Designing CB Garment Hoods to Improve Interface with M50 JSGPM Mask

DTRA CBD S&T Conference
30 November 2017

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DTRA Funded Research
Introduction

• Critical focus area of the Integrated Protective Fabric Systems Program (IPFS) is improving aerosol protection

• JSTO-CBD/NSRDEC/ECBC demonstrated capability to improve aerosol protection for CB ensembles by:
  • Inclusion of aerosol liner in material composites
  • Improved garment designs and closure areas, especially the interface between the hood and mask
  • Addition of a Second Skin on M50 Joint Service General Purpose Mask (JSGMP)

• All garment designs, component solutions and knowledge are transitioning to the UIPE Family of Systems (FoS) program
Presentation Topics

- Evaluating protective ensembles: Aerosol System Test (AST), Visual Outward Aerosol Leakage Test (VOALT)
- Performance of Baseline Hood
- 2014 IPFS garment hood design and results
- IPFS CB Lightweight Improved Thermal Ensemble (CBLITE 1) hood design and results
- Joint effort between NSRDEC and ECBC to improve the hood mask interface
- Future Studies: CBLITE 1AerO and M50 JSGPM Second Skin
Aerosol System Test

• Aerosol system testing (AST) is described in detail in “Test Operations Procedure (TOP) 10-2-022, Chemical Vapor and Aerosol System-level Testing of Chemical/Biological Protective Suits (December 2013)”.

• AST is performed according to the TOP at Research Triangle Institute (RTI) in Research Triangle Park, NC in a chamber using test participants.

Typical Test Conditions
• 28’ x 50’ chamber
• 10 mph wind speed
• 70°F / 50%RH
• ~170 mg/m³ aerosol concentration
Determination of Aerosol Deposition

Skin rinse

Sampling locations

Fluorometric analysis
Body Region Hazard Analysis (BRHA)

- BRHA is a model used to combine the deposition values obtained with the susceptibility of the different body regions to agent effects to yield a measure of protection provided by an ensemble.

- The deposition velocity (DV) values from the specific samples locations (shown on the previous slide) are combined into twenty-six (26) body regions, of which twenty-three (23) are used in the BRHA model.

- BRHA yields values for the overall systemic (nerve agent) minimum exposure dosage ($\text{MED}_{\text{SYS}}$) and the overall local (blister agent) minimum exposure dosage ($\text{MED}_{\text{HD}}$). A higher value for these two system measures indicates a higher level of protection.

- There is no pass/fail criteria at this time, performance is relative to a baseline
Visual Outward Aerosol Leakage Test (VOALT)

*Design Tool/Screening Test for AST*

- Conducted at Research Triangle Institute
- Quickly identify closure leakage as a means of improving garment design
- Theatrical fog injected into the hollow interior of a mannequin at very low pressure (typically ~ 0.05” H20)
- Holes through the mannequin’s “skin” allows the fog to flow to all areas under the garment.
- Fog escaping from leak paths in the garment are observed visually in real time.
- Hands-on “workshop” environment enables design changes to be rapidly made and immediately retested

![Diagram of VOALT setup]

- **Mixing chamber**
- **Fog machine**
- **Tube from chamber to injection point**
- **Injection point on mannequin’s leg**
- **Evaluating hood concept via VOALT**
Addressing Aerosol Protection within the IPFS Program

• Integrated Protective Fabric System (IPFS) program objectives include transitioning durable aerosol protective materials and garment design solutions to the UIPE FoS program

• Approaches include:
  
  • Dual garment systems (outer + undergarment) vs. single layer systems
  • One piece garments vs. two piece (top + bottom)
  • Improved closures and interfaces
  • Addition of aerosol liners to garment structure
IPFS Hood Design

Hood design elements leveraged from congressionally-funded, Laboratory for Engineered Human Protection Program (Philadelphia University)

Design Features:

- Attached hood
- Carbon cloth inner hood assembly
- Brim insert above lens area of mask
- Shaped garment hood that contours around features of mask
- Canister loops
IPFS and Aerosol Protection

- Determined that significant leakage exists at the hood/mask interface for the baseline and for all IPFS concepts - *This was a key driver especially for overall blister (MED_{HD}) protection performance*

- Hood/mask interface is crucial to aerosol protection for two reasons:
  - A large amount of aerosol penetrates through that interface
  - Ear/temple area more sensitive to agent toxicity than most of body

![Deposition velocity diagram](image)

"head"

Typical of all IPFS garments
Baseline Hood Aerosol Deposition

Hot Spots: Deposition at ear and neck regions is typical

Post-AST black light photos of two replicates
CB LITE 1 Hood Design

Minimize Thermal Burden, No Aerosol Liner

Design Features:

