System Assessment and Validation for Emergency Responders (SAVER)

Chemical, Biological, Radiological, and Nuclear Air-Purifying Respirators Assessment Report

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SAVER
System Assessment and Validation for Emergency Responders

Prepared by the Savannah River National Laboratory

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The cover photo was provided by the Savannah River National Laboratory. Product images included herein were provided by the respective vendors and/or as photographed by the Savannah River National Laboratory.

FOREWORD

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercially available equipment and systems and develops knowledge products that provide relevant equipment information to the emergency responder community. The SAVER Program mission includes:

- Conducting impartial, practitioner-relevant, operationally oriented assessments and validations of emergency response equipment
- Providing information, in the form of knowledge products, that enables decision-makers and responders to better select, procure, use, and maintain emergency response equipment.

SAVER Program knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the responder community: "What equipment is available?" and "How does it perform?" These knowledge products are shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is supported by a network of Technical Agents who perform assessment and validation activities. As a SAVER Program Technical Agent, the Savannah River National Laboratory (SRNL) was tasked to provide expertise and analysis on chemical, biological, radiological, and nuclear (CBRN) air-purifying respirators (APRs). In support of this tasking, SRNL developed this report to provide emergency responders with information obtained from an operationally oriented assessment of CBRN APRs. CBRN APRs fall under AEL reference number 01AR-02-APR titled Respirator, Air-Purifying, Full-Face, Tight-Fitting, Negative Pressure, CBRN. CBRN canisters fall under AEL reference number 01AR-02-APRC titled Canister, CBRN, APR.

For more information on the SAVER Program or to view additional reports on CBRN APRs or other technologies, visit www.dhs.gov/science-and-technology/SAVER.

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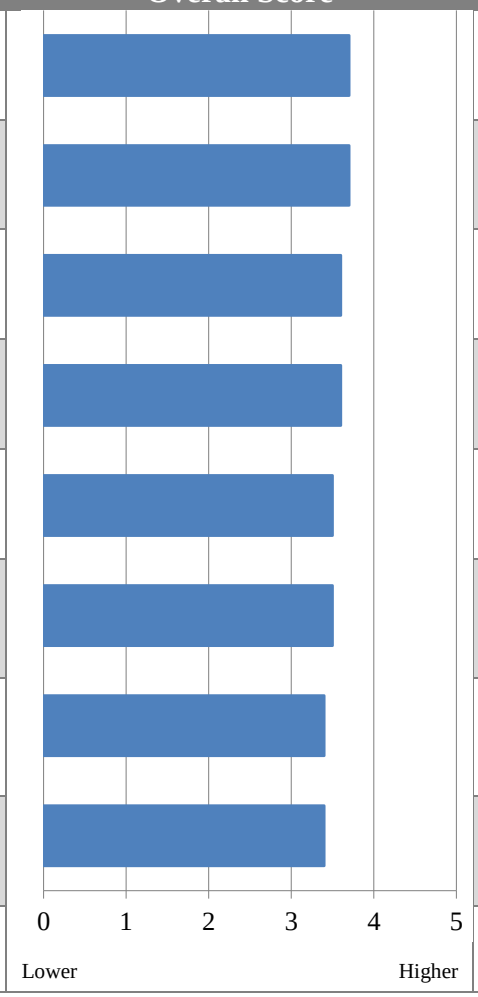
Chemical, biological, radiological, and nuclear (CBRN) air-purifying respirators (APRs) are a type of personal protective equipment (PPE) worn by emergency responders to protect them from inhaling harmful contaminants that may be present when responding to CBRN incidents. In December 2016, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of CBRN APRs.

Eight CBRN APRs were assessed by emergency responders. The criteria and scenarios used in this assessment were derived from the results of a focus group of emergency responders with experience using CBRN APRs. The assessment addressed 25 evaluation criteria in five SAVER categories: Affordability, Capability, Deployability, Maintainability, and Usability. The overall results of the assessment are highlighted in the following table.

Product	Overall Score	Overall	Capability	Usability	Deployability	Maintainability	Affordability
Scott Safety AV-3000 HT		**3.7**	4.0	3.7	3.8	3.6	3.5
Scott Safety FRR		**3.7**	3.7	3.6	3.6	3.7	3.7
Draeger Safety Inc. CDR 4500		**3.6**	3.5	3.4	3.6	3.7	3.8
Mine Safety Appliances Millennium		**3.6**	3.8	3.7	3.1	3.9	2.9
Honeywell Opti-Fit		**3.5**	3.5	3.5	3.2	3.8	3.8
Avon Protection Systems C50		**3.5**	3.6	3.6	3.6	3.5	2.8
Avon Protection Systems FM53		**3.4**	3.7	3.6	3.5	3.3	2.1
3M FR-7800B		**3.4**	3.4	3.2	3.3	3.4	3.4



1. INTRODUCTION

Chemical, biological, radiological, and nuclear (CBRN) air-purifying respirators (APRs) are a type of personal protective equipment (PPE) worn by emergency responders to guard against inhaling contaminants that may be present when responding to CBRN incidents. In December 2016, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of CBRN APRs. The purpose of this assessment was to obtain information on CBRN APRs to assist in making operational and procurement decisions. The activities associated with this assessment were based on recommendations from a focus group of emergency responders with experience using CBRN APRs.

