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HUMAN FACTORS EVALUATION AND FITTING SURVEY OF THE CHEMICAL BIOLOGICAL  
SUIT AND ASSOCIATED EQUIPMENT IN COMBINATION WITH THE  
COMBAT VEHICLE CREWMEMBER CLOTHING SYSTEM

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Richard S. Bruno

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| Combat Vehicle Crewmember Clothing                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Nomex                                                                                      | Uniforms                                    |
| Human Factors Evaluation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Clothing                                                                                   | Equipment                                   |
| Chemical Biological                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Coverall                                                                                   | Body Armor                                  |
| Gloves                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Face Mask                                                                                  | Balaclava                                   |
| Bib-Overall                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Jacket                                                                                     |                                             |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>This report describes a human factors evaluation of the proposed ground Combat Vehicle Crewmember Clothing System (CVCCS). The CVCCS is an integrated clothing system that will protect the crewmember from environmental, occupational, and imposed hazards. The US Army Natick Research and Development Command tasked the US Army Human Engineering Laboratory to evaluate body extraction, fit, sizing, and general compatibility of the CVCCS. There were a few minor problems which were easily corrected. Comments and recommendations concerning each component of the CVCCS are described. |                                                                                            |                                             |

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HUMAN FACTORS EVALUATION AND FITTING SURVEY OF THE CHEMICAL BIOLOGICAL  
SUIT AND ASSOCIATED EQUIPMENT IN COMBINATION WITH THE  
COMBAT VEHICLE CREWMEMBER CLOTHING SYSTEM

(CB Protective Suit Fitting and General Compatibility  
Report No. 3)

Richard S. Bruno

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COMBAT VEHICLE CREWMEMBER CLOTHING SYSTEM

INTRODUCTION

The mounting threat of Chemical-Biological (CB) warfare requires a reassessment of personnel protection. The current CB protective ensemble uses an activated charcoal-impregnated foam suit (overgarment) which was developed by the US Army Natick Research and Development Command (NARADCOM) to replace an undergarment-type liner. The CB overgarment is worn with foot-wear covers, butyl rubber gloves, protective mask and hood. It was designed to be used by ground troops, aircrew members, and armored vehicle crewmembers; both male and female.

NARADCOM tasked the US Army Human Engineering Laboratory (USAHEL), Aberdeen Proving Ground, MD, with the responsibility for conducting sizing, fitting, and compatibility evaluations to insure this universality of application; Project Number Q793035. The initial report in this series was USAHEL Technical Note 5-79 (1) in which the CB-protective suit was evaluated for fit while worn by 15 females in combination with infantry field clothing. A future report will give the results of an evaluation of the CB clothing when worn by aviators.

Presently, the US Army combat vehicle crewmembers use the Standard "A" Infantry uniform because the Standard "A" CVC uniform is not available. This report reviewed the CB suit and equipment in combination with the CVCCS, which was type classified Standard "A" in July of 1980.

OBJECTIVE

This survey was performed to determine the adequacy of fit, sizing, general compatibility, and to identify gross problems when CB protective clothing is worn by male soldiers in conjunction with the CVCCS for hot and cold environments.

METHOD

Subjects

Three tankers, MOS 19E, from the Soldier Operator Maintainer Test Evaluator (SOMTE), Material Testing Directorate, Aberdeen Proving Ground, MD, served as test participants (TFs) during this evaluation. They were selected as being representative of US Army soldiers of 7th, 35th, and 99th percentiles in stature (7). Their basic anthropometric statistical values

are shown in Table 1, and indicates that the men represented near-extremes of sizes found in the US Army population.

TABLE 1  
Basic Anthropometric Statistical Values

| Subject | Stature |         | Chest Cir. |         | Waist Cir. |         | Weight |         |
|---------|---------|---------|------------|---------|------------|---------|--------|---------|
|         | (cm)    | Percent | (cm)       | Percent | (cm)       | Percent | (kg)   | Percent |
| 1       | 164.6   | 7       | 92.2       | 45      | 84.8       | 75      | 69.1   | 46      |
| 2       | 171.9   | 35      | 96.6       | 70      | 89.6       | 87      | 81.5   | 83      |
| 3       | 194.2   | 99      | 105.7      | 95      | 100.0      | 98      | 105.4  | 99      |

#### Clothing and Equipment Ensembles

CVCCS Uniform Ensembles per environment, listed in Table 2, were assessed in combinations with CB protective clothing and equipment. The CB protective clothing and equipment used is listed in Table 3. Table 4 illustrates the CB Protective Suit Size Prediction Chart which was provided by NARADCOM. Table 5 illustrates the NARADCOM CVCCS Fitting Guidelines.

