Provides Minimum Requirements for FR Garments
  - Design
  - Construction
  - Evaluation
  - Certification
- Primarily for Manufacturers, not End-Users
- Required Tests (3rd Party Certified)
  - Instrumented Thermal Manikin
  - Vertical Flammability (New and 100x IL)
  - Heat Transfer Performance (HTP)
  - Thermal Shrinkage Resistance
  - Heat Resistance
  - Sewing Thread
CONSENSUS STANDARDS – SELECTION, CARE, & USE

**NFPA 2113:** Standard on Selection, Care, Use, and Maintenance of Flame Resistant Garments for Protection of Industrial Personnel Against Flash Fire

- OSHA Recognized Tool for 29 CFR 1910.132
- Perform Fire / Exposure Hazard Assessment
- Primarily for End-Users
- Protective Clothing Selection
  - Meet Minimum NFPA 2112 Specifications
  - Meet Required Protection Identified in Hazard Assessment
- Flame Resistant Workwear Fit & Coverage
- Wearing / Training Information
- Care & Maintenance Information
- Neck, Face, Head, Hand & Foot Coverings PPE
INDUSTRY FOCUSES ON “FLASH FIRES”......WHY?
WHAT IS A FLASH FIRE?

Flash Fire: A non-explosive combustion of a vapor cloud from a release of flammable material into the open air

Its duration, intensity, and magnitude depend on many factors

- Flammable gas generation rate (discharge rate)
- Total vapor cloud mass released (prior to ignition)
- Dispersion and turbulence (dilution and mixing with air)
- Flammability properties (upper & lower flammability limits)
- Degree of congestion & confinement (flame propagation speed, overpressure)
- Weather (wind speed, atmospheric conditions)
- Thermo-chemical characteristics of the vapor (heat of combustion, heat release rate)
WHY FOCUS ON FLASH FIRE?

Common industry term when standards developed

HISTORICAL REFERENCE

“Flash Fire” was a common industry term used for fire events when the NFPA & CGSB standards were first developed in 2000.

NFPA 2112  
NFPA 2113  
CGSB 155.20
WHY FOCUS ON FLASH FIRE?

NFPA 2112 and 2113 standard evolution

NFPA 2112 & 2113 have been moving towards recognizing all fire/thermal hazards not just flash fires

The wording in the standards purpose statement has added the term “short duration thermal exposure”

NFPA 2112 – 2012, 1.2.1* This standard shall provide minimum requirements for the design, construction, evaluation, and certification of flame-resistant garments for use by industrial personnel, with the intent of not contributing to the burn injury of the wearer … resulting from short-duration thermal exposures or accidental exposure to flash fires

NFPA 2113 – 2012, 1.1.1* This standard shall specify the minimum selection, care, use, and maintenance requirements for flame-resistant garments for use in areas at risk from flash fires or short-duration flame exposure by industrial personnel that are complaint with NFPA 2112.
THE ORIGIN OF 3 SECONDS
THE “3 SECOND” MISCONCEPTION

Why the industry thinks workers only need protection for 3 seconds?

- Early editions of NFPA 2113 described a flash fire as typically lasting 3 seconds in the appendix, **this has since been removed**

  - The OSHA 2010 memo to the Oil & Gas market indicated **flash fires can last up to 5 seconds**, exceeding the NFPA 2112 minimum standard.

- NFPA 2112 stipulates a 3 second, 2 cal/cm²s exposure using Test Method ASTM F 1930 for the **minimum** FR performance requirement

- Canadian Standard CGSB 155.20 (**2000 Edition**) states “**typically** 3 seconds or less” in its definition of a flash fire.
AREN’T ALL “FLASH” FIRES 3 SECONDS OR LESS?