1.1 Evaluator Information

Five emergency responders from various jurisdictions and with at least 5 years of experience using CBRN APRs were selected to be evaluators for the assessment. Evaluator information is listed in Table 1-1. Prior to the assessment, evaluators signed a nondisclosure agreement, conflict of interest statement, and photo release form. Evaluators provided proof of a recent physical, which included an Occupational Safety and Health Administration (OSHA) 1910.134 Respiratory Medical Evaluation dated within 1 year of the assessment. This served the purpose of confirming participants' ability to engage in moderate to high physical activity while utilizing various CBRN APRs. Prior to the assessment, evaluators were fit tested for accurate respirator sizing, as detailed in Section 3.1 and Appendix E.

Table 1-1. Evaluator Information

Evaluator	Years	State
Public Safety, Special Operations	30	SC
Public Safety, HAZMAT Coordinator	20	SC
Health and Environmental Control, Emergency Response	16	SC
Public Safety, Engineer	8	SC
Emergency Management, Weapons of Mass Destruction Team	5	SC

1.2 Assessment Products

Eight products were selected and purchased for the assessment based on market research and the focus group's recommendations. Final selection was based on how well each product met the product selection criteria identified by the focus group as listed below.

- Facepiece must be approved by the National Institute for Occupational Safety and Health (NIOSH) for CBRN
- Facepiece must be commercially available
- Facepiece must feature a single lens
- Facepiece must still be manufactured and supported

- Facepiece should be marketed as a CBRN solution
- Facepiece should cost under $500.

While not explicitly noted as product selection criteria, focus group participants recommended the evaluation of newer products on the market that had not yet been evaluated through previous SAVER assessments. Participants also requested as many manufacturers of approved and available CBRN APRs as possible be represented in the assessment. While a $500 cost ceiling was recommended by a majority of focus group participants, it was stressed by several others that cost and budgets vary across agencies, departments, orders (bulk, discounts, etc.), and vendor representatives; therefore, it was recommended cost should be a guideline and not a deciding factor. The products selected for assessment met all product selection criteria except cost.

Table 1-2 presents the products that were assessed.

Table 1-2. Assessed Products

Vendor	Product	Product Image	Vendor	Product	Product Image
3M	FR-7800B		Honeywell	Opti-Fit	
Avon Protection Systems	C50		Mine Safety Appliances	Millennium	
Avon Protection Systems	FM53		Scott Safety	FRR	
Draeger Safety Inc.	CDR 4500		Scott Safety	AV-3000 HT	

2. EVALUATION CRITERIA

The SAVER Program assesses products based on criteria in five established categories:

- **Affordability** groups criteria related to the total cost of ownership over the life of the product. This includes purchase price, training costs, warranty costs, recurring costs, and maintenance costs
- **Capability** groups criteria related to product features or functions needed to perform one or more responder relevant tasks
- **Deployability** groups criteria related to preparing to use the product, including transport, setup, training, and operational/deployment restrictions
- **Maintainability** groups criteria related to the routine maintenance and minor repairs performed by responders, as well as included warranty terms, duration, and coverage
- **Usability** groups criteria related to ergonomics and the relative ease of use when performing one or more responder relevant tasks.

The focus group of emergency responders met in August 2016 and identified 27 evaluation criteria within five SAVER categories: Affordability, Capability, Deployability, Maintainability, and Usability. They assigned a weight for each criterion's level of importance on a scale of 1 to 5, with 1 being somewhat important and 5 being of utmost importance. The SAVER categories were assigned a percentage to represent each category's importance relative to the other categories.

Products were assessed against 25 evaluation criteria. Two criteria recommended by the focus group were not assessed. The warranty criterion and the technical support criterion were not assessed due to insufficient information and time to adequately and equitably assess the criteria. Table 2-1 presents the evaluation criteria and their associated weights as well as the percentages assigned to the SAVER categories. Refer to Appendix A for evaluation criteria definitions.

Table 2-1. Evaluation Criteria

SAVER CATEGORIES				
Capability	**Usability**	**Deployability**	**Maintainability**	**Affordability**
Overall Weight 25%	Overall Weight 25%	Overall Weight 20%	Overall Weight 20%	Overall Weight 10%
Evaluation Criteria				
Facepiece Durability Weight: 5	**Seal Integrity** Weight: 5	**Training Requirements** Weight: 5	**Ease of End-User Maintenance** Weight: 5	**Initial Cost** Weight: 4
Canister Durability Weight: 5	**Breathing Resistance** Weight: 5	**Reference Documentation** Weight: 4	**Decontamination** Weight: 4	**Maintenance Costs** Weight: 4
Convertibility Weight: 4	**Comfort** Weight: 4	**Storage Requirements** Weight: 4	**Warranty** Not Assessed	
Communications Weight: 3	**Visibility** Weight: 4	**Operating Temperature** Weight: 4	**Technical Support** Not Assessed	
Adaptability Weight: 3	**Material** Weight: 3		**Facepiece Shelf Life** Weight: 3	
Canister Longevity Weight: 2	**Mobility/ Ergonomics** Weight: 3		**Canister Shelf Life** Weight: 1	
Available Accessories Weight: 2	**Accessibility** Weight: 3			
	Stored Facepiece Portability Weight: 2			

3. ASSESSMENT METHODOLOGY

The products were assessed over 3 days. On the first day of the assessment, a subject matter expert (SME) and facilitators presented a safety briefing and an overview of the assessment process, procedures, and schedule to the evaluators. Each product was then assessed in two phases: (1) specification assessment and (2) operational assessment.