#### PROCEDURE

The various uniform and equipment combinations were worn in accordance with TM 10-275 (4) and TM 10-277 (5) which describe the utilization of the layered-clothing principle employed by the US Army. This principle permits rapid adjustment of clothing layers to accommodate variations in temperature and activity levels and permits the wearer good freedom of movement. Any deviations from wear doctrine are noted when appropriate.

CVCCS fitting and sizing guidelines were provided by NARADCOM (6) and the clothing labels, and are illustrated in Table 5.

Each TP dressed in each of the uniforms for a given climatic condition. Using the sizing guidance furnished on the package, Table 4, a CB protective suit was then added as an outer garment.

As an extension of CB protection, the CB footwear covers were worn over the basic footwear with the trouser legs outside the covers. CB protective gloves were evaluated in combinations with the CVCCS gloves, Flyers and Cold Weather; and the Mitten, Trigger Finger with inserts, and are listed in Table 6.

TABLE 2

## CVCCS Uniform Ensembles

Hot-Weather Uniform

Coverall w/o Liner  
 Armor, Body, CVC  
 Gloves, Flyers, Summer

Cool-Weather Uniform

Coverall w/Liner  
 Armor, Body, CVC  
 Gloves, Flyers, Summer

Cold-Weather Uniform

Coverall w/Liner  
 Armor, Body, CVC  
 Jacket, Cold-Weather, Nomex  
 Gloves, Cold-Weather, CVCCS

Very-Cold-Weather Uniform

Coverall w/Liner  
 Armor, Body, CVC  
 Jacket, Cold-Weather, Nomex  
 Bib-Overall  
 Gloves, Cold-Weather, CVCCS

NOTE: All uniforms included appropriate Standard "A" underwear and socks. The CVCCS boots were not available during this test. The face mask and balaciava were not used while wearing the CB protective M-25 mask and M-5 hood.

TABLE 3

## Chemical-Biological Protective Clothing and Equipment

1. Suit, Chemical-Biological Protective (coat and trousers).
2. Cover, footwear, CB protective.
3. Glove, butyl rubber with glove, cotton.



TABLE 4

## CB Suit Size Prediction Chart

| Waist Size | Over Underwear<br>and<br>Summer | Over Coat and<br>Trousers<br>Hot Weather | Over Coat and<br>Trousers<br>Man's Field<br>Wear | Over Parka and<br>Trousers<br>Man's Arctic<br>Wear |
|------------|---------------------------------|------------------------------------------|--------------------------------------------------|----------------------------------------------------|
| 27         | XS                              | XS                                       | S                                                | M                                                  |
| 31         | XS                              | S                                        | M                                                | L                                                  |
| 35         | S                               | M                                        | L                                                | XL                                                 |
| 39         | M                               | L                                        | XL                                               | XXL                                                |
| 43         | L                               | XL                                       | XXL                                              | XXL                                                |

TABLE 5

## NARADCOM CVCCS Fitting Guidelines

| Recommended Size      | Chest, Inches (cm) | Height, Inches (cm) |
|-----------------------|--------------------|---------------------|
| X-Small Short (XSS)   | Under 34 (86)      | Under 64 (162)      |
| X-Small Regular (XSR) | Under 34 (86)      | 67-71 (162-180)     |
| Small Regular (SR)    | 34-38 (86-97)      | Under 71 (180)      |
| Small Long            | 34-38 (86-97)      | 71 (180) and over   |
| Medium Regular        | 38-42 (97-107)     | Under 71 (180)      |
| Medium Long           | 38-42 (97-107)     | 71 (180) and over   |
| Large Regular         | 42-46 (107-117)    | Under 71 (180)      |
| Large Long            | 42-46 (107-117)    | 71 (180) and over   |
| X-Large Regular       | 46-50 (117-127)    | Under 71 (180)      |
| X-Large Long          | 46-50 (117-127)    | 71 (180) and over   |

TABLE 6

## CVCCS Handwear and CB Protective Glove Compatibility

| <u>Conditions</u>                                                             |
|-------------------------------------------------------------------------------|
| 1. CB Glove over Glove, Flyers, Summer.                                       |
| 2. CB Glove under Glove, Flyers, Summer.                                      |
| 3. CB Glove over Glove, Flyers, Summer w/Mitten, Trigger Finger w/insert.     |
| 4. CB Glove under Glove, Flyers, Summer w/Mitten, Trigger Finger w/insert.    |
| 5. CB Glove over Glove, CVC, Cold Weather.                                    |
| 6. CB Glove under Glove, CVC, Cold Weather.                                   |
| 7. CB Glove over Glove, CVC, Cold Weather w/Mitten, Trigger Finger w/insert   |
| 8. CB Glove under Glove, CVC, Cold Weather w/Mitten, Trigger Finger w/insert. |

NOTE: The Mitten, Trigger Finger w/insert was added for additional environmental protection.

