

TEST RESULTS OF AIR-PERMEABLE CHARCOAL
IMPREGNATED SUITS TO CHALLENGE BY CHEMICAL
AND BIOLOGICAL WARFARE AGENTS AND
SIMULANTS: EXECUTIVE SUMMARY

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Executive Summary

As part of the Domestic Preparedness Program, five air-permeable charcoal impregnated suit designs were tested to assess their capability to protect in a “CW (chemical warfare) and BW (biological warfare)” agents environment. Swatches of material from each suit design were tested for resistance to permeation by Sarin (GB) and Mustard (HD). From that data, the authors calculated the estimated time it would take for sufficient agent to permeate the suit to reach agent breakthrough criteria derived from limited physiological data. Each suit design was also tested for its protection factor in an aerosol environment (aerosolized corn oil, which may be representative of a chemical or biological agent, was used). Protection factor (PF) is defined as the ratio between the challenge concentration outside the suit and the measured concentration inside the suit. The tests are described, and the calculated physiologically–derived breakthrough times and protection factors are presented.

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Preface

The work described herein was authorized under the Expert Assistance (Equipment Test) Program for the U. S. Army Soldier and Biological Chemical Command (SBCCOM) Program Director for Domestic Preparedness.

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TEST RESULTS OF AIR-PERMEABLE CHARCOAL IMPREGNATED SUITS TO CHALLENGE BY CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS: EXECUTIVE SUMMARY

1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing preparedness for terrorist attacks using weapons of mass destruction. The DoD responded by forming the Domestic Preparedness Program that same year. One of the objectives of the Domestic Preparedness Program is to enhance federal, state and local emergency and hazardous material (HAZMAT) response to nuclear, biological and chemical (NBC) terrorism incidents. As part of an effective response, emergency and HAZMAT personnel who are responding to an incident will use personal protective equipment (PPE) to protect them from exposure to chemical agents or biological agents. The specific PPE that would be used by these federal, state and local emergency and HAZMAT personnel would depend upon the situation encountered and what PPE is held in inventory. In some cases, air-permeable charcoal impregnated protective suits may be used to enter a contaminated or potentially contaminated area. Air-permeable charcoal impregnated protective suits are designed to protect the wearer's skin from chemical vapor. Recognizing this need, the U.S. Army Soldier and Biological Chemical Command (SBCCOM) established a program to test some of the air-permeable charcoal impregnated suit designs, using CW agents and test procedures developed for assessment of military-issue CW protective equipment. A detailed technical report was generated for each suit design tested, and a summary report was prepared that presented the essential results for all the suits in a single document. Because those reports are rather lengthy and technical, this report was prepared. This report is an overview of the results of the evaluation and this information is intended for federal, state and local emergency and HAZMAT personnel as an aid in their evaluation (and possible modification) of current work rules regarding specific air-permeable charcoal impregnated suits currently in inventory and as an aid in future procurement of appropriate air-permeable charcoal impregnated suits. This is especially important if these personnel choose to include military chemical agent protection as a criterion for purchase. This information supplements data and information provided by the suits' manufacturers. The suits were tested in new, as-received condition. The effects of aging, temperature extremes, laundering, and other factors are beyond the intended scope of this test program. These tests are conducted to assess percutaneous (i.e. skin) protection¹ only.

Each suit was examined in two different ways, called swatch tests and aerosol tests. In the swatch tests, sample swatches were cut from selected areas (the basic suit material, a suit seam, and at least four other areas that were dependent upon the suit configuration) of each

¹ Inhalation and ocular protection are typically provided by the use of a respirator that covers the eyes, nose and mouth.

suit design. These swatches were then exposed to the chemical agents Mustard (HD) and Sarin (GB), and the passage of agent through them measured. Sarin is a non-persistent (volatile) nerve agent, and HD is a persistent blister agent. In the aerosol tests, each suit design was donned by volunteer testers, who carried out a prescribed sequence of movements inside a test chamber containing a controlled aerosol of corn oil that is a non-toxic simulant for chemical and biological agent aerosols. Instrumentation continuously measured the concentration of simulant inside the suit. Each of these tests examined different aspects of the protection provided by the suits.

Protection provided by a suit system may vary from one unit to another, due to variations in body size and shape affecting the suit's fit; and from one occasion to another, due to unavoidable differences in the execution of the prescribed movements. For these reasons, each suit system design was subjected to multiple test repetitions, using a number of different sample suits, volunteer testers, and occasions.

2. LIQUID CHALLENGE/VAPOR PERMEATION TEST (SWATCH TEST)

Three swatches were taken from a minimum of six different areas of the suit or ensemble – at least 18 total swatches per suit design for GB and at least 18 others for HD. The swatches were placed in a test fixture and a predetermined (10 g/m^2) liquid agent challenge, GB or HD, was applied to the top surface of each swatch, and the fixture sealed. Periodically, over 24 hr, gas samples were taken from below the swatches. The amount of agent vapor that permeated the test swatch at each sampling time was measured using a highly sensitive, accurate, miniaturized gas chromatograph and sampling system known as MINICAMS™ (OI Analytical, CMS Field Products Group, Birmingham, AL).

