



**EDGEWOOD**

**CHEMICAL BIOLOGICAL CENTER**

**U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND**

**ECBC-TR-280**

**DOMESTIC PREPAREDNESS PROGRAM:  
SARIN VAPOR CHALLENGE AND  
CORN OIL PROTECTION FACTOR (PF) TESTING  
OF COMMERCIAL AIR-PURIFYING NEGATIVE PRESSURE RESPIRATORS**

**Lee E. Campbell  
Ray Lins**

**RESEARCH AND TECHNOLOGY DIRECTORATE**

**Alex G. Pappas  
ENGINEERING DIRECTORATE**

**May 2003**

**20030801 118**

*Approved for public release, distribution is unlimited.*



**Aberdeen Proving Ground, MD 21010-5424**

## **Disclaimer**

**The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorizing documents.**

# 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 the 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 Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE 2003 May	3. REPORT TYPE AND DATES COVERED Final; 00 Mar - 00 Sep		
4. TITLE AND SUBTITLE Domestic Preparedness Program: Sarin Vapor Challenge and Corn Oil Protection Factor (PF) Testing of Commercial Air-Purifying Negative Pressure Respirators			5. FUNDING NUMBERS  None		
6. AUTHOR(S) Campbell, Lee E.; Lins, Ray; and Pappas, Alex G.			8. PERFORMING ORGANIZATION REPORT NUMBER  ECBC-TR-280		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) DIR, ECBC, ATTN: AMSSB-RRT-AE/AMSSB-REN-R, APG, MD 21010-5424					
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) DIR, ECBC, ATTN: AMSSB-REN-HD, APG, MD 21010-5424			10. SPONSORING/MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES Website address to obtain report: <a href="http://hld.sbcom.army.mil/ip/commercial_neg_pressure_resp_download.htm">http://hld.sbcom.army.mil/ip/commercial_neg_pressure_resp_download.htm</a>					
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE		
13. ABSTRACT (Maximum 200 words) Results of performance testing of commercial air-purifying negative pressure respirators (NPR) are described. Three series of tests were performed: (1) breakthrough time determinations of cartridges/canisters against Sarin (GB), (2) GB vapor breakthrough determination of entire NPR systems using manikin headform and simulated breathing, and (3) corn-oil protection factor determinations of NPR systems using human subjects. Results indicate that cartridges provide adequate resistance to GB breakthrough against high-concentration challenges. However, corn oil aerosol and high-concentration GB vapor penetration into the breathing zone of the NPR occurs at unacceptable levels.					
14. SUBJECT TERMS GB Chemical agent Protection factor (PF) testing			Sarin Corn oil Breakthrough testing	Aerosol Cartridge Sarin Challenge Testing	15. NUMBER OF PAGES 29
			16. PRICE CODE		
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL		

**BLANK**

## PREFACE

The work described in this report was authorized under the Expert Assistance Program for the U.S. Army Soldier and Biological Chemical Command (SBCCOM) Program Director for Domestic Preparedness. The work started in March 2000 and was completed in September 2000.

The use of either trade or manufacturers' names in this report does not constitute an official endorsement of any commercial products. This report may not be cited for purposes of advertisement.

This report has been approved for public release. Registered users should request additional copies from the Defense Technical Information Center; unregistered users should direct such requests to the National Technical Information Service. This report is tailored for the first responder.

### Acknowledgments

The authors thank Aaron Hyre and Mike Wasserman for their laboratory expertise during the conduct of agent testing.

The authors also thank Gary Hiob, William Fritch, Stephen Chase, Stephen Kaminsky, Karen Torchia, Linda Strickler, Jeff Hofmann, Malcom Little, and MacDonald Goodman for their help and expertise in PF testing. Frank DiPietro and Anthony Saponaro are acknowledged for managing the equipment acquisition and test scheduling necessary to accomplish the testing in a timely manner.

The authors are grateful to the following members of the Expert Review Panel for CB Equipment Testing for their constructive reviews and comments:

- Dr. Jimmy L. Perkins, University of Texas School of Public Health, San Antonio, TX
- Dr. Annetta P. Watson, Life Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN
- Leo F. Saubier, Battelle Memorial Institute, Edgewood Operations, Bel Air, MD

**BLANK**

## CONTENTS

1.	INTRODUCTION .....	7
2.	OBJECTIVES AND RESPIRATORS DESCRIPTIONS .....	7
3.	CHEMICAL AGENT TESTING .....	8
3.1	Chemical Agent Testing Equipment .....	8
3.1.1	Vapor Generator .....	8
3.1.2	Negative Pressure Respirator (NPR) Test Chamber .....	8
3.1.3	Cartridge/Canister Test Chamber .....	9
3.1.4	Breather Pump .....	9
3.2	Chemical Agent Testing Methods.....	9
3.2.1	Respirator Systems .....	9
3.2.2	Cartridges/Canisters.....	10
3.3	Chemical Agent Test Results and Discussions.....	10
3.3.1	Full Respirator on Head Form.....	10
3.3.2	Cartridges/Canisters.....	17
3.3.3	Discussion .....	17
4.	PROTECTION FACTOR TESTING .....	17
4.1	Corn Oil Testing Equipment.....	17
4.2	Protection Factor Testing Method.....	17
4.3	Protection Factor Test Results and Discussion.....	19
5.	CONCLUSIONS .....	24
	APPENDIX – GLOSSARY .....	27

## FIGURES

1.	MSA Millennium Respirators .....	12
2.	Advantage 1000 CBA/RCA Respirators.....	13
3.	Advantage 1000 P100 Respirators .....	14
4.	MSA Phalanx Respirators.....	15
5.	Scott AV2000 Respirators.....	16

## TABLES

1.	Conditions for Testing Respirator Systems.....	10
2.	Conditions for Testing Cartridges/Canisters .....	10
3.	Concentration of GB Inside Respirator.....	11
4.	Final PF Results, MSA Advantage 1000 FFR with GME-P100 Cartridge .....	20
5.	Final PF Results, MSA Advantage 1000 FFR with CBA/RCA Cartridge .....	21
6.	Final PF Results, MSA Millennium Gas Mask with CBA/RCA Millennium Canister .....	22
7.	Final PF Results, MSA Phalanx Gas Mask with Phalanx Canister.....	23
8.	Final PF Results, Scott AV2000 Mask Facepiece with NBC Canister .....	24
9.	Summary of Pass Percentages for Negative Pressure Respirators at Selected PF Levels.....	25

**DOMESTIC PREPAREDNESS PROGRAM:  
SARIN VAPOR CHALLENGE AND  
CORN OIL PROTECTION FACTOR (PF) TESTING  
OF COMMERCIAL AIR-PURIFYING NEGATIVE PRESSURE RESPIRATORS**

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, commercial respirator systems with canisters/cartridges may be used to enter a contaminated or potentially contaminated area.

