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ECBC-TR-367

DOMESTIC PREPAREDNESS PROGRAM: SARIN (GB) AND DISTILLED SULFUR MUSTARD (HD) VAPOR CHALLENGE TESTING OF COMMERCIAL SELF-CONTAINED BREATHING APPARATUS

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April 2004

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20040524 010

ABERDEEN PROVING GROUND, MD 21010-5424

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE *(DD-MM-YYYY)*
XX-04-2004

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
Mar 2000 - Oct 2002

4. TITLE AND SUBTITLE
Domestic Preparedness Program: Sarin (GB) and Distilled Sulfur Mustard (HD) Vapor Challenge Testing of Commercial Self-Contained Breathing Apparatus

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Lins, Raymond R.; Campbell, Lee E.; and Hyre, Aaron M.

5d. PROJECT NUMBER
None

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
DIR, ECBC, ATTN: AMSRD-ECB-RT-AE, APG, MD 21010-5424

8. PERFORMING ORGANIZATION REPORT NUMBER
ECBC-TR-367

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
DIR, ECBC, ATTN: AMSRD-ECB-EN-R, APG, MD 21010-5424

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
This report may also be accessed at the following website: http://www.ecbc.army.mil/hld/ip/reports.htm#respirators

14. ABSTRACT
Results of performance testing of six National Institute for Occupational Safety and Health approved commercial self-contained breathing apparatus (SCBA) facepiece designs are described. A series of tests was performed to determine sarin (GB) and distilled sulfur mustard (HD) vapor breakthrough of SCBA facepieces using manikin head form and simulated breathing.

15. SUBJECT TERMS

GB	HD	Mustard	Chemical Agent Breakthrough
Sarin	SCBA	Self-Contained Breathing Apparatus	Agent Challenge Testing

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Sandra J. Johnson
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
U	U	U	UL	14	(410) 436-2914

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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PREFACE

The work described in this report was authorized under the Expert Assistance Program for the U.S. Army Edgewood Chemical Biological Center (ECBC) Homeland Defense Business Unit. The work started in March 2000 and was completed in October 2002.

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Acknowledgments

The authors thank Mike Wasserman for his laboratory expertise during agent testing. The authors also acknowledge Frank DiPietro for managing the equipment acquisition and test scheduling necessary to accomplish the testing in a timely manner.

The authors are grateful to Dr. Jimmy L. Perkins, University of Texas School of Public Health, San Antonio, TX, and all the participating members of the Expert Review Panel for CB Equipment Testing for their constructive reviews and comments.

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CONTENTS

1. INTRODUCTION 7

2. OBJECTIVES AND SCBA DESCRIPTIONS 7

3. CHEMICAL AGENT TESTING 8

3.1 Chemical Agent Testing Equipment 8
3.1.1 Vapor Generator 8
3.1.2 SCBA Test Chamber 8
3.1.3 Breather Pump 9
3.2 Chemical Agent Testing Methods 9
3.2.1 SCBA Face Seal 9
3.2.2 Agent Test 9
3.3 Chemical Agent Test Results and Discussion 10
3.3.1 Test Results 10
3.3.2 Discussion 10

4. CONCLUSIONS 10

GLOSSARY 13

TABLES

1. Conditions for Testing SCBAs 10

2. Concentration of Agent Inside SCBA Facepiece 11

DOMESTIC PREPAREDNESS PROGRAM: SARIN (GB) AND DISTILLED SULFUR MUSTARD (HD) VAPOR CHALLENGE TESTING OF COMMERCIAL SELF-CONTAINED BREATHING APPARATUS

1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1966), 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 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, commercial self-contained breathing apparatus (SCBA) may be used when entering an NBC contaminated or potentially contaminated area. A self-contained breathing apparatus is an atmosphere-supplying respirator for which the breathing air source is designed to be carried by the user, that is, the breathing air is contained in a compressed gas cylinder that the user carries on his back. This phase of the program tasked the U.S. Army Edgewood Chemical Biological Center (ECBC), U.S. Army Soldier and Biological Chemical Command (SBCCOM), to perform chemical agent testing of commercial SCBAs.

