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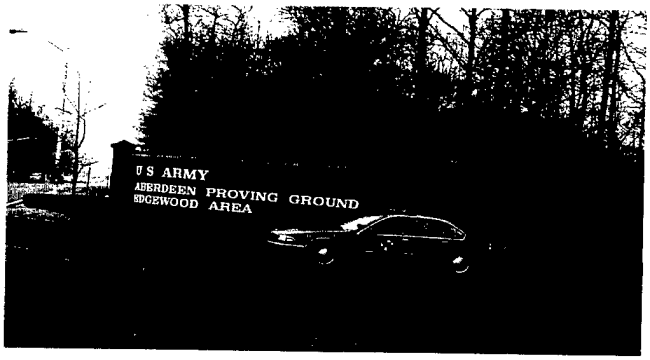
Chemical Protective Clothing for Law Enforcement Patrol Officers and Emergency Medical Services when Responding to Terrorism with Chemical Weapons



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January 2001

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Aberdeen Proving Ground, MD 21010-5424

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This report covers Man In Simulant Testing (MIST) of the following commercially available, Level C chemical protective suits: the Tyvec® Protective Wear™ suit (garage-type, for mechanics), the Kappler CPF®4 suit (model # 4T434), the TyChem® 9400 (style 94160) suit, the TyChem® SL (style 72150) suit, and the Tyvec® ProTech F suit. These suits are being considered by law enforcement agencies for use at scenes where chemical warfare agents have been used by terrorists. This testing examined how well the complete protective suit ensembles protect the wearer against vapor adsorption by the skin by exposing test participants wearing the suits to a chemical agent simulant (methyl salicylate) and measuring the Physiological Protective Dosage Factor (PPDF) the wearers received while performing a set of typical law enforcement activities. The results showed that the respective suits provided the wearers with the following average Overall PPDF: standard police uniform - 2.0; Tyvec® - 4.0; CPF® 4 – 17.6; TyChem® 9400 – 16.5; TyChem® SL – 23.7; and the Tyvec® ProTech F – 41.8.

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Physiological Protective Dosage Factor
Minimum Required Exposure Dosage
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PREFACE

The work described in this report was funded by the Domestic Preparedness Program. This work was started in January 1999 and completed in November 1999.

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Chemical Protective Clothing for Law Enforcement Patrol Officers and Emergency Medical Services when Responding To Terrorism with Chemical Weapons

1. INTRODUCTION AND BACKGROUND

This report contains information related to the testing of commercially available chemical protective suits. The information contained in this report is intended for use by law enforcement patrol officers in the event of a terrorist attack that involves the use of Chemical Warfare Agents (CWA). Additionally, this information may also be applicable for Emergency Medical Services (EMS) personnel and other first responders at this type of incident. For easy dissemination, this report is available at the following web-site: **http://www.nbc-prepare.org**

These protective suit ensembles were tested for use by patrol officers operating on the perimeter of a chemical incident only (in the cold zone – not in the direct vicinity of a chemical spill). They were not tested for use at hazardous materials spills or incidents involving hazardous materials, and should not arbitrarily be used at spill scenes involving industrial chemicals. Only protective suits that are certified by the manufacturer for this purpose should be relied upon for protection against these materials.

The challenges facing law enforcement today are as complex as they are numerous. Whether the crime is terrorism or computer crimes, criminal acts are quickly transitioning from the realm of the traditional to the high tech in which the response and investigation by law enforcement personnel must involve specialized training and equipment suitable for the task at hand. As society evolves into a more technological culture with an emphasis on information technology, criminal acts that were once thought of as impossible to carry out have now become a real possibility. The growing threat of terrorism and the probability that weapons of mass destruction will be used in an attack has increased proportionally to the amount of information readily available to any would be attacker. In carrying out its many responsibilities to the public and preparing to respond to any threat to our communities in the form of terrorism, law enforcement must be prepared to enter a realm that, until recently, was thought of as a military responsibility. Because terrorism is a criminal act, overall responsibility for the management of the incident and command responsibility will lie with law enforcement personnel. Preparation for the event of an attack must include planning, training and protective equipment that will allow law enforcement personnel to effectively operate in a contaminated environment while carrying out their duties. Whether maintaining crime scene control, establishing a perimeter, assisting with decontamination, processing the crime scene, or beginning the investigation, law enforcement personnel cannot respond to an incident without proper protective equipment and training or they will become unable to perform their duties or fulfil their responsibilities to the public.

For these reasons, the Law Enforcement Working Group was created under the Domestic Preparedness (DP) Program with the goal of creating practical solutions to technical problems facing the law enforcement community. This "think tank" approach to problems utilizes the technical expertise and experience possessed by the U.S. Army combined with law enforcement expertise and was created and fostered through a partnership between the U.S. Army's Soldier and Biological Chemical Command (SBCCOM) and the law enforcement community. The Law Enforcement Working Group consists of federal, state and local law enforcement officers with varying levels of expertise across multiple disciplines.

