U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – SOLDIER CENTER

Overview of Developmental Wool Blend Fabrics

Carole Winterhalter
Materials Science and Engineering Branch
Soldier Protection & Survivability Directorate

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Presentation Outline

- Combat Uniform Fabrics
- Interesting Wool Properties
- Long Staple Versus Short Staple Fiber
- Wool Shrink Resist Treatments
- Wool Blend Thermal Fabrics
- Field Study Results
- Glove Fabrics
- Thermal Manikin Testing
Operations in Iraq and Afghanistan demonstrated efficacy of FR protection but durability and colorfastness need improvement. Additional desired performance enhancements include insect resistance, improved camouflage, liquid chemical agent protection – all integrated into one combat uniform fabric with Berry Amendment compliant fiber.
Flame Resistance Performance of Wool
• Wool is flammable, but does not melt or drip
• Some wool blends meet ASTM 6413 without an FR treatment
• Wool is environmentally friendly. Grass is manufactured into fiber and meat; both wool and animal are 100% biodegradable; sustainable
• Dyeable using commercial dyestuffs

Wool Blend Fabric Development Efforts
• UCP camouflage print recipe meets colorfastness and IR requirements, recently reformulated for OCP
• Prototype woven and knit fabrics
• US Patent 8,475,919 B2; Wool & Aramid Blends for Multifunctional Protective Clothing
• Berry compliant
Developmental Wool Blend Fabrics

Objectives:
• Decrease shrinkage
• Improve strength
• Investigate wool fiber fineness
• Reduce cost
• Determine if increased military demand can be supported for new applications of thermal underwear and combat uniforms

Statistics
• 25 million pounds of wool produced annually in US
• 15 – 20% goes to the US military
• Current US military applications: dress clothing, blankets, socks
Optimization of Long Staple Wool/Aramid Blend Fabrics

• Improve fabric strength by utilizing long staple fiber and yarn spinning methods
  ➢ DuPont partner – long staple aramid blends
  ➢ Gaston College, Kraemer partners – carding and blending

• Optimize wool and aramid fiber blend ratio
  ➢ ITG partner

• Balance wool micron with fabric hand, cost/supply, and strength
• Balance wool and aramid blend ratio with camouflage performance
• Prototype yarns demonstrate 20% strength increase over short staple
• DuPont producing long staple Nomex
Shrink Resist Treatments for Wool Fabrics, SBIR Phase I and II

• Sheep Venture Company, Englewood, Colorado

• Investigated traditional and novel environmentally friendly methods to shrink resist treat wool top
  o Chlorine Hercosett (“Superwash”)
  o Potassium Permonosulfate (Oxone)
  o Novel enzyme formulation (Infoscitex, Waltham, MA)
  o Wool Mercerization

• Superwash commercialized at Charguers, Jamestown, SC; demand has exceeded original business projections

• Two mercerization trials conducted under SBIR; additional trials required; if successful mercerization has potential to solve domestic micron supply issues
Wool Blend Thermal Fabrics

Table of Developed Products

<table>
<thead>
<tr>
<th>Flame Resistance Performance</th>
<th>Garment Type</th>
<th>Fiber Blend</th>
<th>Performance Goals</th>
<th>Coloration</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMND¹</td>
<td>Lightweight Long Underwear; Top and Bottom</td>
<td>100% Wool</td>
<td>GL/PD-06-01 and GL/PD-06-14</td>
<td>Desert Sand 503</td>
<td>95 sets</td>
</tr>
<tr>
<td>NMND²</td>
<td>Midweight Long Underwear; Top and Bottom</td>
<td>Wool Blend⁴</td>
<td>GL/PD-06-02 and GL/PD-06-15</td>
<td>Desert Sand 503</td>
<td>95 sets</td>
</tr>
<tr>
<td>NMND³</td>
<td>WRT¹ Jacket and Trouser</td>
<td>90% Wool 10% Nylon</td>
<td>GL/PD-06-05 and GL/PD-06-16</td>
<td>OCP⁵</td>
<td>45 sets</td>
</tr>
<tr>
<td>NMND¹</td>
<td>Socks</td>
<td>Wool Blend⁴</td>
<td>Dam Tough Style 14033</td>
<td>Desert Sand 503</td>
<td>390 pairs</td>
</tr>
<tr>
<td>Flame Resistant²</td>
<td>Lightweight Long Underwear; Top and Bottom</td>
<td>Wool and FR Rayon</td>
<td>GL/PD-06-01 and GL/PD-06-14</td>
<td>Desert Sand 503</td>
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</tr>
</tbody>
</table>