The areas considered were ease of doffing and donning, compatibility with prescribed clothing and field equipment combinations, and allowance for extremes of body size and configuration.

An exercise routine, Table 7, was followed to determine the adequacy of fit and to aid in assessing clothing and equipment compatibility. Any fitting problems encountered (which ranged from changes in basic garment size, garment tightness, excess material, joint fold characteristics or restrictions in range of motion) were reported by the TPs and visually assessed for severity by the USAHEL test personnel.

The TPs performed the exercises and reported any binding or restriction of movement that they felt resulted from the clothing ensembles. Their comments were recorded in brief with emphasis on both body area and aspect of the ensemble involved in the reported interaction.

A cold chamber, maintained at -25°F, was used to assess the cold-temperature effect on the CB-protective suit and associated equipment while wearing the Very-Cold CVCCS uniform. Donning and doffing of the CB-protective suit and equipment was closely monitored. The exercise routine, as previously mentioned, was followed to determine the adequacy of fit and compatibility. Further discussion and results are given in the Cold-Temperature Effect section.

TABLE 7

Exercise Routine

---

TP's Exercised Under all Uniforms and Combinations Listed:

- (1) Basic Position - The TP stands erect with his feet together and arms hanging relaxed at his sides.
  - (2) Position I - TP stands erect, feet together, arms extended horizontally from the sides of the torso with the palms of the hands facing the floor. Thus, a single straight line will connect the fingertips of the right and left hands.
  - (3) Position II - TP stands erect, feet together, with arms crossed horizontally in front of body.
  - (4) Position III - TP stands erect, feet together, arms extended horizontally backwards to the limit of his movement in this direction. The position is attained by swinging the arms in a horizontal plane (at the shoulder level) as though attempting to make the hands meet behind the body.
  - (5) Position IV - TP stands erect, feet together, arms raised vertically, with the palms of the hands facing each other and in contact.
  - (6) Position V - TP stands with feet together and knees locked in a straight, vertical position. The thoracic cage is flexed forward by pivoting about the hip joint and bending the lumbo-sacral spine. Arms are extended out to the sides as in Position I.
  - (7) Position VI - TP stands with feet together and knees locked in a straight, vertical position. The thoracic cage is flexed backward by pivoting about the hip joint and bending the lumbo-sacral spine. Arms are extended out to the sides as in Position I.
  - (8) Position VII - TP stands with feet together and knees and hips locked in a straight vertical position. The thoracic cage is rotated (about the vertical axis of the body) to the side by rotating the lumbo-sacral spine. Arms are extended out to the side as in Position I.
-

## RESULTS

Table 8 shows the sizes of CB-protective suit components which each TP wore with each of the CVCCS uniform combinations, hot to very cold.

TABLE 8

### CB-Protective Suit Sizing with the CVCCS Uniform Combinations

| CB w/Hot-Weather Uniform  |         |            | CB w/Cool-Weather Uniform |         |            |
|---------------------------|---------|------------|---------------------------|---------|------------|
| TP                        | CB Coat | CB Trouser | TP                        | CB Coat | CB Trouser |
| 1                         | S       | S          | 1                         | S       | S          |
| 2                         | M       | M          | 2                         | M       | M          |
| 3                         | L       | L          | 3                         | L       | L          |
| CB w/Cold-Weather Uniform |         |            | CB w/Very-Cold Uniform    |         |            |
| TP                        | CB Coat | CB Trouser | TP                        | CB Coat | CB Trouser |
| 1                         | M       | S          | 1                         | M       | M          |
| 2                         | L       | M          | 2                         | L       | L          |
| 3                         | XL      | L          | 3                         | XL      | XL         |

### Hot- and Cool-Weather CVCCS Uniforms and CB-Protective Suit Compatibility

The hot- and cool-weather CVCCS uniforms were worn under the CB-protective suit. The size prediction chart on the CB suit package, Table 4, was adequate in that the predicted uniform sizes accommodated the basic uniform worn underneath. TPs reported no restriction of motion, and the suits were compatible with the hot- and cool-weather CVCCS uniforms.

The only difference between the hot- and cool-weather CVCCS uniform was the addition of the coverall liner.