A decision was made by the DP Law Enforcement Working Group to evaluate commercially-available protective suits that may be worn by law enforcement officers assigned to patrol during a response to a terrorist attack that involves CWA. This testing was conducted at the Edgewood Chemical Biological Center (ECBC) at Aberdeen Proving Ground to determine the protection needed for law enforcement patrol personnel to effectively operate in the cold and warm zones. It can be expected that most patrol officers who respond to this type of incident will be performing law enforcement functions in the cold zone and/or in the area around the cold/warm zone boundary (i.e., assisting with the evacuation or decontamination process). These areas are away from the primary source and would contain very low to moderate concentrations of chemical agent. ***The primary protection that officers and/or first responders should use in these situations is high quality respiratory protection (masks) to protect their lungs and respiratory system.***

Although this is the most important protection for a first responder (which should be used in every case), there are several other conditions that may occur at the scene which may present unforeseen dangers and require additional protection for law enforcement officers. These dangers may appear in the form of CWA vapors and liquid that may inadvertently come into contact with or be absorbed by exposed skin of law enforcement personnel and other first responders at the scene. Additionally, higher concentrations of CWA vapors may be blown by shifting winds from the primary source area (hot zone) into the cold zone, or may present a danger in the form of "off-gasing" vapors from a victim's clothing coming into contact with exposed skin of law enforcement personnel. Liquid CWA may pose a danger from accidental touching or contact with a victim's contaminated clothing or contaminated objects. For these reasons, skin protection in the form of an impermeable, chemically protective suit and butyl gloves (in addition to a high quality mask) should also be worn to offer additional protection from these dangers. This testing at ECBC evaluated the protection that some commercially available suits provide against vapor adsorption of CWA on the skin using the approved chemical agent simulant Methyl Salicylate (MeS) at the Edgewood Man In Simulant Test Facility. The simulant used is a safe non-toxic liquid (oil of wintergreen) that possesses properties very similar to chemical warfare agents, but can be used safely with live personnel to effectively test equipment.

Man In Simulant Testing (MIST) is the preferred scientific method of determining the overall Physiological Protective Dosage Factor (PPDF) of protective suit ensembles to be used for protection against CWA. This testing exposes the protective suit and wearer to the CWA simulant MeS in a controlled chemical environment and uses self-adhesive skin samplers that absorb chemical vapors at almost the same rate that human skin does. These samplers are placed at specific body locations to measure the amount of CWA simulant being absorbed by the

skin. Evaluation of the protection provided by the suit is based upon this absorption using the Body Region Hazard Analysis (BRHA) model[1]. The BRHA model, an accepted model used by the medical and scientific community, uses actual skin absorption data on CWA[2,3]. The BRHA model uses skin samplers that are placed on designated areas of the body at locations in which the skin absorption rate is known. By using these known figures against the total amount of simulant absorbed by the samplers, the minimum threshold dosages for CWA can be determined and expressed as a relative physiological protective dosage factor.

The suit ensembles tested in this study included the following: the Tyvec® Protective Wear™ suit (garage mechanic-type), the Kappler CPF®4 suit (model # 4T434), the TyChem® 9400 suit (style 94160), the TyChem® SL suit (style 72150), and the Tyvec® ProTech F suit. A baseline test of the standard Maryland State Police duty uniform was also conducted as a control so that the relative improvement of having little protection (uniform) could be evaluated against higher levels of protection.

The SBCCOM Respiratory and Collective Protection Team has performed previous physiological protective dosage factor testing to measure the protection afforded to wearers of Individual Protection Equipment (IPE) ensembles. Several different ensembles have been tested, including the Kappler Responder suit[4], the Army Battle Dress Overgarment (BDO), the U.S. Army Suit, Contamination Avoidance, Liquid Protective (SCALP)[5], and various Level A[6], B, and C commercial haz-mat suits. All tests performed on these suits have adhered to the standard procedures of the MIST program and are conducted in accordance with guidelines set forth by the Joint Services Lightweight Integrated Suit Technology (JSLIST) working group.

The general approach of this testing is to place passive sampling devices (PSD) beneath the garments of test subjects at several different skin locations and to expose them to a constant concentration of simulant vapors while they perform law enforcement activities representative of their mission. The challenge concentration level of the simulant is measured along with the concentration inside the suit using sensitive analytical equipment. The ratio of these two values is the PPDF of each sampler location inside the suit ($PPDF_{SL}$). An overall suit PPDF is calculated using the Fedele[1] method (BRHA model). This provides the relative protective capability of the suit and serves to identify susceptible areas. These tests yield an overall PPDF allowing for comparison with the standard police duty uniform and determining where infiltration is likely to occur.

2. SCOPE OF TESTING

The MIST testing was performed on commercially-available standard protective clothing ensembles that may be worn by law enforcement personnel or EMS personnel when responding to terrorist incidents involving chemical warfare agents. Six protective suit ensembles were evaluated in this testing. The suit ensembles are described in Table 1. The first suit ensemble is what is currently available to law enforcement: the standard Maryland State Police (MSP) duty uniform.