- Attached hood
- Use of stretch material for conformal fit
- Thick aramid rib knit finishes inner hood assembly
- Entry zipper at chest with drawcord and cordlock closure
CB LITE 1 and Aerosol Protection

• CB LITE 1, despite not having an aerosol protective liner, greatly reduced deposition in hood/mask interface area, Mustard protection determined by axillae (armpits) instead of ears

• Trade-off: Aerosol protection from nerve agents will be decreased if fabrics are too air permeable, mustard protection could still be determined by hood/mask design

• Including aerosol liners in material composites will likely put additional stress on closures, such as hood/mask interface
IPFS: Hood/Mask Interface Task

- A joint task funded by DTRA began in March of FY16 between NSRDEC, Battelle (NSRDEC subcontractor), ECBC and Priority Designs (ECBC subcontractor) to improve the hood/mask interface with the aid of a second skin attached to the M50 JSGPM

- Limitation: No permanent change to the M50 JSGPM

- Identified three contributing factors
  - Hood closures, when tensioned, effectively cause a gap at the concave regions of the M50 JSGPM (at temples)
  - Garment closure interferes with the continuity of the seal with M50 JSGPM
  - Traditional closures such as zippers and hook and loop offer no aerosol protection
Hood/Mask Interface Task: Design Process

• Conducted brainstorming session to generate novel designs

• Two design/build cycles for garment hood and second skin concepts
  • Aerosol lined materials utilized for all test configurations
  • Learned that transitions between molded features and textiles are problematic
  • Mask and garment developers worked closely together to ensure integrated solution

• Evaluated concepts via Human Factors Laboratory Evaluation and Visual Outward Aerosol Leakage Test (VOALT)

• Final AST included three novel hood designs, one M50 JSGPM second skin
M50 JSGPM Second Skin Design

Design Features

- Molded urethane material
- Locating features at top center and temples as well as ridge extending along chin
- Semi-rigid insert embedded in urethane to provide a solid surface for hood to tension against
- Interior wall forms seal with the mask
- Designed and fabricated by ECBC/subcontractor

Exterior view of M50 JSGPM Second Skin

Interior view of M50 JSGPM Second Skin
Hood Design #1: “Hoodie”

- Pull-over style shirt with no entry zipper
  - Enabled by the use of protective stretch material
- Interface is tensioned with elastic drawcord and cordlock which exits the exterior surface of the binding at chin
- Lightweight aerosol lined cover fabric (no carbon) used as binding/channel for drawcord at interface with second skin
  - When interface is tensioned, low bulk of material, no large folds/leak paths
- Hood is positioned behind locating features on the second skin
- No urethane features on the hood
Hood Design #2: Hybrid

- Pull-over style shirt with no entry zipper
  - Enabled by the use of protective stretch material
- Urethane molded feature on hood extending from temple to temple, across the top of visor, with locating feature on the hood
- Interface is tensioned on the lower portion of the hood with drawcord/cordlock which exits the exterior surface of the binding at chin
- Lightweight aerosol lined cover fabric (no carbon) used as binding/channel for drawcord at interface with second skin
  - When interface is tensioned, low bulk of material, no large folds/leak paths
- Hood is positioned behind locating features on the second skin
Hood Design #3: Urethane Features with Double Zipper

- Two entry zippers used to create a more torturous path for aerosol
- Urethane strips backing zipper
- Molded “button” feature to secure interface
- Urethane molded feature on hood around perimeter of interface
- Hood is positioned behind locating features on the second skin
Novel Hood/Mask Interface Results

- Results show dramatic improvements in protection for all novel interfaces that are statistically significant for both blister (MED\textsubscript{HD}) and nerve (MED\textsubscript{SYS})

Higher MED values indicate greater protection
Novel Hood/Mask Interface Results

- Best novel hood/mask design has 6 times more blister protection than baseline garment and 3 times more nerve protection.

- Best performing configuration is a “hoodie” concept with no neck closure used with second skin over M50 JSGPM.

No “hot spots” seen in temple region.
CBLITE with Aerosol Liner AND Improved Hood Mask Interface

“Hoodie” design with Mask Second Skin

Conducting Aerosol System Test on this latest configuration
Testing/reporting will be completed in January 2018

IPFS material composite, including aerosol liner
Conclusions

• Improving aerosol protection can not be accomplished without addressing the hood/mask interface

• Improvements in aerosol protection, both for mustard and for nerve agents, are possible when
  • utilizing aerosol protective materials
  • modifying the garment hood design
  • adding a second skin to the M50 JSGPM

• Close collaboration between garment and mask developers is critical to solving interface issues
Special Thanks To:

JSTO-CBD, DTRA
Dr. Charles Bass and
Mr. Salvatore Clementi

Questions from the Audience?