¹ No Melt No Drip
² ASTM 6413, no greater than 4.5 in char length
³ Water Repellent Treated
⁴ May include stretch fiber such as spandex/elastane
⁵ Operation Enduring Freedom Camouflage Pattern
⁶ Short Staple Wool
Wool Blend Thermal Fabrics

**Next-to-skin Layer**

- 18.5 micron wool
  - 4.5 osy
- 19.5 micron wool
  - 4.6 osy
- 19.5 micron wool
  - 4.6 osy
- 53% wool 47% rayon
  - 4.5 osy
- 100 bottoms

**Mid-Weight Layer**

- PDR
  - 88% wool 12% nylon
  - 7 osy
- 19.5 micron wool
  - plated with spandex
- 100 bottoms

**Additional Items**

- Cushion Sole Socks
  - 390 pairs
- 100 pairs to Marine Corps
Field Study Results

Comfort study: 18.5 versus 19.5 micron wool next-to-skin tops – Soldiers found no difference in comfort.

Germany Cold Weather Undergarment and Sock Study – Soldiers preferred wool and wool blend products over legacy.

SOF Sock Study – participants preferred the wool blend candidate sock. NCTRF thermal foot study found this product had greatest toe warmth over legacy and commercial socks. Initially developed by Wigwam manufactured by Crescent Sock Company.
Objectives: Develop gloves with improved durability and comfort over legacy without increasing life cycle cost of the Army Combat Glove

- Improved comfort in all environments
- Same or better fit
- Same or better dexterity

- Legacy fabric **96% Kevlar, 4% anti-stat fiber**
- Developed three wool blend simplex and interlock knit fabrics
- Best candidate **49% Kevlar, 47% wool, 4% anti-stat fiber**
- Met FR, cut and burst requirements
- $10 less per yard, almost twice as cut resistant, twice as strong and now dyeable (legacy made from producer colored Kevlar).
- Made with touch screen conductive leather
- Produced 150 pairs of each of three fabrics; available for LUE
Permethrin Treatment of Wool Blend Fabrics

- SBIR and congressionally funded
- ITG (Burlington Industries)
- Determine most appropriate formulation and method to treat wool/aramid blend camouflage printed materials
- Develop recipe and treat fabric and fabricate garments
- Treat garments made from same base fabric with legacy treatment
- Untreated/control garments, treated fabric and garments tested in LUE, Germany
Wool/Nomex Permethrin Treated Combat Uniform
Wool Blend Fabric Results

Wool/Nomex/Kevlar/P140:

- Camouflage print reformulated to a two step process to dye both wool and Nomex. Visual and NIR look promising. Additional trials required.
- LUE conducted in Germany 2016; soldiers preferred the wool blend over legacy fabrics due to improved comfort.
- Wool/Nomex/Kevlar/P140 – solid shade; currently under evaluation in joint Air Force/Navy Coverall Product Improvement Program; manikin test results look promising.
Summary of Thermal Manikin Burn Studies of Various Fabrics and Clothing Systems

- ASTM 1930 conducted at NCSU under contract

- Outer layer provides flame resistance; first line of defense

- Underlayers provide insulation, protection time increases with each added layer

- Long underwear provides greater coverage and protection than t-shirt and briefs

- One piece system better than two-piece

- Heavier weight fabrics provide more protection than lighter weight even made from same fiber blend

- Fully crystallized Nomex performs better than partially crystallized Nomex at a lower fabric weight
Thermal Manikin Overview

Instrumented Manikin

- Research tool
- ASTM 1930
- Size 42 Regular Male
- Results dependent on material, garment size and design
- 122 Sensors
- % Body burn, 2nd, 3rd degree
- Thermal Flux - 2.0 cal/cm2sec
- Exposure - 2.5 to 10 sec
- Fire chamber- 8 propane torches
Example: Thermal Manikin Fire Testing of Nonwoven Nomex Coverall over BDU

- Nonwoven fabric
- Nomex IIIA blend
- Over BDU, t-shirt, and briefs
- Simple coverall construction
- Coverall quick don
- Low cost ($60)
- Disposable
- Limited wear life
- DuPont tested
- 4 sec exposure
- Provides protective char
- Underlayers intact
- Reduces body burn from 88 to 8%
- Field evaluated
- Coverall patent
Thank You!