Table 1. Description of Suit Ensembles Tested

Suit Ensemble	Description of Suit Ensemble
1	A standard duty uniform of the Maryland State Police with M17 mask, and thin butyl gloves (see Figure 1);
2	The standard duty uniform with the Tyvec ® Protective Wear™ suit (a white maintenance coverall - garage-type - that has integral booties and is made with Dupont fabric material, manufactured by Lakeland Industries, Inc. meeting ANSI/ISEA 101-1993 – see Figure 2), along with the MCU2P Mask using standard NATO Canister, C2A1, NSN 4240-01-361-1319, thin butyl gloves (Gloves, Chemical Protective, Type III, 7 mil, Mil-G-43976C, NSN 8415-01-138-2501), and commercially available boot covers (rain totes);
3	The protective ensemble described above (suit ensemble 2) with the Kappler CPF®4 suit, model # 4T434 (see Figure 3) used instead of the Tyvec ® suit (protective suit ensembles 2 through 6 were identical except for the protective suit worn);
4	The protective ensemble described above (suit ensemble 2) with the Dupont TyChem® 9400 suit, style 94160 (see Figure 4);
5	The protective ensemble described above (suit ensemble 2) with the Dupont TyChem® SL suit, style 72150 (see Figure 5); and
6	The protective ensemble described above (suit ensemble 2) with the Tyvek® ProTech F suit (see Figure 6).

Suit ensemble 1 was used as the baseline for comparative purposes. Suit ensemble 2 examined the added protection offered by wearing the low cost ($1-2/suit), garage-type protective coverall. Suit ensembles 3 through 6 were evaluated to determine the difference in protection offered by use of different protective coverall suits. Suits 3 and 4 are moderately priced suits (cost per suit $35 each); suit 5 is a relatively low cost suit ($12-20 each), and suit 6 is a higher priced suit ($45- 60 each). The gloves used were standard chemical protective gloves. These offer higher manual dexterity and tactile sensitivity for the wearer. The test schedule was designed to evaluate five of each suit at the Edgewood MIST Facility during this series of testing; however, for some of the suits only four were tested. A list of the suits tested during each of the six tests is provided in Table 2.

Table 2. Schedule of MIST Testing of Law Enforcement Protective Suit Ensembles

	Suit 1	Suit 2	Suit 3	Suit 4	Suit 5
Test 1*	Standard	TyChem® SL	TyChem® 9400	********	********
Test 2	TyChem® SL	Tyvek® F	CPF®4	Tyvec®	TyChem® 9400
Test 3	Tyvek® F	Standard	TyChem® SL	CPF®4	TyChem® 9400
Test 4	Tyvek® F	TyChem® SL	Tyvec®	Standard	TyChem® 9400
Test 5	TyChem® 9400	CPF®4	Tyvec®	Tyvek® F	TyChem® SL
Test 6	TyChem® SL	CPF®4	TyChem® 9400	Tyvec®	Tyvek® F

*QuickMask II used as the respirator during these tests; thereafter the MCU2P mask was used.