This program tasked the U.S. Army Edgewood Chemical Biological Center (ECBC) of the U.S. Army Soldier and Biological Chemical Command (SBCCOM) to perform chemical agent testing of commercial respirator systems and canisters/cartridges. A cartridge is distinguished from a canister by virtue of the quantity of adsorbent, i.e., a canister contains more than 150 mL of adsorbent and a cartridge contains less.

For this phase of the program five different NIOSH-approved air-purifying negative pressure respirators were selected. A negative pressure respirator (tight-fitting) is a respirator in which the air pressure inside the facepiece is negative during inhalation with respect to the ambient air pressure outside the respirator. A tight-fitting facepiece means a respiratory inlet covering that forms a complete seal with the face.

A glossary of terms used is included in the appendix of this report.

2. OBJECTIVES AND RESPIRATORS DESCRIPTIONS

The objectives of this project were threefold: (1) to determine the protective potential of some commercial air-purifying full facepiece negative pressure respirators against GB vapor; (2) to determine the adsorption efficiency of the canister/cartridge to GB vapor; and (3) to determine the protection factor (PF) for the respirators.

The air-purifying negative pressure respirators tested in this phase of the project follow:

- MSA Advantage 1000 Full Facepiece Respirator (FFR) with GME-P100 Advantage Cartridge
- MSA Advantage 1000 CBA/RCA FFR with CBA/RCA Advantage Cartridge
- MSA Millennium Gas Mask with CBA/RCA Millennium Canister (NATO 40 mm thread)
- MSA Phalanx CBA/RCA Gas Mask with CBA/RCA Phalanx Canister
- Scott AV2000 Comfo, 4-Point Rubber Mask Facepiece with NBC Canister and 42-40 mm adapter.

### 3. CHEMICAL AGENT TESTING

#### 3.1 Chemical Agent Testing Equipment.

##### 3.1.1 Vapor Generator.

GB vapors were generated by using a syringe pump to inject liquid GB into a heated tee in the dilution airline. The volume of dilution air and the amount of GB injected were controlled at such rates that the resultant concentration was that specified in the test plan. The GB, vaporized in the heated tee, was carried by the dilution air into a mixing chamber for uniform mixing. From the mixing chamber the mixture was passed into the systems test chamber at the beginning of the test. A Hydrogen Flame Emission Detector (HYFED) was used to monitor the concentration in the test chamber during the test.

##### 3.1.2 Negative Pressure Respirator (NPR) Test Chamber.

The test chamber for the NPRs was a Plexiglas box approximately 2 feet cubed with a removable front panel and four legs on the bottom about 4 inches 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 face piece and an inflatable peripheral seal, was attached to the floor of the chamber. 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 Cartridge/Canister Test Chamber.

The test chamber for the canister comprises two parts, the base plate and the cover. Both parts are machined from stainless steel. The assembled chamber is a closed cylinder. The base plate has a raised portion and a somewhat wider rim; when the cover is in place the bottom of the cover rests on the rim while the raised portion of the base plate seals against the inside of the cover by means of O-rings. In the center of the base is an orifice and an adapter machined to accommodate a NATO thread of a canister. Another orifice is offset from the center and is machined with pipe threads; agent challenge is introduced into the chamber by this means. The chamber, when closed, accommodates a canister up to the size of a C2A1. The center orifice is connected by a line outside the chamber to a vacuum source of a breather pump in order to pull the agent challenge through the chamber. A rotameter and a scrubber filter are placed in this line; there is also a connection between the rotameter and the test chamber for a detector used to monitor GB agent breakthrough.

### 3.1.4 Breather Pump.

The Military Breather Pump E1R1 (Jaeco Fluid Systems, Inc, Exton, PA) was used to simulate breathing through the respirator. 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 respirator (including the canister); 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 one minute) and the number of strokes per minute (breaths) can be adjusted on this pump.

## 3.2 Chemical Agent Testing Methods.

### 3.2.1 Respirator Systems.

The respirator system, including an attached canister or cartridge, 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 face blank of the respirator. Before an agent test was started, an aerosol leakage test was performed, using the TDA-99M Aerosol Leak Tester. 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 respirator 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. For the GB test, a MINICAMS® detector was connected to two ports in the eye and nose areas, to monitor for the presence of GB inside the respirator. The GB challenge, generated as described above (para. 3.A. (1)), was passed from the mixing chamber into the NPR test chamber. The conditions used for testing are listed in Table 1.

Table 1. Conditions for Testing Respirator Systems

Rate of air flow through exposure chamber	50 L/min
Concentration of challenge GB	200 mg/m <sup>3</sup>
Breakthrough concentration limit	0.0001 mg/m <sup>3</sup>
Total test time if breakthrough is not observed	60 min or 6 hr
Precondition of cartridge/canister	25°C/50% RH/6 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

### 3.2.2 Cartridges/Canisters.

The cartridges/canisters were tested separately to establish their performance against a GB vapor challenge. A total of 22 canisters (of each type) was tested. This number represents 90% reliability at 90% confidence level when no failures occur amongst the 22 items tested. The canisters were preconditioned at 50% relative humidity (RH) and 25 C for 6 hr before agent testing. The purpose of the preconditioning was to establish a uniform level of moisture on the adsorbent similar to what might be encountered in use, and that would not adversely affect the adsorption of GB. Testing the canisters alone would also allow one to infer if a system failure occurs that the reason is either the respirator or the canister. Each canister was tested for 60 min, which is the maximum time the system is expected to be used. The test conditions are listed in Table 2.

Table 2. Conditions for Testing Cartridges/Canisters

GB challenge concentration	200 mg/m <sup>3</sup>
Flow rate, NPR canisters	25 L/min
Breakthrough concentration	0.0001 mg/m <sup>3</sup>
Test time if breakthrough is not observed	1 hr
Precondition of cartridge/canister	25°C/50% RH/6 hr
Temperature of test chamber	25±3°C
Relative humidity of test air	50±5%

### 3.3 Chemical Agent Test Results and Discussions.

#### 3.3.1 Full Respirator on Head Form.

The negative pressure respirators were tested for a period of one hour, and the medium size respirator of each model was tested for up to 6 hr. The 6-hr test was done in order to generate additional useful data. The results are tabulated in Table 3. Graphical results for the individual tests are presented in Figures 1 through 5.