The cumulative mass of agent vapor, which has permeated each of the swatches at each sampling time, divided by the area of the swatch, is defined as the permeation, M_f .

The permeation for each suit design tested was compared with other suit designs. Normally, continuous exposure to chemical agent would not exceed 8 hr (480 min) because the responder needs to be concerned with heat stress and fatigue.

An average cumulative permeation value (M_f) for each suit design and agent combination was calculated by averaging the M_f values for the 18 swatches.

The permeation will typically vary greatly from one area of a suit to the next, because of differences in materials and thickness. A composite average permeation value was calculated by assigning a weighting factor to the permeation value for each swatch, roughly proportional to the actual area on the suit system that the swatch represents. This resulted in a calculated overall permeation for each suit design.

Mustard vapor can produce skin irritation (erythema) at dosages (product of concentration and exposure time) of approximately 100 mg-min/m^3 . Sarin vapor can produce

incapacitation at dosages of approximately 8000 mg-min/m³. These dosages were set as limits, and the average time to reach each of the limits was calculated using the weighted values of the swatch test results, and this average time was designated the "physiologically-derived breakthrough time" for the suit, under the specific test conditions.

The calculated breakthrough times from all the suit swatches were collected and presented in Table 1.

Table 1. Swatch Test Results for Suits

Test Item	Breakthrough time, minutes	
	GB incapacitation	HD erythema
LANX Chemical Protective Undergarment Ensemble	>480	71
LANX Chemical Protective Overgarment	>480	161
Giat Tactical Operations Multipurpose Protective Suit	>480	342
Giat NBC SWAT Suit	>480	>480
Giat UNISCAPH Undergarment	>480	>480

3. SYSTEM TEST (AEROSOL SIMULANT)

This test measured the leakage of a challenge corn-oil aerosol (physical simulant for biological or chemical aerosol) into a suit ensemble while people were wearing ensembles of different sizes. Volunteers dressed in air-permeable suits with self-contained breathing apparatus (SCBA) entered a chamber with aerosol simulant. Instrumentation measured any aerosol leakage (presumed to be penetration) into the suit through gaps between ensemble components. During the test, the people in the suits performed standardized pre-operational movements.

Eight suits of each design were worn by 12 volunteers on each of two days (not necessarily the same 12 on both days), for a total of at least 22 trials for each suit design. Thus not all of the volunteers or suit replicates were used in equal numbers of trials to accomplish the tests. Only pre-operational routines were run for these suits. See Table 2.

Table 2. Aerosol Test Exercise Routine

Test	Description of Exercise
Pre-Operational – Each exercise performed for 1 min.	1) Standing still, normal breathing
	2) Bending forward and touching toes
	3) Jogging in place
	4) Raising arms above head and looking upward
	5) Bending knees and squatting
	6) Crawling on hands and knees
	7) Torso twists with hands folded on chest
	8) Standing still, normal breathing

Protection Factor (PF) testing of permeable suits was only completed in the pre-operational exercise scenario. From this test a protection factor (PF) is derived. In simplest terms, PF is a measure of the challenge concentration outside the suit divided by the concentration inside the suit ensemble. For example, if the concentration of aerosol inside the suit ensemble is found to be 1/10th the value of the average concentration outside the suit ensemble, the PF is equal to 10. The operational test scenario was not run on these suits due to the low PF values achieved in the pre-operational exercise scenario. Permeable suits are designed to filter and react with chemical agents through absorption by the carbon-impregnated cloth. They are designed to trap agent vapors while allowing moisture to escape.

Samples of aerosol are taken continuously at the neck area and upper arm within the suit and their concentrations are measured by laser photometry, recorded in a computer file and displayed continuously on a computer monitor. These sampling locations were selected as being the most likely locations for aerosol leakage to occur. Therefore the PF is thought to be the worst-case estimation. The PF data are presented based upon predetermined PF pass levels, ranging from 2 to 100,000 (i.e., at each pass level the number of failing and passing suits is recorded). The higher the percentage of test runs that pass at a given PF, the greater the probability that the suit will provide that level of protection in use. These levels are point estimates and are derived from Army requirements. The results are given in Table 3.

Table 3. Summary of Overall Aerosol Test Results

Item	Aerosol PF Pass Rate Per Cent at PF Equal to:		
	2	5	10
	Pre-Operational	Pre-Operational	Pre-Operational
LANX Chemical Protective Undergarment	91	11	0
LANX Chemical Protective Overgarment	91	11	0
Giat Tactical Operations Multipurpose Protective Suit	93	48	0
Giat NBC SWAT Suit	73	34	5
Giat UNISCAPH Undergarment	90	12	0

4. CONCLUSIONS

The test data reveals that the air-permeable charcoal impregnated protective suit materials tested can protect the wearers from liquid CW agents but that the suits only provide minimal protection from a vapor or aerosol threat. Breakthrough times should not be interpreted as the time that a suit can be safely worn, either for HD or GB. Breakthrough times should only be used to compare suit materials. In other words, the suit material does provide limited skin protection, but the suit itself provides little or no skin protection.