Figure 1. The Standard Maryland State Police Uniform and MCU2P Mask

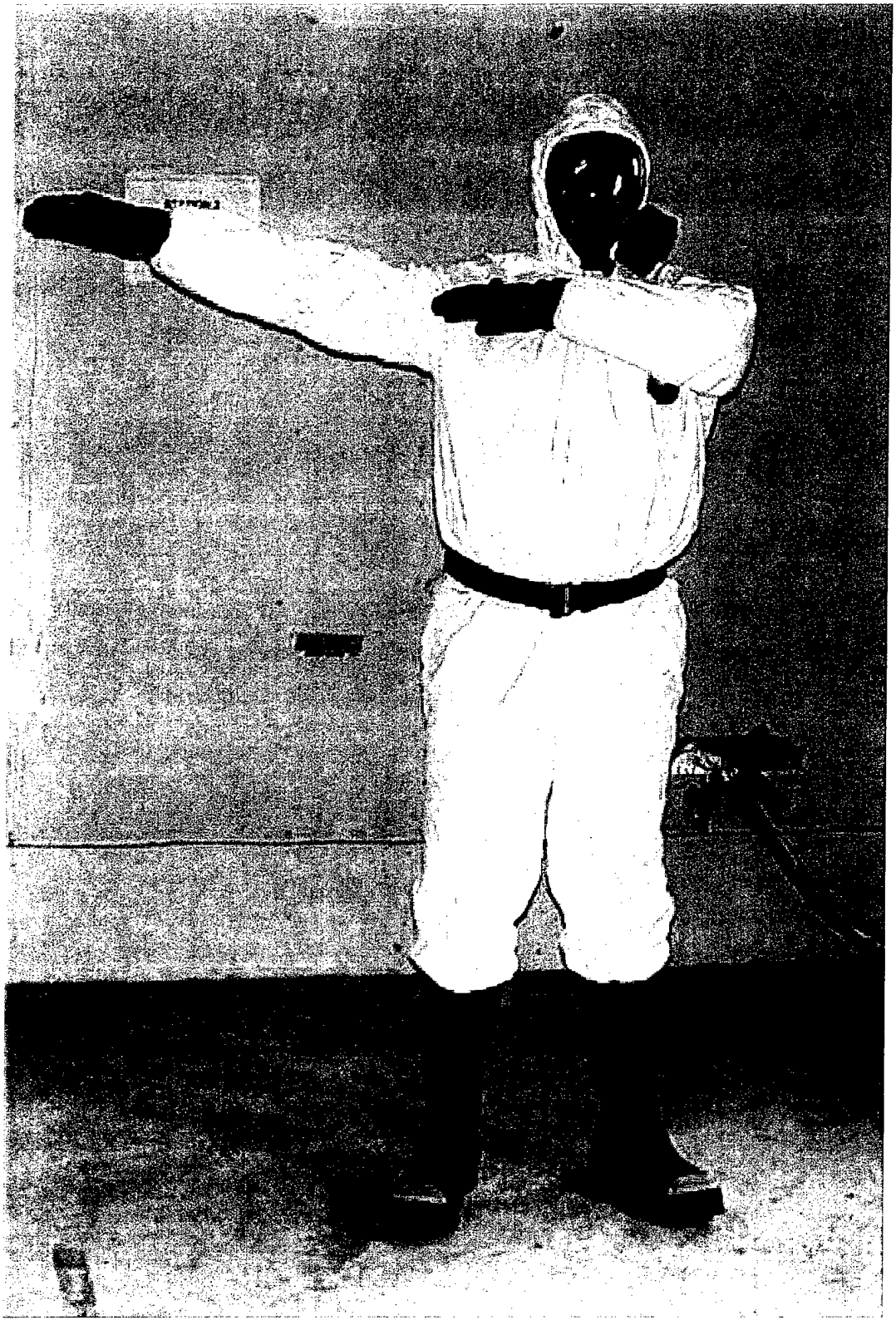

Figure 2. The Tyvec® Protective Wear™ Suit and MCU2P Mask

Figure 3. The Kappler CPF®4 (model # 4T434) Protective Suit Ensemble

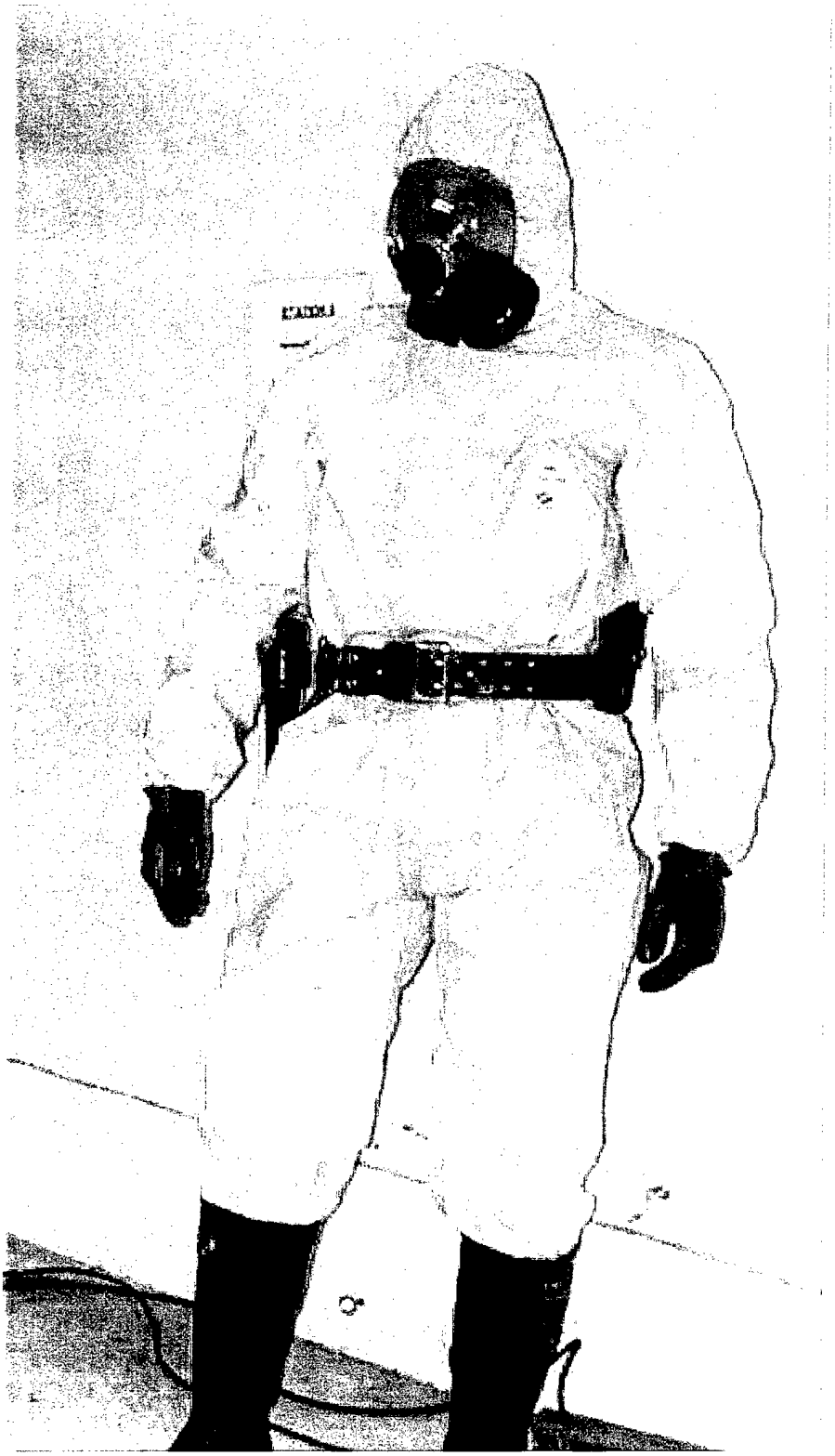

Figure 4. The TyChem® 9400 (Style 94160) Protective Suit Ensemble

Figure 5. The TyChem® SL (Style 72150) Protective Suit Ensemble

Figure 6. The Tyvec® ProTech F Protective Suit Ensemble

The trials were conducted with Maryland State Police (MSP) participants wearing each suit in its normal configuration, over the standard MSP duty uniform. Testing involved vapor challenge with the simulant methyl salicylate at a concentration of 60±10 mg/m^3. Subjects were exposed to the MeS for a time period of 30 minutes and performed a set of standard activities that police officers are expected to perform in response to a terrorist incident (see Table 3). Tests with the standard MSP duty uniform alone (suit ensemble 1) were used as baseline tests, to determine how much protection officers would have without any additional protective suit.