Table 3. Concentration of GB Inside Respirator (acceptable concentration is <0.1 ng/L)

<i>Respirator</i>	<i>Concentration After 1 hr, ng/L</i>		<i>Concentration After 6 hr, ng/L</i>	
	<i>Eye</i>	<i>Nose</i>	<i>Eye</i>	<i>Nose</i>
MSA Millennium, small	0.3	3.0		
MSA Millennium, medium	0.0	4.0	8.0	29
MSA Millennium, large	0.6	3.4		
MSA Advantage 1000, small CBA/RCA	0.7	3.3		
MSA Advantage 1000, medium CBA/RCA	0.0	4.0	24	45
MSA Advantage 1000, large CBA/RCA	2.5	8.0		
MSA Advantage 1000, small GME-P100	0.0	2.8		
MSA Advantage 1000, medium GME-P100	0.0	0.5	0.5	8.0
MSA Advantage 1000, large GME-P100	0.0	0.0		
MSA Phalanx small	7	8		
MSA Phalanx medium	4	5	41	52
MSA Phalanx large	2	11		
Scott AV2000 small	7.0	18		
Scott AV2000 medium	0.0	25	3.0	70
Scott AV2000 large	4.0	2.5		

Figure 1. MSA Millennium Respirators

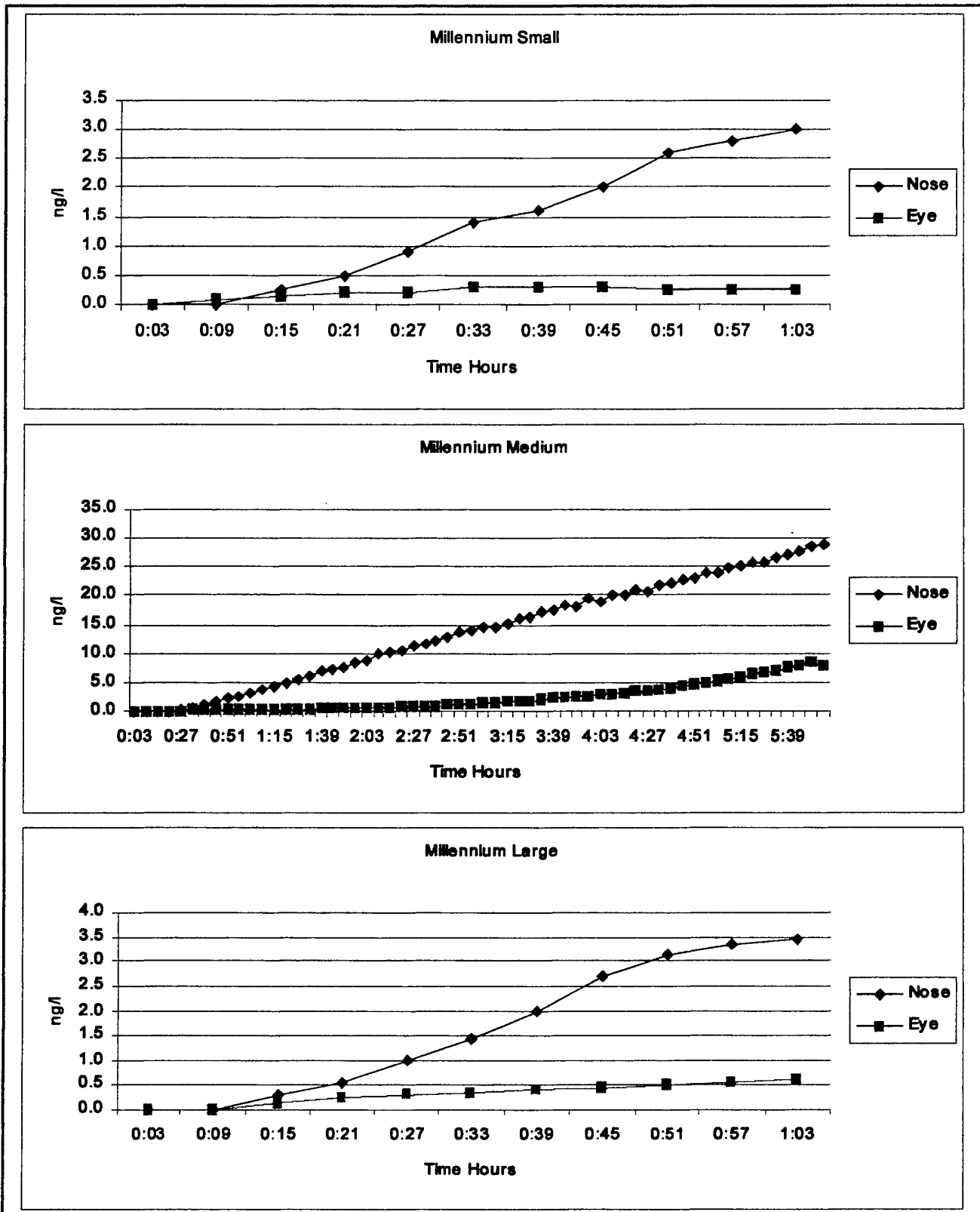


Figure 2. Advantage 1000 CBA/RCA Respirators

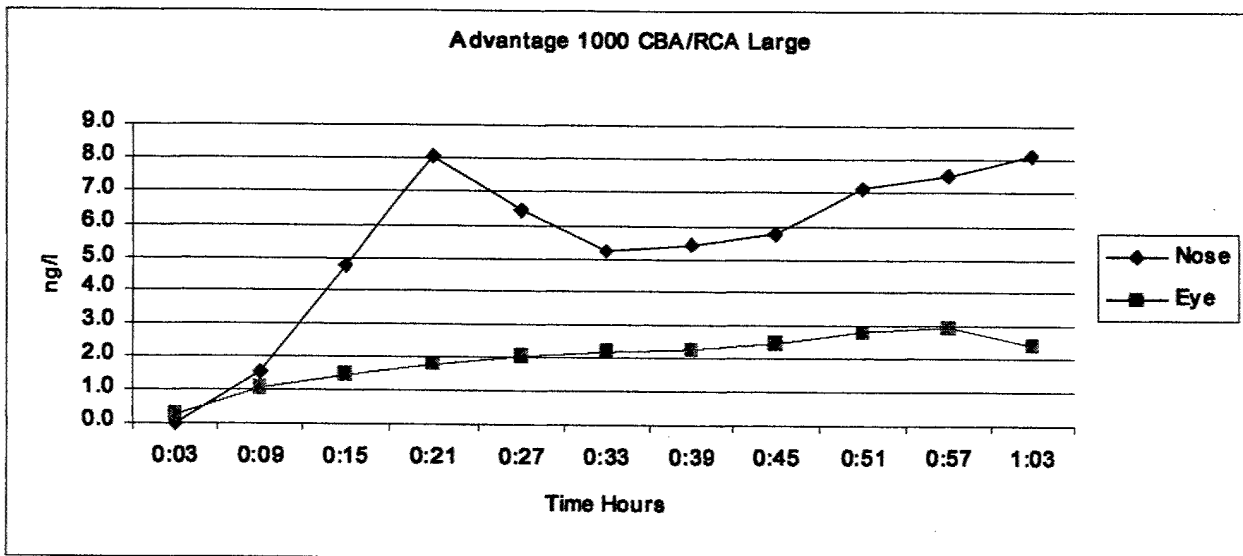
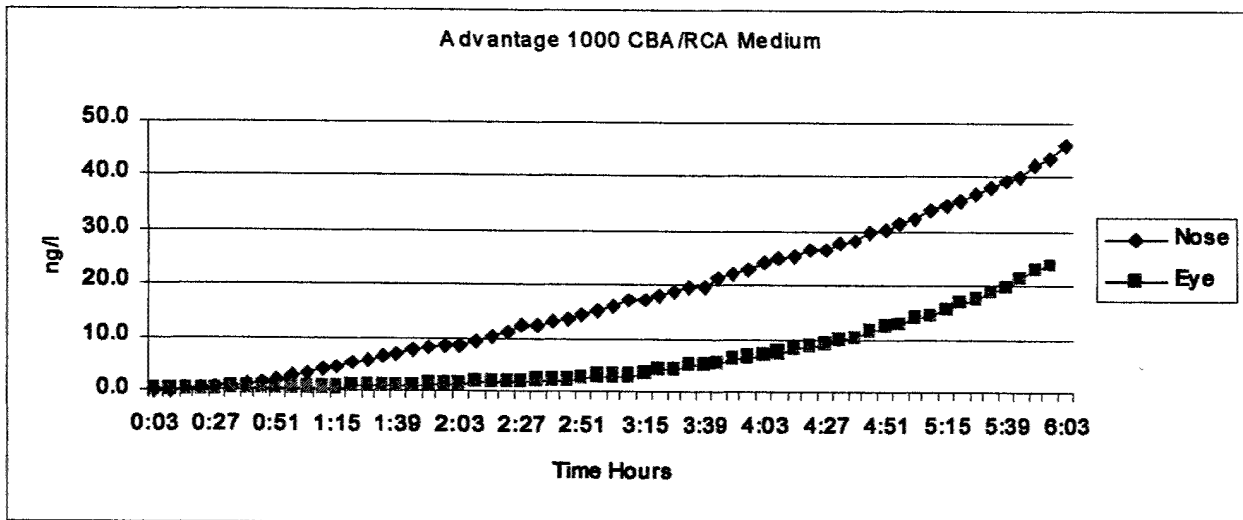
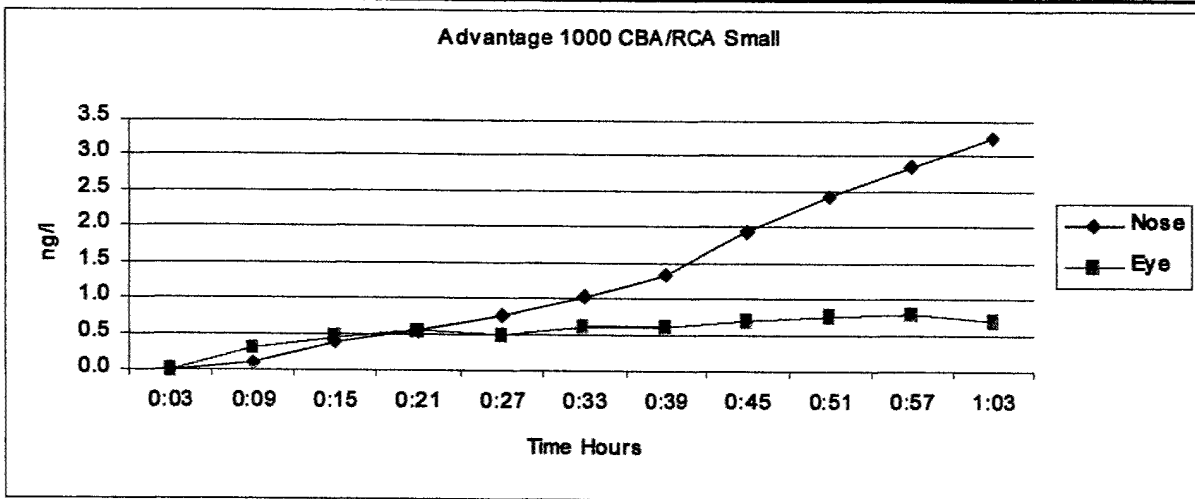