3.1 Fit Testing for Individual Fit and Sizes

A fit test day was held at the Savannah River Site (SRS) in Aiken, South Carolina, in November 2016 to perform OSHA-required fit test procedures and achieve necessary fit factor ratings. These fit tests allowed evaluators to become more familiar with the selected CBRN APRs ahead of the assessment, as well as provide individual sizing data to facilitators in order to place more accurate equipment orders and plan scenario runs according to sizing and fit needs. Fit tests utilized the PortaCount® quantitative fit testing equipment and followed OSHA-accepted fit testing procedures under §1910.134, including read back of the traditional rainbow passage.

While no specific aspects of fit testing were recommended to be assessed by emergency responders during the focus group, facilitators took note of evaluators' comments verbally. Evaluators were encouraged to convey any thoughts or comments to fit test personnel. Evaluators were also given the opportunity to provide written comments after the fit testing was complete.

Due to scheduling and unforeseen operational deployments, not all evaluators could attend the SRS fit test day. Makeup fit tests for each CBRN APR were completed prior to beginning operational assessment scenarios with the CBRN APR in question. Fit test quantitative data for all evaluators with each CBRN APR can be found in Appendix E.

3.2 Phase I/Specification Assessment

During the specification assessment, evaluators assessed each product based on vendor-provided information and specifications. Product information was gathered through Internet research, vendor publications, a government-issued Request for Information (RFI) that was posted on the Federal Business Opportunities website, and subsequent communication between Savannah River National Laboratory and vendors. Information was confirmed in several stages by vendors prior to the assessment, and all vendors were given the opportunity to clarify previously submitted specification information. The specification assessment for all CBRN APRs occurred after product familiarization but prior to the start of operational assessment scenarios.

3.3 Phase II/Operational Assessment

During the operational assessment, evaluators assessed each product based on their hands-on experience using the product after becoming familiar with its proper use, capabilities, and features. The SME and facilitators assisted the evaluators with product familiarization, and evaluators had access to the reference material included with each product. The products were assessed in three scenarios: (1) Victim Drag and Cutout, (2) Donning, Use, and Decontamination, and (3) Troubleshoot and Repair Scenarios. Products were evaluated in operational scenarios one at a time by evaluators and assessment worksheets were completed for each product before assessing the next product.

3.3.1 Victim Drag and Cutout Scenario

First, each evaluator inspected a CBRN APR facepiece and its included components (e.g., strap, lenses, canister, etc.) for overall ruggedness. Second, evaluators confirmed the correct facepiece and size for fit, and ensured no straps were twisted, tangled, or unhinged prior to beginning the operational scenario. Each evaluator, in alternating groups of two or three, then readied the appropriately sized facepiece per their individual fit test for the scenario run, attached a CBRN canister, and donned and adjusted the CBRN APR as necessary for individual fit.

After donning CBRN APRs, evaluators waited 5 minutes in a starting zone while wearing respective CBRN APRs. During this period, evaluators provided ratings and comments for initial Facepiece Durability and Canister Durability, Comfort, Adaptability, and Accessibility. Facilitators assisted with this logging when requested.

After 5 minutes with CBRN APRs donned,[1] evaluators walked through the scenario hallway with facilitators while listening to a safety refresher and pre-job brief. Next, evaluators briskly descended and ascended three flights of stairs before returning to the starting zone. Evaluators then approached a roughly 105-pound simulated victim mannequin. The mannequin was team-lifted and placed on a rescue medical sked.

Figure 1. Preparing to Place Victim on Sked with Opti-Fit Donned

Figure 2. Lifting Victim onto Stretcher with FR-7800B Donned

Evaluators dragged the sked and victim down a hallway approximately 100 feet from the hot zone to a decontamination station. Evaluators removed simulated contaminated clothing, placed it into contaminate bags, and sealed the bags. Evaluators then simulated transfer to emergency medical service personnel for decontamination and treatment by team-lifting the mannequin and placing it on a nearby stretcher. Finally, evaluators returned to the starting zone and were instructed to doff CBRN APRs at approximately 14.5 minutes after scenario start. Evaluators immediately completed the scenario's worksheets in their respective assessment workbooks.

[1] As no contaminates were used, 'loading' of the CBRN canister, and resultant increases in breathing resistance, was minimal. Therefore, it was decided to stretch scenario time closer to the 15-minute capacity rating of the canisters.