The mask initially proposed to be used during this testing (the FumeFree QuickMask II) was eliminated from the testing because some of the test participants had difficulty wearing it. This mask is designed primarily as an escape mask and has an attached elastic hood which seals around the neck. A snorkel type mouth-bit is used to breathe in and out through the filter and a noseclip is used to prevent breathing through the nose. The noseclip came off and three of the five test participants experienced difficulties with the hood collapsing on their faces. This is the reason only three suits were tested during the first trial. This problem may be overcome with additional training and familiarization of the subjects with the mask; however, an alternate mask (the MCU2P) was put into use for the remainder of the testing after the first day.

MIST testing evaluates only the protection provided by the suit ensemble against vapor absorption through the skin. Respiratory protection is not evaluated in this testing. The protection factor (PF) of the mask is assumed to be the value certified by the manufacturer, typically, negative pressure masks give PFs of 500 to 1,000.

3. MIST TEST EQUIPMENT AND PROCEDURES

The MIST trials were conducted according to procedures used at the Edgewood MIST facility. These procedures follow the basic standard test procedures outlined in TOP 10-2-022. A brief outline of the equipment and procedures used is presented below; for a more detailed explanation, the reader is referred to the Technical Report published at ECBC* for this study. The Clean Room and the Doffing Room described below are both part of a single building structure that are constantly purged with filtered air (flow is from the Clean Room through the Doffing Room to the outside). There are protective entryways (airlocks) between both rooms and also between the Doffing Room and the outside environment (there are two airlocks in series at this location).

- The test subjects had patch samplers (PSDs) placed directly on their skin (see Figure 7) and/or underclothing at 17 locations (see Table 4) in the Clean Room. These locations were chosen to adequately represent the different body skin regions contained in the BRHA model that was used to evaluate the Overall PPDF of the suit ensembles.

*Arca, Victor J. et al., *Man in Simulant Testing of Protective Suits for Law Enforcement Officials at the Edgewood MIST Facility*, U.S. Army Edgewood Chemical Biological Center, Aberdeen Proving Ground, Maryland, October 1999, unpublished data.

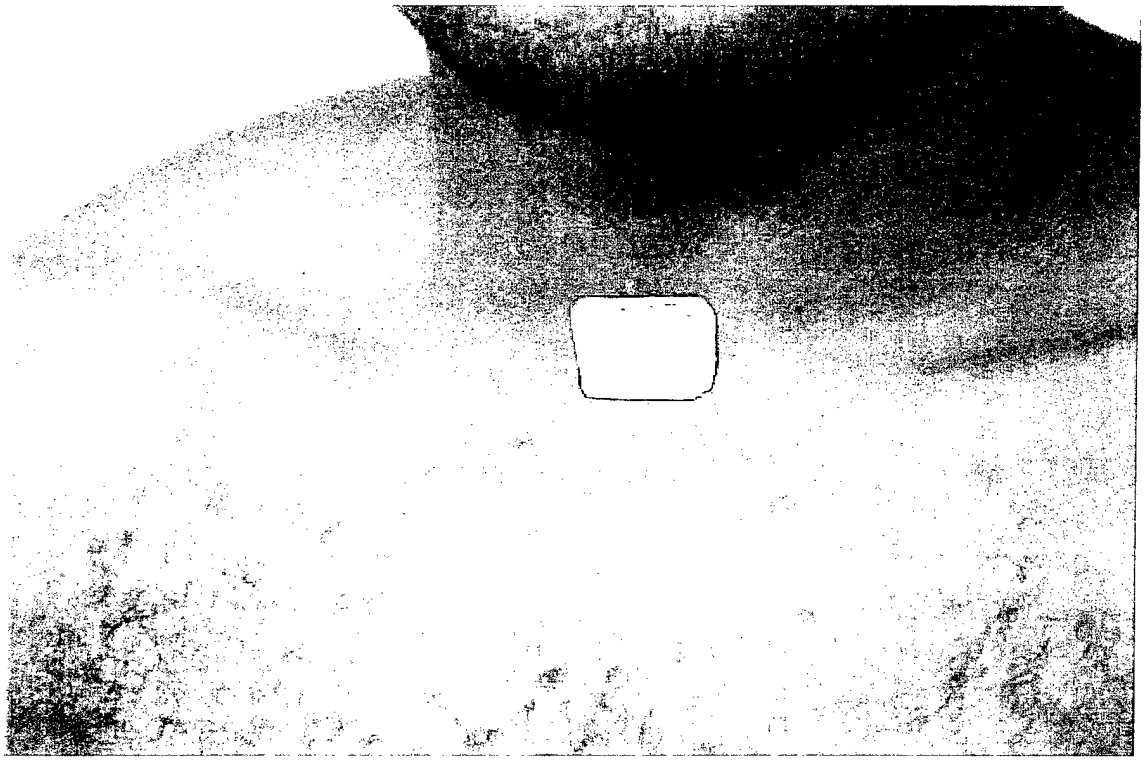

Figure 7. Sampler Applied to Neck Region

- The subjects left the Clean Room and entered the test chamber where a high concentration (approximately 60 mg/m^3) of MeS vapor was present. They were exposed to the simulant vapors inside the test chamber for a period of 30 minutes.