Figure 3. Advantage 1000 P100 Respirators

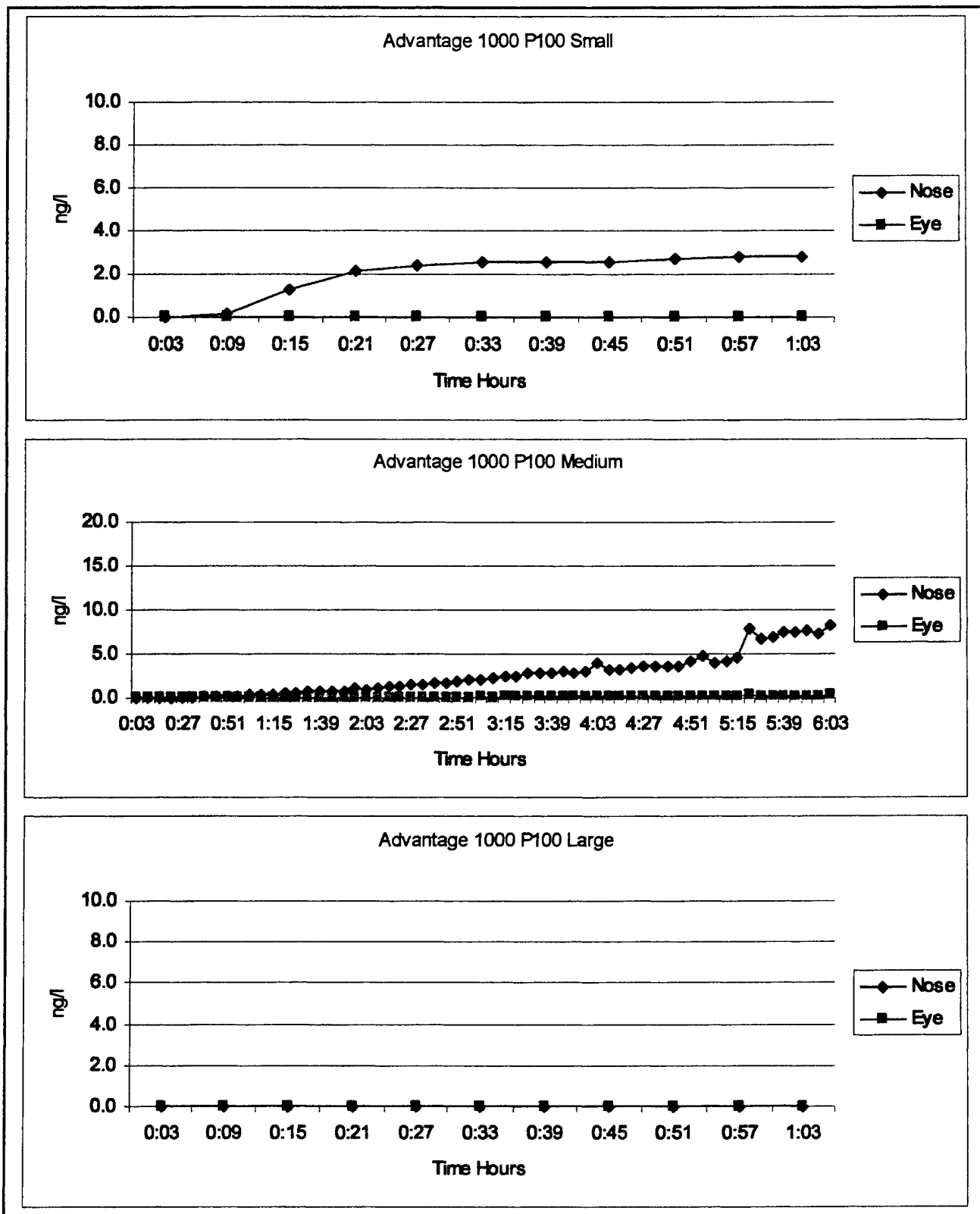


Figure 4. MSA