3.3.2 Donning, Use, and Decontamination Trial

Figure 3. Dragging Sked with FRR Donned

Evaluators donned facepieces from carrying cases or similar mobile storage on the user, selected through personal preference from available options (i.e., some vendors offer both belt straps and leg straps). Evaluators then walked roughly 75 feet down a hallway to a room where peripheral and direct vision was tested at a vision station. Evaluators stepped onto a marker in the center of the room, aligned toes with line, and were asked by facilitators if they could view markers at different angles in the evaluator's periphery. If the evaluator could not see the marker, the facilitator brought the marker in another indicator step; this process was repeated until the marker was visible to the evaluator. Facilitators noted the widest angle of view on the both left and right sides of peripheral vision, and then this process was repeated in near-dark with overhead lights turned off and ambient light entering the room from the hallway. Evaluators were allowed a five-second count to let their vision adjust to the lighting shift.

Figure 4. Donning CDR 4500 with Neck Strap and Leg Carrier

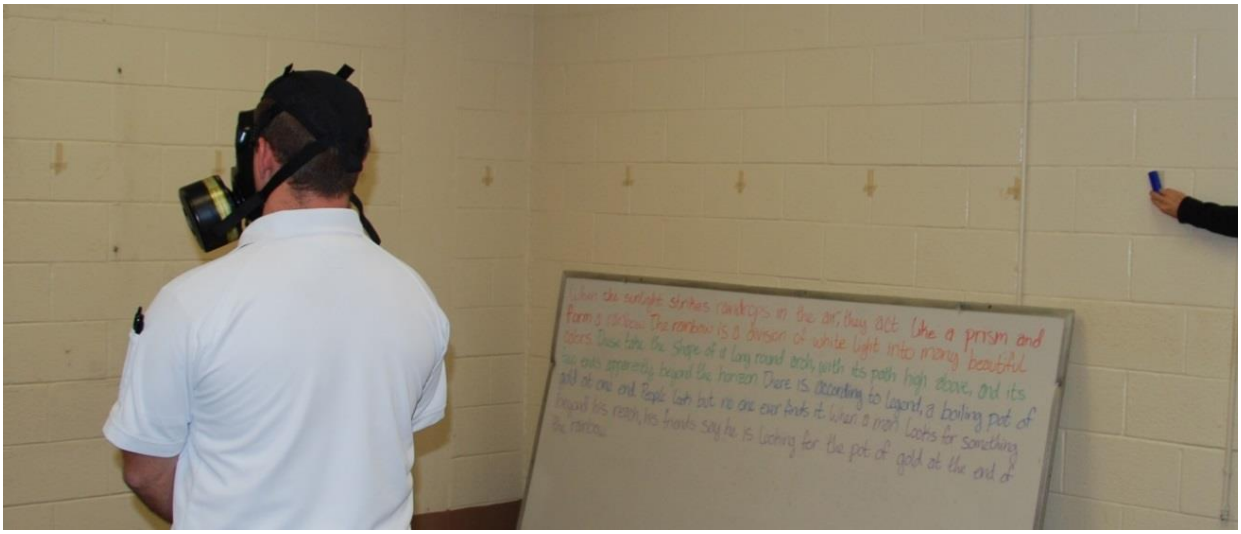


Figure 5. Bright Peripheral Vision Test and Rainbow Passage with C50 Donned

Figure 6. Sighting Weapon with Millennium Donned

Evaluators then proceeded to a communications station in pairs and read back the fit test 'rainbow passage' to one another. Evaluators also announced a variable, randomly generated confirmation phrase at the end of the passage to test communications clarity, which the paired evaluator had to repeat back. For this paired process, odd and even-numbered evaluators were assigned separate phrases for each respirator. For visibility and communications tests, evaluators completed baseline comparisons prior to beginning operational scenarios with CBRN APRs donned.

Evaluators then entered a designated safe zone, doffed facepieces, and swapped out CBRN canisters. After donning the facepieces again and adjusting for individual fit, evaluators walked to a weapon sighting station and bent forward, reaching down to pick up a simulated training weapon. Evaluators returned to the center of the room, aligned themselves with the floor marker, and sighted the weapon downrange through the facepiece lens a minimum of three times. Evaluators finally returned to the safe zone and removed and decontaminated the facepiece in order to ascertain its ease of decontamination with handheld wipes. After facepiece decontamination, evaluators returned to starting zone and completed scenario worksheets in their respective assessment workbooks.

Figure 7. FM53 Canister Swap

Figure 8. AV-3000 HT Decontamination

See Appendix C and Appendix D for quantitative vision and communications data compiled from the Donning, Use, and Decontamination Trial. This data did not directly impact criteria scores, although this quantitative information supplements the qualitative evaluator scoring.