- During the 30-minute exposure period, subjects performed law enforcement activities that police officers might participate in at the scene of a terrorist incident where a chemical bomb/device was used (see Table 3).

- The subjects left the test chamber and entered the Doffing Room (through the two airlocks) where they removed the protective suits and their standard police uniforms.

- The subjects entered the Clean Room where the samplers were removed from their bodies. They left the Clean Room immediately after all samplers were removed.

- The adsorbent from each sampler was transferred to a sorbent tube and tubes were taken to the MIST Facility's analytical chemistry lab for analysis.

- The concentration of MeS was determined from each of the patch samplers and the dosage that reached the skin was calculated from the exposure time.

- These skin dosages were evaluated using the Body Region Hazard Analysis (BRHA) model to determine the protective suit ensemble's Overall PPDF.

Table 3. Exercise/Activity Regimen

Station		
1	Standing	3 minutes
2	Slow Walk On Treadmill, Moderate Rate (2.5 km/hr)	3 minutes
3	Traffic Directing Hand Movement	2 minutes
	Radio Operation Hand Movement	1 minute
4	Knocking On Doors/Evacuation Procedures	3 minutes
5	Running in Place, Treadmill, Fast Rate (5.0 km/hr)	3 minutes
6	Seated Rest	3 minutes
7	Traffic Directing Hand Movement	2 minutes
	Radio Operation Hand Movement	1 minute
8	Handcuff Motions	1 minute
	Shoulder Firearm	2 minutes
9	Slow Walk On Treadmill, Moderate Rate (2.5 km/hr)	3 minutes
10	Seated Rest	3 minutes

Table 4. Location of PSDs on Test Subjects During MIST Testing

(1) Scalp	(10) Lower Right Arm, Inner
(2) Ear	(11) Glove, Left Hand
(3) Chin/Neck (Front Center)	(12) Lower Back, Lumbar
(4) Upper Back, Between Shoulder Blades	(13) Lower Abdomen, Below Navel
(5) Stomach/Abdomen	(14) Crotch
(6) Middle of Back	(15) Inner Left Thigh
(7) Left Axilla, on Ribs	(16) Inner Left Calf
(8) Upper Right Arm, Inner	(17) Left Foot/Boot
(9) Upper Left Arm, Outer	

4. METHOD OF ANALYSIS FOR MIST TESTING

The analysis methods used for this testing consisted of the standard MIST analysis procedures using the Body Region Hazard Analysis (BRHA) method. The results of the BRHA yield an Overall PPDF for the complete protective suit ensemble worn during the test (including the suit, mask, gloves, and boots). The BRHA is also used to calculate other information on how much dosage of nerve agent or mustard gas a patrol officer can be exposed to (while wearing the protective suit ensemble in this configuration) before he or she will be affected. The reader is referred to the ECBC Technical report[7] for a more complete description of the analysis details using the BRHA and for this additional dosage calculation information.

5. RESULTS AND DISCUSSION

The results of the MIST Body Region Hazard Analysis (BRHA) for each protective suit ensemble tested are summarized in Table 5.

None of the data from the first day of testing (when the Quick Mask II was used) was used in the calculation of the average PPDF values. Quick Mask II tests were discarded and the MCU2P mask was used in all remaining tests. In addition to this, there was one additional test data point that was not used. The discarded data point occurred in test 2 and resulted in an unusually high PPDF for the TyChem® 9400 suit. A two-tailed T-test for normality was performed on all of the data and this point failed the test; therefore, it was not included in the PPDF calculations. After a thorough review of all the PPDF data at each of the sample points, it appears that this high value occurred because of improper placement of the PSD on the Scalp area. For this test subject, the strap of the mask was placed over the Scalp sampler and therefore the Scalp sampler did not properly sample general vapor exposure of the scalp.

The Overall PPDFs, listed in Table 5, indicate how well the protective ensemble protects the police officer's skin from chemical agent vapors, compared to direct exposure of the bare skin, with no clothing. For example, in Table 5, the average PPDF is 42 for a police officer wearing the Tyvek® ProTech F suit with butyl rubber gloves, rubber boots, and MCU2P Mask. That means that the police officers' skin protection from chemical agent vapors while wearing the Tyvek® ProTech F suit will be 42 times better than would be experienced while wearing no clothing at all. The Tyvek® ProTech F Suit provided the best overall protection. This was the most expensive suit ($45) and it appeared to have a good seal around the chin and neck areas.

The results in Table 5 also show that the use of the standard Maryland State Police duty uniform with mask provided the test participants with an average Overall PPDF of 2. Wearing the standard MSP duty uniform provides the wearer with two times the protection he would receive from skin alone, that is, if he were wearing nothing.