Phalanx Respirators

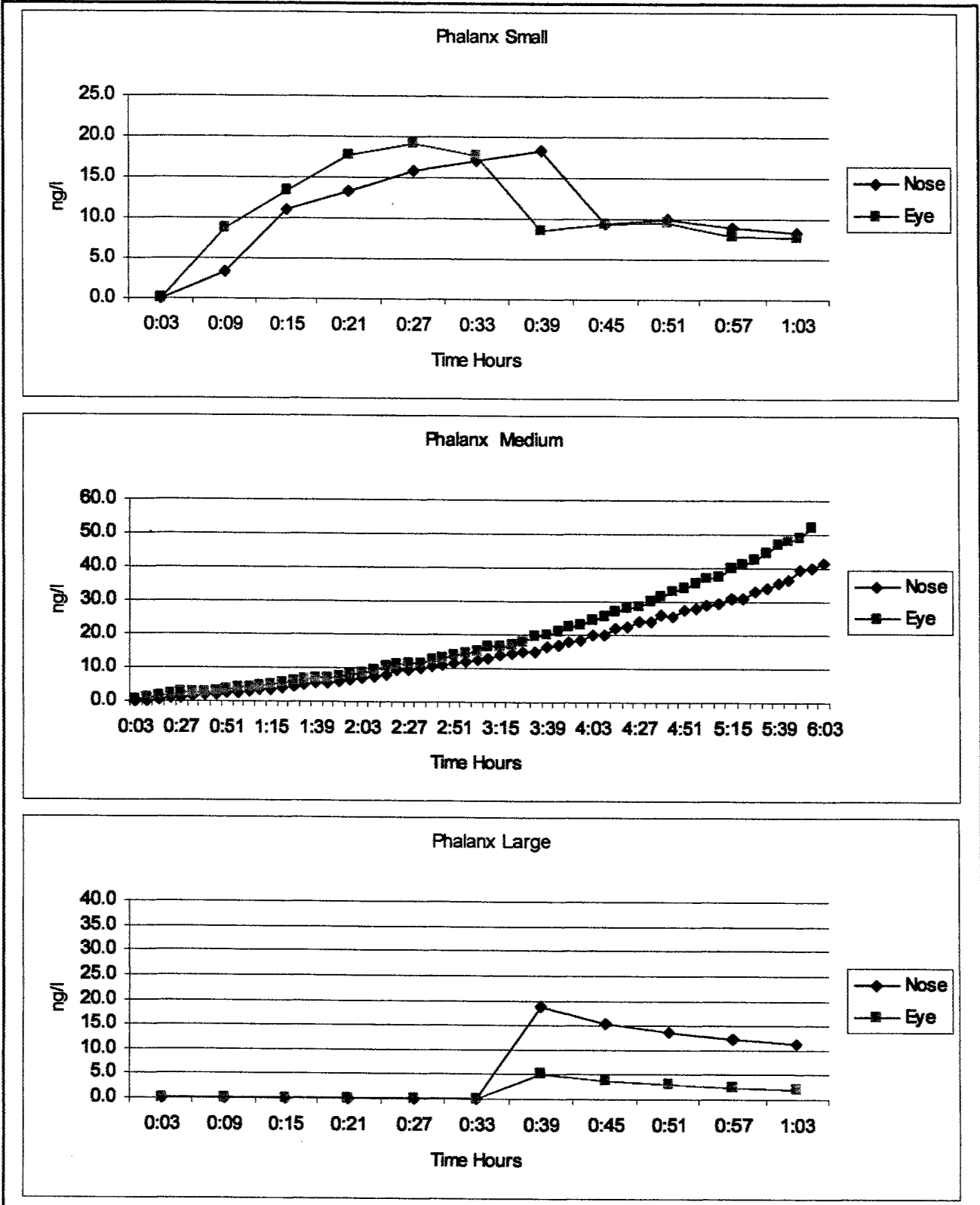
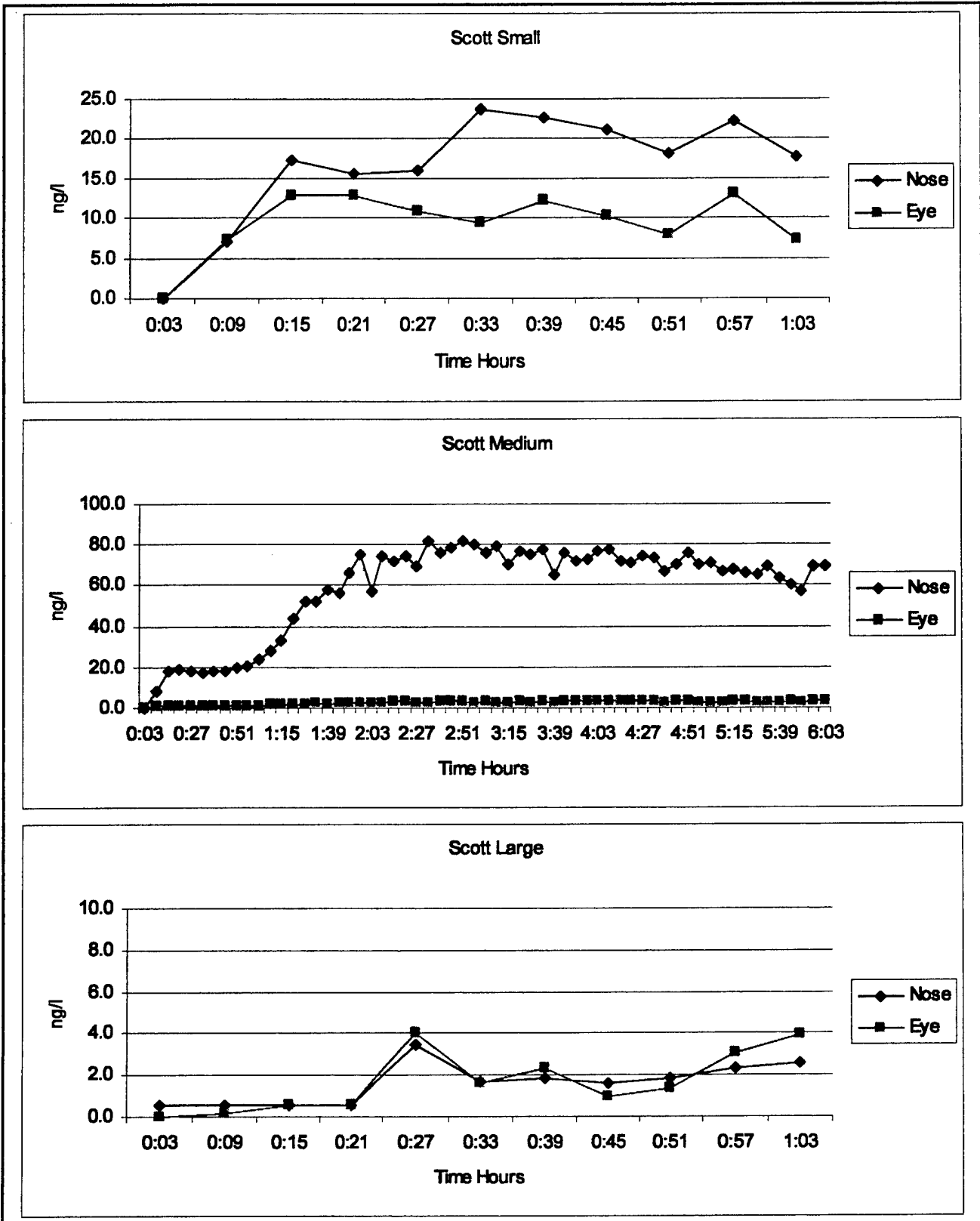