3.3.3 Troubleshoot and Repair Scenario

Evaluators performed routine maintenance on CBRN APRs by following manufacturer instructions to access, remove, and replace facepieces' exhalation valves to ascertain the Ease of End-User Maintenance. If the CBRN APR facepiece had multiple ports and end-user maintenance for port swaps was not restricted due to warranty and/or required training, a port swap was attempted. Evaluators also assessed the CBRN APRs' Reference Documentation during this scenario. Evaluators made comments and completed the scenario's worksheets in their respective assessment workbooks as they proceeded with maintenance.

3.4 Data Gathering and Analysis

Each evaluator was issued an assessment workbook that contained vendor-provided information and specifications, assessment procedures, and worksheets for recording criteria ratings and comments. Evaluators used the following 1 to 5 scale:

1. The product *meets none* of my expectations for this criterion
2. The product *meets some* of my expectations for this criterion
3. The product *meets most* of my expectations for this criterion
4. The product *meets all* of my expectations for this criterion
5. The product *exceeds* my expectations for this criterion.

Criteria that were rated multiple times throughout the assessment were tallied and assigned final overall ratings by the evaluators. Facilitators captured advantages and disadvantages for the assessed products, as well as general comments on the CBRN APRs assessment and the assessment process. Once assessment activities were completed, evaluators had an opportunity to review their criteria ratings and comments for all products and make adjustments as necessary.

At the conclusion of the assessment activities, overall assessment scores, as well as category scores and criteria scores, were calculated for each product using the formulas referenced in Appendix B. In addition, evaluator comments for each product were reviewed and summarized for this assessment report.

Quantitative data was gathered in preparation for operational assessment (fit test data), as well as during the assessment (vision and communications data). While not directly linked to scoring, this data can provide further insight into CBRN APR performance and in many cases reinforces evaluator comments. The data on peripheral vision, communications repeatability, and facepiece fit factors are provided in Appendix C, Appendix D, and Appendix E, respectively.

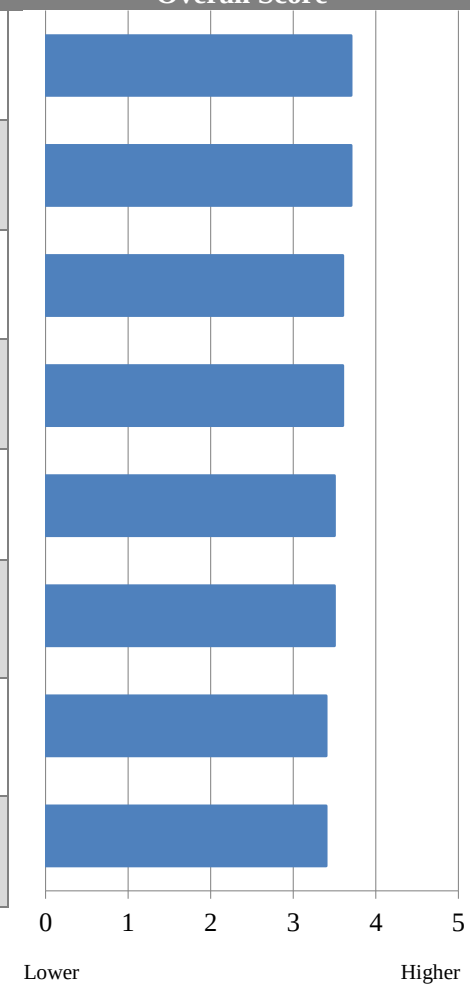
3.4.1 Overall Scoring Procedure

After all operational scenarios were complete for a particular CBRN APR, evaluators inspected the CBRN APR facepiece and included components and again provided ratings and comments for Facepiece Durability and Canister Durability for a before-and-after comparison. Then, evaluators completed the overall scoring worksheets in their workbooks; if criteria were assessed multiple times, evaluators noted all locations where each aspect was previously individually rated, denoted a composite overall score, and provided final comments. It is worth noting that these composite overall scores were not necessarily an average of each individual criteria score, but rather weighted based on the evaluators' own individual experiences and preferences.

4. ASSESSMENT RESULTS

Overall scores for the assessed products ranged 0.3 points, from 3.7 to 3.4. Table 4-1 presents the overall assessment score and category scores for each product. Products are listed in order from highest to lowest overall assessment score throughout this section. Calculation of the overall score uses the raw scores for each category, prior to rounding, and accounts for category weighting; products with the same rounded overall score are in order based on the raw data.

Table 4-1. Assessment Results



Product	Overall	Capability	Usability	Deployability	Maintainability	Affordability
Scott Safety AV-3000 HT	**3.7**	4.0	3.7	3.8	3.6	3.5
Scott Safety FRR	**3.7**	3.7	3.6	3.6	3.7	3.7
Draeger Safety Inc. CDR 4500	**3.6**	3.5	3.4	3.6	3.7	3.8
Mine Safety Appliances Millennium	**3.6**	3.8	3.7	3.1	3.9	2.9
Honeywell Opti-Fit	**3.5**	3.5	3.5	3.2	3.8	3.8
Avon Protection Systems C50	**3.5**	3.6	3.6	3.6	3.5	2.8
Avon Protection Systems FM53	**3.4**	3.7	3.6	3.5	3.3	2.1
3M FR-7800B	**3.4**	3.4	3.2	3.3	3.4	3.4

Table 4-2. **Criteria Ratings** presents the criteria ratings for each product. The ratings are graphically represented by colored and shaded circles. A green, fully shaded circle represents the highest rating. Refer to Appendix A for evaluation criteria definitions. Table 4-3 presents vendor-provided key specifications for the assessed products. Table 4-4 provides a listing of available accessories and whether the product is equipped with the accessory, not equipped with accessory nor available or available for an additional cost.