The Kappler CPF®4, the TyChem® 9400, and the TyChem® SL suit ensembles provided some protection against possible vapor exposures that might occur in the Cold Zone. The MD State Police uniform and the garage-type Tyvek® suit ensembles did not provide any significant protection. The test subjects who wore the garage-type suit reported that they could smell the MeS vapor strongly, on their clothes after they took off the suit, indicating that the vapor went right through this suit, in high concentrations.

The PPDF values, reported in Table 5, correspond to the protection afforded against adsorption of vapor through the skin only. These values are not indicators of the respiratory protection offered by the masks. The PF of the mask is assumed to be the value certified by the manufacturer, typically, negative pressure masks give PFs of 500 to 1,000. For all situations where a police officer will need protection against CWA, respiratory protection is the most vital. Protection against vapor adsorption at the skin is secondary.

Table 5. Physiological Protective Dosage Factor (PPDF) Results

Suit Configuration	# Suits Tested	Average Overall PPDF	Standard Deviation
Standard MD State Police Uniform	3	2	0.8
Tyvek® Garage-Type Protective Suit	4	4	0.7
TyChem® 9400 Protective Suit	4	17	4.0
Kappler® CPF4 Protective Suit	4	18	2.6
TyChem® SL Protective Suit	5	24	12.6
Tyvek® ProTech F Protective Suit	5	42	13.5

An analysis of the BRHA results at local skin regions was conducted to determine the most vulnerable areas in the protective suit ensembles. The affected body regions show that the primary area of concern in most of the protective suits was around the chin & neck region (more mass adsorbed on the samplers at these locations). Also, a visual example at Figure 8 demonstrates where vapor leakage occurs at the neck region. For the standard MSP duty uniform and the garage-type Tyvek® suit, the most vulnerable regions were at the crotch.

The Tyvek® ProTech F suit demonstrated the best seal at the neck region. A literature search of other manufacturers who provide the same protective suits revealed that there are other models of the TyChem® 9400 suit that may have better neck closures. The brand tested was manufactured by Mar Mac, which corresponded to a model type similar to the Lakeland model 94160 suit (having the TyChem® coverall, with hood, elastic face, elastic wrists, attached boots with boot flaps). The Lakeland model style 94165 seemed to improve the neck and chin region by adding a "30 in. zipper extended to the chin" and a "double storm flap with Velcro®". This suit may provide greater protection to the wearer. The TyChem® SL suit used in this testing was similar to the Lakeland model 72150. The improvements mentioned above for the TyChem® 9400 suit were also available in a different style TyChem® SL suit. This suit's style number is 72165 and it may provide better protection against vapor adsorption at the skin.

6. CONCLUSIONS AND RECOMMENDATIONS

This assessment demonstrates that Law Enforcement and EMS personnel can be equipped with an effective low-cost clothing ensemble when responding to an incident of CW terrorism. An ensemble consisting of a high quality respirator, butyl rubber gloves and a commercial chemical overgarment (**elastic wrists & hood closures with built in boots**) provides some liquid-droplet and vapor protection to the responder. This level of protection is excellent for personnel working on the perimeter (**cold zone only**) of an incident and also provides some protection in the area around the cold/warm zone boundary (i.e., assisting with the evacuation or decontamination process). However, it must be emphasized that this clothing ensemble is inadequate protection for patrol officers in areas where significant levels of CW agent vapor concentration may be present (hot zone) i.e.: the immediate vicinity of the actual weapon or the weapon's release. This area should only be entered by HazMat qualified personnel

wearing a higher level of protective clothing (i.e., Level A fully encapsulated suits with Self-Contained Breathing Apparatus – SCBA).