Figure 5. Scott AV2000 Respirators



### 3.3.2 Cartridges/Canisters.

Cartridges/canisters for the negative pressure respirators were tested with GB under the conditions stated above. None of the cartridges/canisters showed any breakthrough of GB.

### 3.3.3 Discussion.

Because none of the cartridge/canister tests showed any GB breakthrough, it is unlikely that any of the GB detected inside the respirators during the system tests penetrated the cartridges/canisters. Each system had an aerosol leak test performed before and after the agent test to assure that any agent detected inside the respirator did not enter by the sealed surfaces or the exhalation valves. Most of the NPRs allowed permeation of agent within the first hour; that a few allowed no permeation indicates that the quality of the respirators is inconsistent.

## 4. PROTECTION FACTOR TESTING

### 4.1 Corn Oil Testing Equipment.

A challenge aerosol concentration of approximately 20-40 mg/m<sup>3</sup>, polydispersed corn oil aerosol having a mass median aerodynamic diameter (MMAD) of 0.4-0.6 microns (the Army Standard) was generated in a 10-ft × 10-ft × 32-ft test chamber. The test chamber challenge aerosol was generated by atomizing liquid corn oil at room temperature using a Laskin nozzle. The Laskin nozzle produced a coarse aerosol cloud, which was directed into an impaction plate to remove the larger particles and yield an aerosol in the desired size range. The concentrated aerosol from the generator was diluted with filtered ambient air to control the challenge aerosol concentration in the exposure chamber.

A 6-decade, 45 degree off-axis light-scattering laser photometer, sampling at a flow rate of 1-2 L/min, was used to quantify concentration of the challenge and the in-mask corn oil aerosols. For a given particle size, the quantity of scattered light is proportional to the aerosol concentration. The photometer converted the quantity of scattered light to a voltage, which was then digitized and recorded by a microcomputer.

The respirator sampling port, located in the oro-nasal area, was connected to the photometer with flexible silicone tubing to measure the amount of aerosol penetrating the mask. A Tygon® sampling tube line was connected from the exposure chamber sampling port to the photometer to determine the challenge aerosol concentration.

### 4.2 Protection Factor Testing Method.

Each respirator was donned by military volunteers and challenged, on separate dates, with the corn oil aerosol. The number of volunteers for each test ranged from 6 to 24, and 12 respirators were used of each model. Prior to testing, each test volunteer was given an orientation in which the PF test was explained by ECBC personnel and a volunteer agreement

was signed by each test volunteer. The number of trials ranged from 36 to 53. Where fewer trials are reported it is because the test data were invalidated for some reason unrelated to the respirator design. Fewer trials were reported due to human errors not reflective of the mask performance. The minimum number of trials necessary is 22 to give a statistical validity or 90% reliability at a 90% confidence level. Additional trials may have been performed simply to provide a larger sample.

All volunteers had anthropometric measurements taken of their facial features, and then they were given a respirator and asked to wear their normal clothing (Battle Dress Uniform (BDU)). The test volunteers were then led into the aerosol exposure chamber, 8 at a time, by ECBC personnel, hooked up to their photometer stations, and asked to perform a standard Army PF Test devised to stress the face seal of the respirator, namely the following 10 exercises for 1 min each:

1. Normal Breathing
2. Deep Breathing
3. Turn Head Side to Side
4. Move Head Up and Down
5. Recite the Rainbow Passage (Reading a paragraph aloud to stress talking)
6. Sight the Rifle
7. Reach for the Floor and Ceiling
8. On Hands and Knees, Turn Head Side to Side
9. Facial Expressions
10. Normal Breathing

The test equipment operator monitored and communicated with the test volunteers on when to start an exercise, finish an exercise, and exit the aerosol chamber, and monitored their performance. All exercises were completed by the test volunteers without the intervention of test personnel.