Actually, no (and flash fire is not defined this way per NFPA)

The duration of any fire depends on the basics of the fire “equation”

- Quantity of fuel
- Oxygen availability
- Ignition temperature / Heat
- Reaction rate of combustion
  - Vapor dispersion/air mixing
  - The chemical reaction rate of the fuel (how fast it burns)

3.3.13* Flash Fire. A fire that spreads by means of a flame front rapidly through a diffuse fuel, such as dust, gas, or the vapor of an ignitable liquid, without the production of damaging pressure.
WHERE DID 3 SECONDS ORIGINATE?

Testing helicopter pilot flight suit materials for the military

1970’s - U.S. military ran a test to determine **total heat exposure** received by pilots escaping through the burning fuel of a helicopter crash

- Sensored and clothed manikin was pulled through burning pool fire of JP4 jet fuel

**Conclusion:** Total exposure of 6 cal/cm² represented **this specific hazard**

- No reference to 3 second duration
DuPont developed the manikin test to provide a repeatable test method that can easily and safely generate 6 cal/cm² total energy exposure needed by the military.

- Propane is a common, easily controlled fuel
- Propane can be adjusted to have a heat flux of 2 cal/cm²/sec
- 2 cal/cm²/sec heat flux for 3 seconds equals the 6 cal/cm² total exposure energy desired

Industry picked up on the 6 cal/cm² exposure energy

In essence, the manikin test established the 3 seconds
In the graph of these tests, burn times reached more than **15 sec.**

- Highlights the need to understand the hazard

The Fire Protection Engineering handbook has vapor cloud fire models

- Various flammable gasses
- These models predict flame duration

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1. Consider Research Conducted by the U.S. Department of Energy

“FLASH” FIRE INTENSITY MISCONCEPTION

All “Flash” fires are 2 cal/cm²s -> the intensity used in the NFPA 2112 thermal manikin test

Experimental data\(^1,3\) has shown potential for significantly higher values

DOE China Lake Experiments with Liquid Natural Gas Vapor Cloud Fires
- Measured peak heat flux values of over \(7.2 \text{ cal/cm}^2\text{s}\)
- Over a short duration (\(~ 5 \text{ sec}\))
- 28 m\(^3\) spills occurring in \(~1.6 \text{ min}\)

DOE China Lake Experiments with Liquid Propane Gas Vapor Cloud Fires
- Measured an average heat flux value of \(3.3 \text{ cal/cm}^2\text{s}\)
- Over a sustained period of time (\(15 \text{ sec}\))
- 5.8 m\(^3\) (1,530 gal) release

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HOW FLAME-RESISTANT FABRICS WORK

ALL FR IS NOT CREATED EQUAL
PURPOSE OF FLAME RESISTANT (FR) FABRICS

Reduce Burn Injury and Increase Chance of Survival

- Does Not Ignite and Continue to Burn
- Does Not Melt and Drip
- Maintains a Barrier
- Insulates the Wearer from Heat
- Resists Breaking Open
- Provides Valuable Escape Time

However, Burn Injuries Can Occur In Spite Of The Use of FR Clothing
TYPES OF FLAME RESISTANT (FR) FABRICS

Not All FR Is Made The Same

Inherent \((e.g.\ Nomex^\text{®},\ Kevlar^\text{®},\ PBI^\text{®},\ Kermel^\text{®},\ etc)\)
- FR performance is present in the DNA / chemistry of the fiber at the time of production
- Fiber molecular structure does not support combustion

Inherent Blends \((e.g.\ Nomex^\text{®}\ MHP,\ Tecasafe^\text{®}\ Plus,\ Spentex^\text{®},\ etc)\)
- Synergistic effect of FR and non-FR fibers
- No chemical treatments
- Blend dependent, may produce gas to inhibit combustion

Chemically Treated \((e.g.\ Ultrasoft^\text{®},\ Proban^\text{®},\ Dale\ Antiflame^\text{®},\ etc)\)
- After fabric is manufactured, it is treated with flame retardant chemicals to make it flame resistant (FR)
- Produces char/gases to inhibit combustion
NOMEX® - PROVEN PERFORMANCE

Hazards are Unpredictable. Nomex® is Not.