For this phase of the program, six National Institute for Occupational Safety and Health (NIOSH), Washington, DC, approved SCBA designs were selected for testing. For these tests, the compressed gas cylinders were not challenged with agent vapor. Air was supplied from an external source. All other components of the SCBA were challenged with agent.

A glossary of terms used is included at the end of this report.

2. OBJECTIVES AND SCBA DESCRIPTIONS

The objective of this project was to determine the protective potential of the SCBAs against Sarin (GB) and distilled sulfur mustard (HD) vapor while the SCBA was operated in dynamic mode by means of a breather pump. The facepiece of the SCBA was mounted on a manikin test fixture; the breather pump was connected to the mouth orifice. The air cylinders were not challenged with CW agent vapor; only the air regulator, hoses, harness, and facepieces were in the agent exposure chamber. The agent vapor challenge was a much higher concentration than the SCBA is authorized to be used in, but this challenge was selected to be more effective in evaluating the agent resistance of the SCBA components. All the SCBAs

were tested in demand mode. The test results apply only to protection from GB and HD vapor and should not be extrapolated to infer results from other chemical challenges.

A listing of the SCBAs (six of each model) tested in this phase of the project are as follows:

- Draeger 4500 Air Boss
- Scott AirPak 50 4.5 SCBA
- MSA Custom 4500
- Survivair Panther
- Interspiro (Spiromatic 9030)
- Interspiro (Chemical Warfare Kit)

3. CHEMICAL AGENT TESTING

3.1 Chemical Agent Testing Equipment.

3.1.1 Vapor Generator.

GB and HD vapors were generated by using a syringe pump that injected liquid agent into a heated tee in the air dilution line. The rate of injection was such that the concentration was controlled to that specified in the test plan. The agent was vaporized in a heated tee, and carried by the dilution air into the mixing chamber, thence into the exposure chamber. An Ambient Air Analyzer, (MIRAN) model 1A, was used to monitor the concentration in the test chamber during the test.

3.1.2 SCBA Test Chamber.

The test chamber for the SCBAs was a Plexiglas box of approximately 200 L volume with a removable front panel and four legs on the bottom about 4 in. long, which allowed air to flow under the chamber when it was located inside a fume hood. A test fixture, called SMARTMAN (SiMulant Agent Resistant Test MANikin), which is a human head form, medium size, with a movable facepiece and an inflatable peripheral seal, was attached to the floor of the chamber. The peripheral seal is used to prevent face seal leaks so that permeation of CW agents through the face mask can be evaluated. The mouth orifice of the head form was connected by a large tube to a breather pump; there were also two sampling tubes in the nose, one in the eye, and one in the forehead. All these tubes pass down through the interior of the head form, down through the floor of the chamber, and connect to remote detectors and the breather pump or other monitoring devices, such as pressure gauges. Since agent-air mixture passes through the test chamber during the test, the outlet ports on top of the chamber are covered by military M12A1

filters to scrub agent from the air passing through. Other ports in the chamber walls are used for introducing the agent challenge into the chamber, to attach pressure gauges for monitoring pressure, to introduce oil aerosol for preliminary leak testing of an installed respirator, or to monitor the agent concentration inside the chamber.

3.1.3 Breather Pump.

The Military Breather Pump E1R1 was used to simulate breathing through the SCBA facepiece. This is a reciprocating pump that produces a sinusoidal breathing pattern by means of a reduction planetary gear system that incorporates a Scotch Yoke. With each piston stroke, the flow rate starts at zero liters per minute, rises to a peak flow midway through the stroke, and falls back to zero at the end of the stroke. During the initial stroke air is pulled from the test chamber through the SCBA facepiece; on the return stroke this air is exhausted through the exhalation valve of the respirator. The two pump strokes, forward and reverse, produce a complete sine wave pattern. The peak flow produced by this pump is approximately pi times the minute volume. The minute volume (liters pumped in 1 min) and the number of strokes per minute (breaths) can be adjusted on this pump.