All raw data were collected by a computer-based system and stored for later analysis.

#### Data Analysis.

Mask performance was quantified in terms of a protection factor (PF). The PF was calculated by determining the ratio of the challenge aerosol concentration to the in-mask aerosol concentration as quantified by integrating the peak voltage output from the photometer over the time interval (nominally one minute). A PF was calculated for individual exercises ( $PF_i$ ). The individual PFs were then used to calculate an overall PF for a subject ( $PF_o$ ) as follows:

$$PF_o = n(\sum_{i=1}^{n} 1/PF_i)^{-1}$$

where n is the number of exercises. The overall PF provides a time-integrated measure of the protection afforded. It is somewhat analogous to calculating the total resistance of resistors in

parallel in an electronic circuit. The  $PF_0$  is affected most by the smallest PFs. Under the conditions of this test and the sensitivity of the photometer, the maximum PF that can be reported is 100,000. The PFs were calculated by a computer.

#### 4.3 Protection Factor Test Results and Discussion.

Because these were commercially available respirators there were no Army requirements established for these respirators. Therefore, we took the conservative approach and reported the data in pass and fail percentages for each respirator configuration at selected PF levels. These PF tests were performed to provide useful information to federal, state and local emergency and hazardous materials (HAZMAT) teams operating in a chemical agent environment. The pass percentages included in the summary tables are based on the PF levels used by the Army.

The analyzed data are provided in Tables 4 to 8. The first column lists the lower limit of each range of PF computed. The second column is the number of test occasions which resulted in calculated PF within the range. The third column presents the total number of test occasions which resulted in a PF below the lower limit of the range, presented as a percentage of the sample population. The fourth column is like the third, but presents the percentage which are above the lower limit of the range shown. The final PF range shown is over 100,000, but the current data acquisition system cannot measure PF over 100,000, so it truncates the data and puts all the remaining occasions in the final range.

Table 4 shows that the MSA Advantage 1000 Full Facepiece Respirator (FFR) with GME-P100 Cartridge had the following pass percentages:

- Pass percentage of 70% at the 10,000 PF level.
- Pass percentage of 74% at the 6667 PF level.
- Pass percentage of 88% at the 1667 PF level.
- Pass percentage of 100% at the 500 PF level.

**Table 4. Final PF Results, MSA Advantage 1000 FFR with GME-P100 Cartridge**

<i>PF Range</i>	<i>No. of Occasions in Range</i>	<i>Cumulative Rate, Percent</i>	<i>Cumulative Pass Rate, Percent</i>
0-9	0	.00	100.0
10-49	0	.00	100.0
50-99	0	.00	100.0
100-499	0	.00	100.0
500-999	0	.00	100.0
1000-1666	3	6.00	94.0
1667-1999	3	12.00	88.0
2000-4999	1	14.00	86.0
5000-6666	3	20.00	80.0
6667-9999	3	26.00	74.0
10000-19999	2	30.00	70.0
20000-49999	7	44.00	56.0
50000-99999	6	56.00	44.0
100000 (+)	22	100.00	0.0
No. of Trials	50		

Table 5 shows that the MSA Advantage 1000 FFR with CBA/RCA Advantage Cartridge had the following past percentages:

- Pass percentage of 22% at the 10,000 PF level.
- Pass percentage of 29% at the 6667 PF level.
- Pass percentage of 53% at the 1667 PF level.
- Pass percentage of 100% at the 50 PF level.

**Table 5. Final PF Results, MSA Advantage 1000 FFR with CBA/RCA Cartridge**

<i>PF Range</i>	<i>No. of Occasions in Range</i>	<i>Cumulative Rate, Percent</i>	<i>Cumulative Pass Rate, Percent</i>
0-9	0	.00	100.0
10-49	0	.00	100.0
50-99	0	.00	100.0
100-499	2	4.44	95.6
500-999	8	22.22	77.8
1000-1666	7	37.78	62.2
1667-1999	4	46.67	53.3
2000-4999	4	55.56	44.4
5000-6666	7	71.11	28.9
6667-9999	0	71.11	28.9
10000-19999	3	77.78	22.2
20000-49999	4	86.67	13.3
50000-99999	5	97.78	2.2
100000 (+)	1	100.00	0.0
No. of Trials	45		

Table 6 shows that the MSA Millennium Gas Mask with CBA/RCA Millennium Canister had the following past percentages:

- Pass percentage of 96% at the 10,000 PF level.
- Pass percentage of 96% at the 6667 PF level.
- Pass percentage of 96% at the 1667 PF level.
- Pass percentage of 100% at the 100 PF level.

**Table 6. Final PF Results, MSA Millennium Gas Mask with CBA/RCA Millennium Canister**

<i>PF Range</i>	<i>No. of Occasions in Range</i>	<i>Cumulative Rate, Percent</i>	<i>Cumulative Pass Rate, Percent</i>
0-9	0	.00	100.0
10-49	0	.00	100.0
50-99	0	.00	100.0
100-499	0	.00	100.0
500-999	2	4.08	95.9
1000-1666	0	4.08	95.9
1667-1999	0	4.08	95.9
2000-4999	0	4.08	95.9
5000-6666	0	4.08	95.9
6667-9999	0	4.08	95.9
10000-19999	0	4.08	95.9
20000-49999	0	4.08	95.9
50000-99999	11	26.53	73.5
100000 (+)	36	100.00	0.0
No. of Trials	49		

Table 7 shows that the MSA Phalanx Gas Mask with Phalanx Canister had the following pass percentages:

- Pass percentage of 9% at the 10,000 PF level.
- Pass percentage of 15% at the 6667 PF level.
- Pass percentage of 53% at the 1667 PF level.
- Pass percentage of 100% at the 50 PF level.

**Table 7. Final PF Results, MSA Phalanx Gas Mask with Phalanx Canister**

<i>PF Range</i>	<i>No. of Occasions in Range</i>	<i>Cumulative Rate, Percent</i>	<i>Cumulative Pass Rate, Percent</i>
0-9	0	.00	100.0
10-49	0	.00	100.0
50-99	0	.00	100.0
100-499	2	3.77	96.2
500-999	11	24.53	75.5
1000-1666	9	41.51	58.5
1667-1999	3	47.17	52.8
2000-4999	6	58.49	41.5
5000-6666	11	79.25	20.8
6667-9999	3	84.91	15.1
10000-19999	3	90.57	9.4
20000-49999	4	98.11	1.9
50000-99999	1	100.00	0.0
100000 (+)	0	100.00	0.0
<b>No. of Trials</b>	<b>53</b>		

Table 8 shows that the Scott AV2000 Comfo, 4-Point Rubber Mask Facepiece with NBC Canister and 42-40 mm adapter had the following pass percentages:

- Pass percentage of 22% at the 10,000 PF level.
- Pass percentage of 25% at the 6667 PF level
- Pass percentage of 39% at the 1667 PF level.
- Pass percentage of 100% at the 10 PF level.