- **Heritage**: *40 years* of proven performance
- **Inherent** flame-resistant protection
- Protection from *heat & flame, arc, and welding*
- **Lightweight** single layer protection
- Market leading **durability** & low life cycle cost
- Rigorous product testing and **stewardship**
- Protection **beyond the standards** (Exceeds NFPA 2112)
- Exceptional **fit, appearance**, and **color retention**

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40+ years of the best thermal protection

**Inherent (Not Treated)** lightweight protection

**Superior Durability** = more cost-effective

**Peace of Mind** because of rigorous testing
WHY DOES EXPOSURE DURATION MATTER?
DURATION IS A VARIABLE OF TOTAL EXPOSURE

You can generate total exposure by changing duration

<table>
<thead>
<tr>
<th>Duration (sec)</th>
<th>Heat Flux / Intensity (cal/cm²s)</th>
<th>Total Exposure (cal/cm²)</th>
</tr>
</thead>
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<td>2.5</td>
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<td>8.0</td>
</tr>
</tbody>
</table>

Total Exposure Energy = Duration X Intensity

7 oz/sy FR Treated Cotton typically “activates” at approx. 6.8 cal/cm²
DURATION & INTENSITY IMPACT PREDICTED BODY BURN INJURY %

You can generate total exposure by changing duration or intensity

NOMEX® IIIA - 6 oz/yd²
3 seconds @ 2.02 cal/cm²s
Total Exposure: 6.06 cal/cm²
16.4% Predicted Body Burn Injury

88/12 FR Treated Cotton / Nylon – 7 oz/yd²
3 seconds @ 2.02 cal/cm²s
Total Exposure: 6.06 cal/cm²
11.5% Predicted Body Burn Injury
You can generate total exposure by changing duration or intensity.

**DuPont™ Thermo-Man® System**

3 Second Exposure Comparison

Nomex® IIIA 6.0 oz/yd²

and

88/12 FRT Cotton / Nylon 7.0 oz/yd²

Exposure: 6.06 cal/cm² [Time: 3 s  Heat Flux: 2.02 cal/cm²s]

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EXAMPLE

- Total Exposure Energy: 6 cal/cm²
- Testing conditions: (ASTM F1930)
  - Intensity: 2 cal/cm²/sec
  - Duration: 3 seconds
- Body burns vary by 4%
- Regardless of fabric choice, the probability of survival is 99% +

At NFPA 2112 conditions – Less variation in FR fabric performance

Ages: 30-39
DURATION AND PREDICTED BODY BURN INJURY %

You can generate total exposure by changing duration

NOMEX® IIIA - 6 oz/yd²
4 seconds @ 2.06 cal/cm²s
Total Exposure: 8.24 cal/cm²
43.4% Predicted Body Burn Injury

88/12 FR Treated Cotton / Nylon – 7 oz/yd²
4 seconds @ 2.06 cal/cm²s
Total Exposure: 8.24 cal/cm²
77.9% Predicted Body Burn Injury
DURATION AND PREDICTED BODY BURN INJURY %

You can generate total exposure by changing duration

DuPont™ Thermo-Man® System
4 Second Exposure Comparison

Nomex® IIIA 6.0 oz/yd²
and
88/12 FRT Cotton / Nylon 7.0 oz/yd²

Exposure: 8.24 cal/cm² [Time: 4 s  Heat Flux: 2.06 cal/cm²s]
PREDICTED BODY BURN INJURY % AT INCREASED DURATION

NOMEX® IIIA, 6 oz/yd²

- 4 seconds @ 2.06 cal/cm²s
- Total Exposure: 8.24 cal/cm²
- Predicted Burn Injury: 43.4%