As reported in USAHEL TN 5-79 (1) and HEL TN 12-80 (2) CB suit fitting reports, the waist adjustments were again insufficient to take up excess material.

### Cold-Weather CVCCS Uniform and CB-Protective Suit Compatibility

The cold-weather CVCCS uniform consisted of the cool-weather CVCCS uniform plus the Jacket, Cold Weather. The added bulk of the jacket filled the CB-protective coat and required a one-size larger refit. Arm reach was slightly limited and there was some constriction because of the added bulk.

The CB trouser size was not affected, since no additional clothing layers were donned.

### Very-Cold-Weather CVCCS Uniform and CB-Protective Suit Compatibility

The Very-Cold-Weather CVCCS uniform consisted of the Cold-Weather CVCCS uniform plus the bib-overall. The Jacket, Cold Weather, was worn over the bib-overall. The CB-protective coat sizes remained the same since there was little change in clothing bulk. The bib-overall bulk did affect the CB protective trouser size and required a one-size larger trouser refit.

### CVCCS Handwear and CB-Protective Glove Compatibility

CB-protective gloves were fitted and worn over and under the following handwear:

1. Gloves, CVC, Cold Weather; and with Mitten, Trigger Finger, Standard "A".

Overall compatibility, fit, and manual dexterity were of concern.

2. CB-Protective Gloves worn over and under Gloves, Flyers, Summer.

In these test conditions, there were slight size changes in fitted sizes as illustrated in Table 9. The TPs reported a very slight degradation of finger dexterity because of excessive CB glove finger length.

For additional environmental protection, Mittens, Trigger Finger with insert, were donned over the previously mentioned handwear conditions. The TPs reported a slight degradation of manual dexterity in these conditions.

3. CB-Protective Gloves worn over and under CVCC Cold-Weather Gloves.

In these test conditions, the exterior gloves indexed one size larger as illustrated in Table 9. The subjects reported an overall degradation of manual dexterity in both conditions caused by material bulk and excessive CB glove finger length.

TABLE 9

Test Conditions of CB-Protective Gloves Worn Over and Under  
CVC Cold-Weather Gloves

| #1 CB over CVC Light       |   |    |   | #2 CB under CVC Light       |   |    |   |
|----------------------------|---|----|---|-----------------------------|---|----|---|
|                            | S | 7  |   |                             | S | 10 |   |
|                            | M | 10 |   |                             | M | 10 |   |
|                            | M | 10 |   |                             | M | 10 |   |
| #3 CB over CVC Light w/MTF |   |    |   | #4 CB under CVC Light w/MTF |   |    |   |
|                            | S | 7  | X |                             | S | 10 | X |
|                            | M | 10 | X |                             | M | 10 | X |
|                            | M | 10 | X |                             | M | 10 | X |
| #5 CB over CVC Hy          |   |    |   | #6 CB under CVC Hy          |   |    |   |
|                            | M | 5  |   |                             | S | 8  |   |
|                            | L | 8  |   |                             | M | 8  |   |
|                            | L | 8  |   |                             | M | 8  |   |
| #7 CB over CVC Hy w/MTF    |   |    |   | #8 CB under CVC Hy w/MTF    |   |    |   |
|                            | M | 5  | X |                             | S | 8  | X |
|                            | L | 8  | X |                             | M | 8  | X |
|                            | L | 8  |   |                             | M | 8  |   |

For additional environmental protection, Mittens, Trigger Finger with insert were donned over these handwear conditions. Manual dexterity was further degraded by these conditions.

#### DISCUSSION

##### CVCCS Uniforms and CB-Protective Suit Compatibility

The CVCCS uniforms and CB-protective suit were compatible considering the additional bulk and CB suit size adjustment.

The CB suit package directs that suspenders be issued with the overgarment as an "...aid to suspension of trousers." The present trousers have belt loops and suspender attachment points. In the less bulky CVCCS uniform, there is an excess of material around the waist. A belt should provide a single solution to both problems, and be particularly appropriate since belt loops are already provided. Generally, there are no spare belts

or suspenders available to the soldier in the field. Therefore, an integral waist tie rope would be more appropriate.

Aside from the excessive waist dimension, the CB suit was compatible with the CVCCS uniform clothing ensemble.

#### CVCCS Handwear and CB-Protective Glove Compatibility

Fit problems were common to all combinations of climatic and CB-protective gloves. As glove layers were added, manual dexterity was further degraded.

Any wear concept that requires the wearing of environmental clothing outside the CB clothing and equipment will probably result in the loss of environmental protection when contaminated.