**Table 8. Final PF Results, Scott AV2000 Mask Facepiece with NBC Canister**

<i><b>PF Range</b></i>	<i><b>No. of Occasions in Range</b></i>	<i><b>Cumulative Rate, Percent</b></i>	<i><b>Cumulative Pass Rate, Percent</b></i>
0-9	0	.00	100.0
10-49	0	.00	100.0
50-99	6	16.67	83.3
100-499	3	25.00	75.0
500-999	9	50.00	50.0
1000-1666	1	52.78	47.2
1667-1999	3	61.11	38.9
2000-4999	1	63.89	36.1
5000-6666	4	75.00	25.0
6667-9999	0	75.00	25.0
10000-19999	1	77.78	22.2
20000-49999	5	91.67	8.3
50000-99999	1	94.44	5.6
100000 (+)	2	100.00	0.0
<b>No. of Trials</b>	<b>36</b>		

## 5. CONCLUSIONS

A total of 110 cartridges/canisters (22 each of 5 models) were tested against a concentration challenge of 200 mg/m<sup>3</sup> of Sarin (GB). The cartridges/canisters were tested for 1 hr. None of the cartridges/canisters showed any penetration of GB.

Fifteen air-purifying negative pressure respirators (3 sizes of each model) mounted on the SMARTMAN headform were tested against a concentration challenge of 200 mg/m<sup>3</sup> of GB. Each of the five systems with the exception of the large size MSA Advantage 1000 w/GME-P100 cartridge, showed breakthrough of GB by the time the test was terminated (1 hr).

PF testing was performed on volunteers who wore the air-purifying negative pressure respirators (NPRs) for 36 to 53 trials for each respirator in accordance with the U.S. Army PF testing standard for positive and negative pressure respirators used in a chemical-biological environment (available upon request). Table 9 summarizes the pass percentages at selected PF levels for the 5 NPRs tested.

**Table 9. Summary of Pass Percentages for Negative Pressure Respirators at Selected PF Levels**

<b><i>PF Level</i></b>	<b><i>MSA Advantage 1000 FFR w/GME-P100 Cartridge</i></b>	<b><i>MSA Advantage 1000 FFR w/CBA/RCA Cartridge</i></b>	<b><i>MSA Millennium Gas Mask w/CBA/RCA Millennium Canister</i></b>	<b><i>MSA Phalanx Gas Mask w/Phalanx Canister</i></b>	<b><i>Scott AV2000 Mask Facepiece with NBC Canister</i></b>
1667	88.0%	53.3%	95.9%	52.8%	38.9%
6667	74.0%	28.9%	95.9%	15.1%	25.0%
10000	70.0%	22.2%	95.9%	9.4%	22.2%

**BLANK**

## APPENDIX

### GLOSSARY

#### **Air-Purifying Respirator**

These respirators contain an air-purifying filter, cartridge, or canister that removes specific contaminants by passing ambient air through the air-purifying element. These do not supply oxygen and must be used only when there is sufficient oxygen to sustain life and the air contaminant is below the concentration limits of the cartridge/canister. In addition, these cartridge/canisters usually do not include any method of indicating when their ability to remove air contaminants has been reduced.

#### **Breather Pump**

A pump used to simulate human breathing through a filter. The pump is a piston pump designed to begin the stroke at zero flow, rise to a maximum (peak) flow at midstroke, and decrease to zero at the end of the stroke. The resultant flow is sinusoidal, that is, shaped like a sine wave when plotted. The pump stroke can be adjusted to change the volume of air per stroke over a finite range; some pumps are capable of changing the number of strokes per minute.

#### **Canister (Air-Purifying)**

A container filled with sorbents, catalysts and filters that removes gases, vapors, and/or particulates from air drawn through the unit. Canisters rely on a variety of mechanisms for contaminant removal such as chemical absorption, adsorption, catalytic action, neutralization, and mechanical filtration.

#### **Cartridge**

A container filled with sorbents, catalysts, and filters that removes gases, vapors, and/or particulates from air drawn through the unit. Cartridges are smaller than canisters (<150 ml capacity) but are designed to work on the same principles.

#### **DoD**

Department of Defense

#### **ECBC**

Edgewood Chemical Biological Center

#### **Exhalation Valve**

A device that allows exhaled air to leave a respiratory device and prevents outside air from entering through the valve while inhaling.

### **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 inhalation valves, exhalation valves, and connectors for the air-purifying cartridges or filters.

### **Filter**

A fibrous medium used in respirators to remove solid or liquid particulates from the air before it enters the facepiece (this term may be used interchangeably with cartridge).

### **Fit Factor (FF)**

A Fit Factor is a number that is the direct result of a quantitative respirator fit test. It is a measurement made by an instrument during a simulation of workplace activities or scenarios. It is expressed as the challenge aerosol concentration outside the respirator divided by the challenge aerosol concentration that leaks inside the respirator during a Fit Test.

### **NPR, Negative Pressure Respirator**

This is a respirator that fits tightly to the face; it has a negative (lower) air pressure inside the facepiece with respect to ambient air pressure outside the respirator during inhalation.

### **SBCCOM**

Soldier and Biological Chemical Command

### **Hydrogen-Flame Emission Detector (HYFED)**

A detector in which organophosphorus chemical compounds are burned in a hydrogen flame. Phosphorus compounds are formed that emit electromagnetic radiation whose wavelengths can be isolated and quantified.

### **Inhalation Valve**

A device that allows air to enter the facepiece through the filtering media but prevents exhaled air from leaving the facepiece through the intake openings.

### **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."

### **Particulate Matter**

A suspension of fine solid or liquid particles in air, i.e., dust, fog, fume, smoke, or sprays. Particulate matter suspended in air is commonly known as an aerosol.

### **Protection Factor**

The overall protection afforded by a certain type of respirator as defined by the ratio of the concentration of contaminant outside a facemask or hood to that inside the mask while in a contaminated atmosphere. The protection factor as used in this report is the overall factor calculated from individual fit factors determined on a number of human volunteers for each of several exercises performed while wearing the respirator.

### **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.