88/12 FR Treated Cotton / Nylon, 7 oz/yd²

- 4 seconds @ 2.06 cal/cm²s
- Total Exposure: 8.24 cal/cm²
- Predicted Burn Injury: 77.9%
EXAMPLE

Total Exposure Energy: 8 cal/cm²

Testing conditions:
- Intensity: 2 cal/cm²s
- Duration: 4 seconds

Body burns vary by 35%

Survivability greatly depends on the fabric

In the lighter weight garment made of Nomex®, your chance of surviving more than doubles

Ages: 30-39

Impact of Hazard & Apparel Selection on Survivability

35% variance
TOTAL HEAT EXPOSURE FROM INDUSTRIAL FIRES CAN BE……

Real world fires (flash fire or other)

- **6 cal/cm² Exposure** (per NFPA 2112)
  - Body burns: 12 – 16%
  - Survivability: 99% + Regardless of FR fabric type

- **8 cal/cm² Exposure**
  - Body burns: 43 – 78%
  - Survivability: 42 – 91% Depends on FR fabric type

NFPA 2112 Minimum Performance Level
(50% Total Predicted Body Burn @ 6 cal/cm²)
Only A Starting Point For Protection
WHY DOES EXPOSURE INTENSITY MATTER?
### INTENSITY IS A VARIABLE OF TOTAL EXPOSURE

You can generate total exposure by changing duration or intensity

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<td>2.67</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Total Exposure Energy = Duration X Intensity

7 oz/sy FR Treated Cotton typically “activates” at approx. 6.8 cal/cm²
INTENSITY AND PREDICTED BODY BURN INJURY %

FR Treated Cotton at 3 seconds with varying intensity

88/12 FR Treated Cotton / Nylon – 7 oz/yd²
3 seconds @ 2.02 cal/cm²s
Total Exposure: 6.06 cal/cm²
11.5% Predicted Body Burn Injury

88/12 FR Treated Cotton / Nylon – 7 oz/yd²
3 seconds @ 2.36 cal/cm²s
Total Exposure: 7.08 cal/cm²
83.6% Predicted Body Burn Injury

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INTENSITY AND PREDICTED BODY BURN INJURY %

FR Treated Cotton at 3 seconds with varying intensity

DuPont™ Thermo-Man® System

3 Second Exposure Comparison

88/12 FRT Cotton / Nylon 7.0 oz/yd²

at

Heat Flux 2.02 & 2.36 cal/cm²s

(Exposure Energy: 6.06 cal/cm² & 7.08 cal/cm²)

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INTENSITY AND PREDICTED BODY BURN INJURY %

NOMEX® IIIA at 3 seconds with varying intensity

NOMEX® IIIA - 6 oz/yd²
3 seconds @ 2.02 cal/cm²s
Total Exposure: 6.06 cal/cm²
16.4% Predicted Body Burn Injury

NOMEX® IIIA - 6 oz/yd²
3 seconds @ 2.36 cal/cm²s
Total Exposure: 7.08 cal/cm²
43.4% Predicted Body Burn Injury

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INTENSITY AND PREDICTED BODY BURN INJURY %

NOMEX® IIIA at 3 seconds with varying intensity

DuPont™ Thermo-Man® System

3 Second Exposure Comparison

Nomex® IIIA 6.0 oz/yd²

at

Heat Flux 2.02 & 2.36 cal/cm²s

(Exposure Energy: 6.06 cal/cm² & 7.08 cal/cm²)

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INTENSITY AND PREDICTED BODY BURN INJURY %

You can generate total exposure by changing intensity

NOMEX® IIIA - 6 oz/yd²
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INTENSITY AND PREDICTED BODY BURN INJURY %

You can generate total exposure by changing intensity

DuPont™ Thermo-Man® System
December 12, 2012

Nomex® IIIA 6.0 oz/yd²
&
88/12 FRT Cotton / Nylon 7.0 oz/yd²

Exposure: 7.08 cal/cm² [Time: 3 s  Heat Flux: 2.36 cal/cm²s]