Table 4-2. Criteria Ratings

KEY

Lowest Rating → Highest Rating

○ ◔ ◑ ◕ ●

Category	Evaluation Criteria	AV-3000 HT	FRR	CDR 4500	Millennium	Opti-Fit	C50	FM53	FR-7800B
									
Capability	Facepiece Durability	◕	◑	◕	◕	◑	◕	◑	◕
	Canister Durability	◕	◕	◕	◕	◕	◕	◕	◕
	Convertibility	●	◕	◑	◕	◕	◕	◕	◑
	Communications	◕	◕	◕	◕	◕	◕	◕	◑
	Adaptability	◑	◕	◑	◕	◑	◑	◑	◑
	Canister Longevity	◑	◑	◑	◑	◑	◑	◑	◑
	Available Accessories	◕	◕	◕	◕	◑	◕	◕	◕
Usability	Seal Integrity	◕	◕	◕	◕	◕	◕	◕	◕
	Breathing Resistance	◕	◕	◕	◕	◕	◕	◕	◑
	Comfort	◕	◑	◑	◑	◑	◑	◑	◑
	Visibility	◕	◕	◕	◕	◕	◕	◕	◑
	Material	◕	◑	◑	◑	◑	◑	◕	◑
	Mobility/Ergonomics	◑	◕	◑	◑	◑	◕	◕	◕
	Accessibility	◕	◑	◑	◕	◑	◑	◑	◑
	Stored Facepiece Portability	◑	◕	◑	◕	◑	◑	◑	○

KEY

Lowest Rating → Highest Rating

○ ◔ ◑ ◕ ●

Category	Evaluation Criteria	AV-3000 HT	FRR	CDR 4500	Millennium	Opti-Fit	C50	FM53	FR-7800B
									
Deployability	Training Requirements	◕	◕	◑	◑	◑	◑	◑	◑
	Reference Documentation	◑	◑	◕	◕	◑	◕	◑	◑
	Storage Requirements	◕	◑	◕	◑	◕	◕	◕	◕
	Operating Temperature	◕	◕	◕	◑	◑	◕	◕	◑
Maintainability	Ease of Maintenance	◑	◑	◕	◑	◕	◑	◑	◑
	Decontamination	◕	◕	◑	◕	◕	◑	◑	◑
	Facepiece Shelf Life	●	◕	◕	●	●	◕	◕	●
	Canister Shelf Life	◕	◕	●	◑	◕	◑	◑	◑
Afford ability	Initial Cost	◑	◑	◕	◑	◕	◑	◔	◕
	Maintenance Cost	◕	◕	◑	◑	◕	◑	◑	◑

Table 4-3. Key Specifications[1]

Key Specification		AV-3000 HT	FRR	CDR 4500	Millennium	Opti-Fit	C50	FM53	FR-7800B
Facepiece MSRP[2]		$416[3]	$385	$207	$595	$278 to $323[4]	$422	$1,117 to $1,142[5]	$335
Canister MSRP[1]		$57	$57	$81	$74	$65	$62 to $63	$62 to $63	$64[6]
Warranty		10 years	1 year	1 year	1 year	1 year	1.5 years	1.5 years	NP
Convertibility[7]		CBRN PAPR, SCBA, CN/CS/P100, Riot	PAPR, SCBA	PAPR	CBRN PAPR, CN/CS/P100, Riot	CBRN PAPR, CN/CS/P100, Riot	CBRN PAPR, CN/CS/P100, Riot	PAPR, SCBA, Hybrid, CN/CS/P100, Riot	CN/CS/P100, Riot
Canister Longevity		CAP 1	CAP 1	CAP 1	CAP 1	CAP 1	CAP 1	CAP 1	CAP 1
Sizing Availability		S, M, L	S, M, M/L, L	S, M, L, U	S, M, L	S, M, L	S, M, L	XS, S, M, L	S, M, L
Nosecup		Interchangeable	Integrated	Integrated	Integrated	Interchangeable	Integrated	Interchangeable	Integrated
Material	**Facepiece**	Ethylene Propylene Diene Monomer Blend	Butyl Blend	Silicone-free Elastomer	Hycar Rubber	Silicone and Butyl Rubber	Chlorobutyl/ Silicone	Chlorobutyl/ Silicone	Butyl Rubber
	Nosecup	Silicone Blend	NP	NP	NP	NP	NP	Silicone	Silicone
	Lens	Polycarbonate	Proprietary	Polycarbonate	Polyurethane	Polycarbonate	Polyurethane	Polyurethane	Polycarbonate
Facepiece Service Life		None	15 years	10 years minimum	None	None	10 years, additional 10 possible	10 years, additional 10 possible	None
Canister Shelf Life		8 years	8 years	12 years	5 years	10 years	5.5 years	5.5 years	5 years