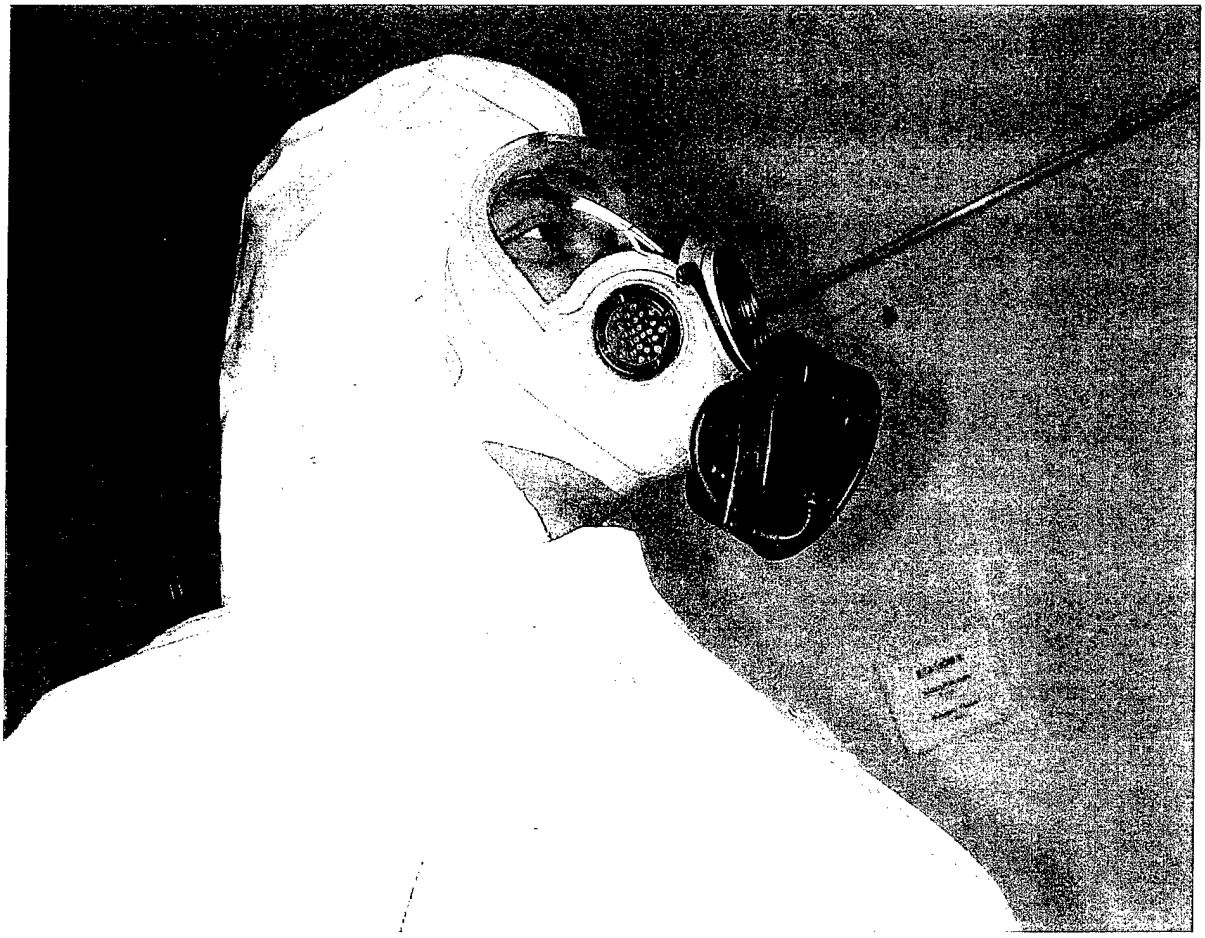

Figure 8. Open Neck Area Where Leakage Occurred

For Law Enforcement use, the application of this ensemble is to support the needs of the "average patrol officer" responding to the incident scene. It is anticipated that the patrol officer will be on the incident perimeter (cold zone) directing traffic, evacuating casualties, and maintaining control of the incident site. SWAT teams, Bomb Squads, evidence recovery teams, and other specialty units that may be closer to the weapons release point would require higher levels of protective clothing. Conclusions and recommendations specific to the ensembles tested are outlined below:

- The protective ensembles of the MD State Police standard duty uniform and mask, and the garage-type Tyvek® suit provided insignificant protection against vapor adsorption by the skin. These suit ensembles should not be used for protection against CWA. In addition, these ensembles do not provide protection against liquid CWA (if a liquid-contaminated victim were to touch the police officer).

- Some protection was offered by the Kappler CPF®4, the TyChem® 9400

(style 94160), and the TyChem® SL (style 72150) suits. This protection would be valuable for police officers operating in the cold zone, at a terrorist incident involving CWA. These suits are also manufactured with a fabric material that provides some protection against liquid chemical agents.

- The Tyvek® ProTech F suit ensemble provided the best protection against vapor adsorption by the skin in this set of tests.

- Police forces opting to use the lower cost TyChem® SL suit should choose the coverall style 72165 (with the 30 in. zipper extended to the chin) instead of the style 72150.

- If the TyChem ® 9400 suit is used, the coverall style 94165 should be chosen (also manufactured with the 30 in. zipper extended to the chin) instead of the style 94160.

- The respirator chosen for use with these suit ensembles should be used with a rubber or plastic hood to seal the areas around the head and neck. The mask and hood combination should be worn ***underneath*** the hood of the protective suit.

Blank

LITERATURE CITED

1. Fedele, Dr. Paul D., Nelson, Douglas C., A Method of Assessing Full Individual Protective System Performance Against Cutaneous Effects of Aerosol and Vapour Exposures, U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, Maryland, October, 1995; Section 1-3 "Body Region Hazard Analysis Process" included in report for the JSLIST Program: Cronin, Tracy D., Final Report For The Development of the Man-In-Simulant Test (MIST) Methodology For Evaluation of Chemical/Biological (CB) Protective Garments, TECOM Project No. 8-EI-825-ABO-004, U.S. Army Dugway Proving Ground, Dugway, Utah, April 1996.

2. Maibach et al, "Regional Variation in Percutaneous Penetration in Man," *Arch. Environ. Health,* Volume 23, pp 208-211 (1971).

3. Sim, V.S., *Variation of Different Intact Human-Skin Sites to the Penetration of VX*, U.S. Army Chemical Research and Development Laboratories, CRDLR 3122, 1962.

4. Arca, Victor J. et al, *Physiological Protective Dosage Factor Testing of The Responder Suit*, ERDEC-TR-312, U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, Maryland, January 1996.

5. Arca, Victor J., *Physiological Protective Dosage Factor Testing of The Suit, Contamination Avoidance, Liquid Protective (SCALP),* ERDEC-TR-444, U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, Maryland, December 1997.

6. Arca, Victor J., *Man In Simulant Testing (MIST) of Domestic Preparedness Suits, Kappler Model 42483, Responder CSM Level A Suit,* ECBC-TR-030, U.S. Army Edgewood Chemical Biological Center, Aberdeen Proving Ground, Maryland, May 1999.