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PREDICTED BODY BURN INJURY % AT INCREASED INTENSITY

**NOMEX® IIIA, 6 oz/yd²**
- 3 seconds @ 2.36 cal/cm²s
- Total Exposure: 7.08 cal/cm²
- Predicted Burn Injury: 43.4%

**88/12 FR Treated Cotton / Nylon, 7 oz/yd²**
- 3 seconds @ 2.36 cal/cm²s
- Total Exposure: 7.08 cal/cm²
- Predicted Burn Injury: 83.6%
EXAMPLE

Total Exposure Energy: 7.08 cal/cm²

Testing conditions:
- Intensity: 2.36 cal/cm²sec
- Duration: 3 seconds

Body burns vary by 41%

In the lighter weight garment made of Nomex® your chance or surviving nearly triples

Ages: 30-39
KEY DURATION & INTENSITY TAKEAWAYS

Industrial fires do not have a consistent duration and intensity

- Using 3 seconds as a “general rule of thumb” is not an accurate way to establish the level of protection workers need.

- The 3 seconds concept is rooted in a test method developed for the military; and the focus of their test method was not seconds but “total energy exposure” (6 cal/cm²).

- As thermal exposure increases, the type of FR fabric plays an increasingly important role in survivability.

- The goal is to assess the hazard and identify appropriate FR clothing to meet that hazard – refer to NFPA 2113.
DUPONT THERMO-MAN®

*How you know you picked the right FR clothing*
WHY DO WE USE DUPONT™ THERMO-MAN®?

When it comes to fire protection, companies need to be prepared for the worst-case scenario, not the best.

- A UL manikin testing facility certified to NFPA 2112
- Used for NFPA 2113 clothing performance assessments
- Enables a direct comparison of materials under the same conditions, live
- Simulate conditions and use garment ensembles that reflect a customer's hazards
- It enables you to test the performance limits of the materials you use for FR protection

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National Fire Protection Association
The authority on fire, electrical, and building safety

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HOW THERMO-MAN® HELPS YOU WITH NFPA 2113?

Clothing systems designed to address your hazards

- Visit our Thermo-Man® facility in Richmond, VA
- Attend or host a Thermo-Man® event at your facility or conference with DuPont’s one of a kind traveling unit
- You can use the video and data from the testing to educate your employees on using proper PPE and how it responds.
- We’re happy to help you with manikin testing to assess how well your clothing systems address your hazards or range of potential hazards.
CONCLUSIONS

NFPA 2112 compliance may not mean adequate protection

- Fires are unpredictable – duration and intensity matter
- Thinking all fires last 3 seconds is a misconception
- Thinking all fire intensities are equal (2 cal/cm²s) is a misconception
- NFPA 2112 garment compliance/certification does not mean NFPA 2113 compliance
- Not all FR is created equal - choose FR fabrics/garments based on your specific hazards
- Nomex® protects over a wide range of fire and hazard scenarios
  - Proven performance
  - Testing beyond the minimum standards
  - Inherent protection – no “activation” risk
  - Durable and lightweight
Thank You for Attending!

For additional questions, please visit www.nomex.com
“This information corresponds to our current knowledge on the subject and may be subject to revision as new knowledge becomes available. It is your responsibility to investigate other sources of information on this issue that more appropriately addresses your product and its intended use. DuPont Thermo-Man® thermal protection system is based on ASTM Standard F 1930-99 which applies to flame resistant clothing. These conditions may not by typical of the conditions encountered in actual situations. The results of these tests are only predictions of body burn injury under these specific laboratory conditions. These results do not duplicate or represent garment or fabric performance under actual flash fire conditions. The user is solely responsible for any interpretations of the test data provided by DuPont, and included in this material, and for all conclusions and implications made concerning the relationship between mannequin test data and real life burn injury protection. 

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