Notes: NP-Not Provided by vendor
CN/CS/P100 – NIOSH-approved for protection against chloroacetophenone, cholorobenzylidene, and particulates at the P100 level.
[1]See the CBRN APR Market Survey Report for more information on system components and specifications.
[2] MSRPs are as provided by the vendor, and as assessed. Listed prices are subject to change at the discretion of respective vendors.
[3]This price includes AV-3000 HT Facepiece and First Responder Adapter, which is required for CBRN canister attachment; see section 4.1 for more details.[4]$284 for small and medium sizes, $278 for large; with hydration valve, $323 for small and medium sizes, $312 for large.
[5] $1,117 for single port model, $1,142 for twin port model.
[6] Canister MSRP as assessed for 3M's FR-15-CBRN canister - $254 for a case of four.
[7] Includes various NIOSH-approved for CBRN and Non-CBRN configurations. Check with manufacturers for products' most up to date approved configurations.

Table 4-4. Available Accessories

Available Accessories	AV-3000 HT[1]	FRR	CDR 4500	Millennium	Opti-Fit	C50	FM53	FR-7800B
Hydration Valve	NE	✓	NE	✓	O	✓	✓	NE
Mechanical Voice Amplification	✓	✓	✓	✓	NE	NE	NE	✓
Electronic Voice Amplification	O	O	NE	O	NE	O	✓	NE
Radio Interface	O	✓	NE	NE	NE	✓	✓	O
Vision Correction	O	O	O	O	O	O	O	O
Lens Covers/Outserts	NE	O		✓ and O[2]	O	O	O	O
Other Included Accessories	NA	Canister Port Cap, Secondary Inline Filter in Nosecup	Neck Strap	Clamshell Storage Case	Canister Port Caps	Storage Faceform, Storage Bag, Canister Port Insert	Storage Faceform, Storage Bag, Canister Port Insert	Canister Port Insert
Other Optional Accessories	Thermal Imaging System, Tactical Facepiece Bag, (Belt, Shoulder, and Leg options) Facepiece Cleaner	Tactical Facepiece Bag (Belt, Shoulder, and Leg options)	Anti-misting Gel, Tactical Mask Bag, Mask Plug, Air Quality Test Kit	Butyl-Coated Nylon Hood, Gas Mask Pouch	Carrying Bag, Anti-fog Wipes, Neck Strap	Mask Carrier, Universal Carrier	Mask Carrier, Universal Carrier, Protective Hood	Neck Strap, Cleaning Wipes, Storage Bags

Notes: NE— Not equipped, product is not equipped with corresponding feature nor is it offered as an accessory by vendor
NA—Not available
✓—product is equipped with corresponding feature
O —optional for additional cost
[1]40mm First Responder Adapter required for CBRN use at extra cost, see Section 4.1 for more information.
[2]Clear lens cover included with facepiece, additional outserts optional for additional cost.

4.1 Scott Safety AV-3000 HT Facepiece

The AV-3000 HT (Figure 9) received an overall assessment score of 3.7 and costs $416, including the 40mm First Responder Adapter required for CBRN use. The facepiece has a single canister port, weighs 2 pounds, and is available in small, medium, and large. A 10-year warranty is included with purchase. The AV-3000 HT includes a plastic drawstring bag, a lens warning label, a facepiece bezel labeling kit, a manual, and a safety warning insert.

Figure 9. Scott Safety AV-3000 HT Donned

The following sections, broken out by SAVER category, summarize the assessment results.

Capability

The AV-3000 HT received a Capability score of 4.0. The following information is based on evaluator comments:

- The facepiece can be deployed in multiple alternate configurations and environments, including SCBA for firefighting applications. The AV-3000 HT is also NIOSH-approved for CBRN Powered Air-Purifying Respirator (PAPR) use.
- The facepiece appeared durable and well built. In addition to NIOSH approval for CBRN, information for the AV-3000 HT noted multiple durability specifications such as water, flame, and impact resistance.

Figure 10. Scott Safety 40mm First Responder Adapter

- The First Responder adapter required for CBRN use was difficult to install on the facepiece for the first time. After the adapter was attached, canisters were easy to connect and swap, and no issues with the connection were noted.

Usability

The AV-3000 HT received a Usability score of 3.7. The following information is based on evaluator comments:

- Multiple sizing possibilities and interchangeable nosecups allowed for finding a good fit. The facepiece's thin inner seal and thicker outer seal, Kevlar® head harness, and material made the facepiece comfortable to wear.
- Low to no breathing resistance was encountered.

- Canister packages were easy to open. The APR was able to be quickly and easily donned, although the mask carrier was bulky and the facepiece fit tightly inside.
- The weight of the canister caused the facepiece to tilt downwards in the front, although this did not compromise the seal. Extended use could fatigue the neck.
- Peripheral vision was slightly impaired.
- The facepiece's single port and profile of the equipment interfered with weapon sighting, and the facepiece and canister hit or rubbed up against the weapon when raised.