3.2 Chemical Agent Testing Methods.

3.2.1 SCBA Face Seal.

The SCBA facepiece was mounted on the SMARTMAN by tightening the straps of the harness. The peripheral seal was inflated (3-5 psig) to form a seal against the inside of the facepiece. Before an agent test was started, an aerosol leakage test was performed, using the TDA-99M Aerosol Leak Tester, to assure that any agent detected inside the facepiece did not enter by the sealed surfaces. The detector section of the tester was connected to one of the SMARTMAN sampling ports inside the respirator, and the aerosol was directed against the facepiece through a wand. The breather pump was turned on during the leak test. If no leak was detected, then the chamber was closed and the aerosol was injected into the test chamber. If an aerosol leak was detected, the leak path was found and corrected. If there was no leak, the agent test was performed.

3.2.2 Agent Test.

For the agent test, a MINICAMS® detector was connected to a port in the nose area, to monitor for the presence of agent inside the facepiece. The agent challenge, generated as described above (Section 3.1.1), was passed from the mixing chamber into the SCBA test chamber. Each facepiece was tested three times with an HD challenge and three times with a GB challenge. One of each set of three trials was continued for an additional 2 hr, unless the facepiece showed a high concentration after 1 hr. The conditions used for testing are listed in Table 1.

Table 1. Conditions for Testing SCBAs

Rate of air flow through exposure chamber	50 L/min
Concentration of agent challenge	200 mg/m^3
Total test time if breakthrough is not observed	60 min or 3 hr
Temperature of test chamber	25 ± 3°C
Flow rate of breather pump	25 L/min
Pump strokes per minute	25
Volume per breath	1 L

3.3 Chemical Agent Test Results and Discussion.

3.3.1 Test Results.

Six different types of SCBA were tested. Since the SCBA is normally used for 1 hr, the tests were conducted for 1 hr, with the exception that one of each type was tested for 3 hr. Agent concentration was monitored at the nose of the headform. The data are tabulated in Table 2. The concentration of agent inside the facepiece at the nose sampling port is given in nanograms per liter at the end of either 1 or 3 hr.

3.3.2 Discussion.

Each system had an aerosol leak test performed before the agent test to assure that any agent detected inside the facepiece did not enter by the sealed surfaces. Of the SCBAs tested, only with the Interspiro Spirometer 9030 and the Interspiro Chemical Warfare Kit was no agent detected inside the facepiece after 1 hr, or in two cases, after 3 hr. The SCBAs tested, except the Interspiro Chemical Warfare Kit , were not designed for use in a chemical agent environment.

4. CONCLUSIONS

Six types of commercial self-contained breathing apparatuses (SCBAs) were tested. Three of each type were tested against a challenge concentration of 200 mg/m^3 of GB, and three of each type were tested against a challenge concentration of 200 mg/m^3 of HD for 1 hr, the normal usage time for a SCBA. One of each type (both agents) was tested for an additional 2 hr, unless the facepiece showed a high concentration of agent after 1 hr. Of the six tested, only the Interspiro Spiromatic 9030 and the Interspiro Chemical Warfare Kit had no agent detected inside the facepiece during the tests. The Interspiro Chemical Warfare Kit is the only one of the six that was designed for use in a chemical agent environment.

Table 2. Concentration of Agent Inside SCBA Facepiece

Respirator	Agent	1 hr, ng/L	3 hr, ng/L
Survivair Panther	HD	<0.0001	<0.0001
Survivair Panther	HD	0.0	Not Tested
Survivair Panther	HD	0.0	Not Tested
Survivair Panther	GB	2.5	Not Tested
Survivair Panther	GB	8.0	Not Tested
Survivair Panther	GB	2.0	24.0
MSA	HD	21.4	25.2
MSA	HD	7.2	Not Tested
MSA	HD	16.4	Not Tested
MSA	GB	31.0	Not Tested
MSA	GB	2.3	Not Tested
MSA	GB	58	Not Tested
Scott	HD	23.9	49.4
Scott	HD	51.7	Not Tested
Scott	HD	38.3	Not Tested
Scott	GB	60.0	Not Tested
Scott	GB	8.0	Not Tested
Scott	GB	19.0	Not Tested
Draeger	HD	39.0	65.3
Draeger	HD	46.2	Not Tested
Draeger	HD	61.4	Not Tested
Draeger	GB	160.0	Not Tested
Draeger	GB	120.0	Not Tested
Draeger	GB	200.0	Not Tested
Interspiro Spiromatic 9030	HD	<0.0001	<0.0001
Interspiro Spiromatic 9030	HD	<0.0001	Not Tested
Interspiro Spiromatic 9030	HD	<0.0001	Not Tested
Interspiro Spiromatic 9030	GB	<0.0001	<0.0001
Interspiro Spiromatic 9030	GB	<0.0001	Not Tested
Interspiro Spiromatic 9030	GB	<0.0001	Not Tested
Interspiro Chemical Warfare Kit	HD	<0.0001	<0.0001
Interspiro Chemical Warfare Kit	HD	<0.0001	Not Tested
Interspiro Chemical Warfare Kit	HD	<0.0001	Not Tested
Interspiro Chemical Warfare Kit	GB	<0.0001	<0.0001
Interspiro Chemical Warfare Kit	GB	<0.0001	Not Tested
Interspiro Chemical Warfare Kit	GB	<0.0001	Not Tested

