Introduction

- History
- Uniform types
- Flame Hazards
- Protection & Trade-offs
- FR Requirements
- Test Methods
• Flame Resistant (FR) uniforms originally only for Mounted Soldiers
  – Aviators & Aircrew
    • Vietnam era – non-FR cotton flight suits replaced by FR cotton in the early 1960’s
    • Producer dyed aramid flight suits adopted in late 1960’s & early 1970s, still in use
    • Printed aramid for 2 piece aircrew uniforms adopted in the late 1980s, still in use
  – Combat vehicle crews
    • Adopted producer dyed aramid coveralls in the late 1970s
    • Camouflage-printed blend fabric replaced solid aramid ~ 2005, still in use

• FR uniforms for Dismounted Soldiers
  – Developed due to increase in burn injuries in Iraq/Afghanistan
  – Move to FR blends in order to balance comfort, durability & FR protection
  – FR Army Combat Uniform fielded in 2007
    • Ripstop fabric, FR cellulose/aramid/nylon blend
  – Army Combat Shirt fielded in 2007
    • Multiple knit fabrics, high FR cellulose content
  – Army Combat Pant fielded in 2012
    • Twill fabric, FR cellulose/aramid/nylon blend
    • Integrated, removable kneepads
FR Army Combat Uniform (FRACU)

- Similar design to regular Army Combat Uniform
- Flame resistant fabric
  - FR properties will not wash out
  - Improved version of original 2007 fabric
    - Stronger yarns
    - Tear resistant finish
    - Cellulose/Aramid/Nylon Blend
  - Better air permeability than regular ACU
    - Air permeability is a measure of breathability
- Issued to deploying Soldiers only

Army Combat Pant (ACP)

- Designed to be more durable than FRACU trouser
  - Flame resistant
  - Design changes
    - FR stretch fabric in crotch gusset
    - Small pleats in thigh seam
  - Abrasion resistant seat
  - Integrated, adjustable knee pads
  - Twill fabric – cellulose/aramid/nylon blend
- Intended to be worn with Army Combat Shirt
- Issued to deploying Soldiers only
Army Combat Shirt (ACS)

- Alternate Designs
  - Type I designed to be worn with IOTV body armor
  - Type II to reflect dimensions of plate carrier body armor
    - Wider side panels
    - Front & back yoke
    - Front zipper

- Transitioning to Type II design
- Issued to deploying Soldiers only

Army Aircrew Combat Uniform (A2CU)

- Two-piece FR flight suit designed for operational effectiveness, fit, suitability and durability
- Meets Air Warrior requirements
  - Extraction strap
  - Zipper pocket closures
  - Minimal snag hazards
- Aramid fabric with static-dissipative fiber
- Camouflage print meets Infrared (IR) requirements
- Issued to all rotary aircraft crewmembers
Improved Combat Vehicle Coverall (ICVC)

- One piece FR coverall for combat vehicle crews
- Meets Mounted Warrior requirements
  - Extraction strap
  - Zipper pocket closures
  - Minimal snag hazards
- Aramid fabric with static-dissipative fiber
- Camouflage print meets IR requirements
- Issued to combat vehicle crewmembers

Fire Resistant Environmental Ensemble (FREE)

A multi-layered, versatile, flame resistant, insulating system for combat vehicle crews and aviation crews that is adaptable to varying operational and environmental conditions.
Military Flame Hazards

- IEDs, Explosives & Electric Arc
  - Very short duration
  - Very high temperature
  - Include blast overpressure & shrapnel
- Flash Fire
  - 1.5 – 3 second duration
  - Moderate heat flux/temperature
- Fuel Fire/Pool Fire/Vehicle Fire
  - Longer duration
  - Moderate heat flux/temperature
- Different threats for different groups
- Initial threat versus secondary fire

FR Protection

- FR uniforms protect in 2 ways
  - Provide insulation protection from the initial incident
  - Self-extinguish to prevent additional injury from uniform igniting and continuing to burn
- Data shows that FR uniforms do protect
  - Burn injuries significantly reduced since introduction in 2007-2008
  - Reduction in frequency and severity
  - Injuries continue when FR items not worn
    - Hands when FR gloves not worn
    - Face and neck when FR balaclava not worn
Trade-offs

Protection

• More clothing layers
• Inherent FR Fibers
• Increase clothing bulk and thickness
• Extra cooling devices increase load

Performance

• Fewer clothing layers
• Comfort fibers & finishes
• Decrease clothing bulk and thickness
• No extras, decrease load

Solutions Depend on User Needs, Tasks & Environment

Other Types of Protection

• More protection trade-offs beyond FR protection & Soldier performance
  – Concealment protection
    • Camouflage prints
    • Infra-red signature
    • Thermal signature
  – Vector protection
    • Permethrin finishes
    • New chemistries
  – Impact protection
  – Environmental protection
Other Performance Factors

- Laboratory tests to measure performance
  - Durability tests
    - Abrasion resistance
    - Fabric strength
  - Comfort tests
    - Air Permeability
    - Moisture Vapor Transmission
    - Wicking
  - Colorfastness tests
    - Light
    - Laundering
    - Crocking (rubbing)

FR Testing Requirements

Duty Uniforms and Outerwear

- Fabric
  - Vertical Flame (ASTM D6413)
    - Char length maximum 4.5 - 5.5 inches
    - After flame
    - After glow
    - No melting and dripping
  - Heat Transfer Performance (NFPA 2112)
    - Spaced minimum 10
    - Contact minimum 7
  - Thermal Shrinkage Resistance (NFPA 2112)
    - Maximum 10%
    - Exceptions for outerwear
• Duty Uniforms
  – ASTM F1930, 4 second exposure
    • Single layer garments tested with 100% cotton t-shirt & briefs
    • Record predicted burn injury (PBI) percentage
      – Maximum 32% 2nd & 3rd degree PBI, including the head
      – Maximum 25% 2nd & 3rd degree PBI, excluding the head
    • Observe and comment (qualitative):
      – After flame
      – Thermal shrinkage
      – Condition of garment(s) after test
      – Melting and dripping
  • Multi-layer ensembles expected to have lower predicted burn injury than single layer garments

Test Methods - Materials

ASTM D 6413 – Vertical Flame Test

Heat Transfer Performance
ASTM F2700
Test Methods – Full Scale

ASTM F1930

Pyro Hand and Pyro Head Development

Figure 1. PyroMan Maskin
Questions?

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