These same problems were documented in USAHEL Technical Notes 5-79 (1) and 12-80 (2).

#### Cold-Temperature Effects On CB-Protective Suit and Associated Equipment

##### Objective

The effects of cold temperature on the CB-protective suit and associated equipment were reviewed.

##### Method and Procedure

##### Test Participant

The 99th percentile (stature) TP volunteered for this segment of the evaluation.

##### Clothing and Equipment

The TP wore the Very-Cold-Weather CVCCS, without balaclava and face mask, under the CB protective suit and associated equipment.

##### Apparatus

A cold chamber, located at Aberdeen Proving Ground, MD, was utilized to insure the temperature (-25°F) maintenance throughout the evaluation.

## Procedure

The CB-protective suit and associated equipment were donned over the Very-Cold-Weather CVCCS uniform. The TP then performed the previously mentioned exercises to determine adequate fit and clothing/equipment compatibility. Comments were recorded, in brief, with emphasis on both body area and aspects of the ensemble involved.

## Results and Discussion

The cold temperature caused the CB-protective suit to be very stiff. The trousers and sleeves openings had to be opened up inch-by-inch to allow insertion of the arms and legs.

The Velcro and zipper closures did function satisfactorily considering the temperature.

General fit and compatibility of the CB-protective suit was not affected.

The CB-protective gloves and footwear covers became very stiff. The TPs reported that the glove reduced tactile sensitivity.

## CONCLUSION

The CB-protective suit and associated equipment are compatible with the CVCCS uniforms.

## RECOMMENDATIONS

Recommend that the Army Research Institute for Environmental Medicine (ARIEM) investigate the CLO-values obtained when the CVCCS clothing ensembles are worn in combination with the chemical-biological protective suit and associated equipment.

Recommend an integral waist tie be added to keep the CB-protective suit trouser in position.

Recommend the CB-protective butyl gloves be worn over the CVCCS (flyers and cold weather) gloves to prevent loss of the cold-weather gloves in a contaminated environment.

Recommend a material that is less affected by cold temperature be used for the CB-protective gloves and footwear covers.

Recommend the CB-protective butyl glove finger length be shortened to improve manual dexterity.



Recommend the Size Prediction Chart be expanded to include all uniforms.

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**APPENDIX**

**DESCRIPTION OF PROPOSED CVCCS COMPONENTS**

## Description of Proposed CVCCS Components

### Coverall, CVC

The coverall is made of Nomex, a high-temperature resistant material. This one-piece, hot-weather design has a two-way, zippered, front closure; drop; extraction strap on the upper back to aid in removal of an injured crewmember; reinforced patches at seat, knees, elbows and ankles; zipper-closure pockets strategically located to carry operational, survival and protective equipment; a utility/pencil pocket on the upper left sleeve, right- and left-thigh pockets; and means to secure the standard shoulder holster.

### Liner, Coverall, CVC

The liner is a two-piece garment designed to interface with the coverall and provide cold-weather and flash protection.

### Jacket, Cold-Weather, High-Temperature Resistant, Nomex

The jacket, similar to the standard Army aviator cold-weather jacket, has a Velcro closure access flap to the coverall extraction strap; reinforced elbow patches; and increased interlining for environmental protection.

### Gloves, Flyer, Summer

The standard Army aviator glove, fire-retardant material (Nomex) with leather palm, was used.

### Gloves, CVC Cold-Weather

The gloves were made of fire-retardant (Nomex) material with insulation with a heavy-duty leather palm similar to that of the flyer's glove.

### Body Armor, CVC, Fragmentation

The body armor provides upper torso protection from simulator projectile, airburst, liquid (SPAL), and fragments by means of front and back ballistic inserts in a vest-type carrier system. Worn as an undergarment, it was donned over the head and secured to itself by elastic webbing with hook and pile fasteners, tape straps at the sides.

### **Bib-Overalls, CVC**

The bib-overall is sized to be worn over the CVC coverall with liner for additional fire and cold-weather protection. The following features were incorporated into the garment: center-front slide fasteners, drop seat, adjustable suspenders, and leg slide fasteners.

### **Face Mask, SPAL, Flame, Dust and Wind Protective**

The face mask is a close-fitting face piece that covers the forehead, nose, cheek, and throat areas. It is composed of a non-melting, high-strength, aromatic, polyamide fabric providing flame and ballistic protection.

### **Balaclava**

The balaclava is a close-fitting head covering that has a single opening for eye exposure. Exposure of the total facial area can be achieved by means of a two-layered knit construction sandwiched over a wind barrier. It gives flame, thermal, and cold-weather protection (wind).