Note: The SCBAs were operated in demand mode. The demand mode regulates the amount of air supplied to the facepiece as the user, or breather pump, requires.

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GLOSSARY

Breather Pump Model E1R1

Manufactured by Jaeco Fluid Systems Inc., Exton, PA. This pump is used to simulate human breathing through a filter. The pump stroke can be adjusted to change the volume of air per stroke over a finite range and is capable of changing the number of strokes per minute.

Facepiece

The portion of a respirator that covers the wearer's nose and mouth (a full facepiece also covers the eyes). The facepiece should make a gas-tight or dust-tight seal with the face. The facepiece is supported by headbands, and contains exhalation valves, and connectors for breathing air.

Ambient Air Analyzer (Miran) Model 1A

Manufactured by Thermo Environmental Instruments Inc., Dover, DE. It is an infrared absorption based detector that uses a long path length cell up to 20 meters, into which the air sample is introduced. This analyzer is used to monitor the challenge concentration of vapor in the test chamber.

MINICAMS®

Trade name for a chemical agent detector in which the agent is adsorbed from a specified volume of air onto an adsorbent tube which is then desorbed into the injection port of a gas chromatograph for analysis (quantitation). The acronym stands for "Miniature Continuous Air Monitoring System." It is manufactured by O. I. Analytical, CMS Field Products Group, Birmingham, AL.

Sarin

An organophosphorus nerve agent, known by the military symbol GB. The chemical name is isopropyl methylphosphonofluoridate. GB reacts with the enzyme cholinesterase, thus interfering with the transmission of nerve impulses.

SMARTMAN

Manufactured by ILC Dover, Frederica. DE. The Simulant Agent Resistant Test Manikin, SMARTMAN, is a cast zinc, hollow shell and comprised of a head, neck, shoulders and upper chest. The head features an anatomically correct surface consisting of dimensional eyes, nose, ears, mouth, forehead, and chin. The facial features are on a movable section of the head to facilitate installing and removing a peripheral front face seal, which is made of rubber and fits into a channel between the face and the permanent part of the head. The seal is inflated to press against the inside of the facepiece seal area to assure against leakage.

Self-Contained Breathing Apparatus

An Open-Circuit Self-Contained Breathing Apparatus is designed to provide the wearer with an atmosphere independent of the ambient air. The air is supplied by a cylinder that is carried on the back of the wearer.

Syringe Pump

A multirange, variable rate infusion pump is used to inject liquid agent at a controlled rate into an air stream to generate a vapor challenge. The liquid agent is contained in a syringe connected by a flexible cannula. The plunger of the syringe is driven at a controlled rate by the pump to deliver a constant flow of agent. The concentration of agent is adjusted by changing the speed setting of the pump.

Leak Detector TDA-99M

The TDA-99M is manufactured by Air Techniques Inc., Baltimore, MD, and is one of the primary tools for assessing aerosol leaks in the mechanical seals of the respirator and the correct fitting of a respirator facepiece to the SMARTMAN headform. The device generates a mineral oil (Brand Name- "Emery 3004") aerosol that is used to detect leakage into the interior of the respirator. A light scattering chamber/photomultiplier tube is used as the sensor in this detector.