Deployability

The AV-3000 HT received a Deployability score of 3.8. The following information is based on evaluator comments:

- Training options were varied and in accordance with end user's respirator protection program. Initial training in operation and maintenance of facepiece is provided at no cost by vendor at time of purchase and offered in a train-the-trainer format to perpetuate ability of the organization to field equipment. Multiple additional levels of training are also available regionally and at Scott Safety University in Monroe, North Carolina.
- The facepiece features large operating and storage temperature ranges, meeting flame and heat resistance requirements for firefighting in addition to NIOSH CBRN approval. Storage requirements were not demanding especially when considering that the facepiece has no shelf life.
- Reference documentation was housed in an easy-to-read manual book with multiple diagrams, but lacked some maintenance guidance and instructions information.

Maintainability

The AV-3000 HT received a Maintainability score of 3.6. The following information is based on evaluator comments:

- No manufacturer-designated service life for the facepiece was great for sustainability or financial concerns.
- Facepiece was easy to decontaminate by hand; all areas were easy to clean and access.
- Performing routine maintenance was easy; however, manufacturer requires certification training in order to perform routine maintenance.

Affordability

The AV-3000 HT received an Affordability score of 3.5. The following information is based on evaluator comments:

- The initial cost for the facepiece with the addition of required First Responder Adapter for CBRN use is high. Yet, cost over time is not impacted by any vendor-required maintenance. The CBRN canister is also affordable and features an 8-year shelf life, which makes replacement or non-use reasonable.

4.2 Scott Safety First Responder Respirator (FRR)

The First Responder Respirator (FRR) (Figure 11) received an overall assessment score of 3.7 and costs $385. The facepiece has twin canister ports, weighs 2 pounds, and is available in small, medium, medium/large, and large. A 1-year warranty is included with purchase. The FRR also includes a safety warning insert, storage faceform, and a manual.

Figure 11. Scott Safety FRR Donned

The following sections, broken out by SAVER category, summarize the assessment results.

Capability

The FRR received a Capability score of 3.7. The following information is based on evaluator comments:

- CBRN canister packages were easy to open, and canisters were easy to connect and swap out as allowed between ports—it was observed that this could be done in the field, if needed.
- The FRR can be deployed in multiple alternate configurations and environments; however, the SCBA and PAPR configurations are not yet NIOSH-approved for CBRN use.
- The facepiece felt durable and seemed very well-built and rugged. However, one facepiece as purchased new had a defect in the chin that would not allow for a successful seal and another facepiece's strap broke on the first pull.

Figure 12. Scott Safety CBRN Canister in Packaging

Usability

The FRR received a Usability score of 3.6. The following information is based on evaluator comments:

- Twin port options and good visibility allowed for clear sighting with no interference from canister or facepiece. The weight of the canister on the side of the facepiece was noticeable but did not hinder mobility.
- The facepiece offered a good seal that did not leak; slight breathing resistance was experienced through the canister but no more than expected.
- The facepiece was quickly and easily donned, but one evaluator had difficulty adjusting the straps. The facepiece fit inside the mask carrier in multiple directions, and although it was bulky, the carrier size and weight did not interfere with operations.

- The facepiece offered multiple sizing possibilities for both facepieces and nosecups, allowing for finding a good fit. The majority of evaluators noted that the facepiece was somewhat uncomfortable, with the top of the nosecup creating discomfort at the bridge of the nose—this could be resolved by changing nosecup sizes. The bottom of the respirator also created discomfort in the chin area, with two evaluators reporting that the chin section rolls and that the chin could fall in between the seal.

Deployability

The FRR received a Deployability score of 3.6. The following information is based on evaluator comments:

- Training options were varied and in accordance with the end user's respirator protection program. Initial training in operation and maintenance of the facepiece is provided at no cost by vendor at time of purchase and offered in train-the-trainer format to perpetuate ability to field equipment. Multiple additional levels of training are also available regionally and at Scott Safety University in Monroe, North Carolina.
- The facepiece features large operating and storage temperature ranges, meeting flame and heat resistance requirements in addition to NIOSH CBRN approval.
- The facepiece requirements for storage are not overly demanding, although they do include a facepiece faceform to insert into the mask when storing for longer periods.
- Reference documentation was provided in an easy-to-read manual book with many diagrams. However, materials covered inspection but did not include maintenance information. There was no information on how to access extra or additional information beyond the manual.

Maintainability

The FRR received a Maintainability score of 3.7. The following information is based on evaluator comments:

- The facepiece was easy to decontaminate by hand; all areas were easy to access.
- The facepiece and canister shelf lives were viewed favorably. It was noted the 15-year facepiece shelf life was essentially the length of an emergency responder career.
- The vendor requires certification to perform maintenance, with special tool(s) required for some maintenance. No issues were encountered when performing maintenance tasks; however, instructions for replacement valves were included with valves rather than included in the manual.

Affordability

The FRR received an Affordability score of 3.7. The following information is based on evaluator comments:

- The initial cost for the facepiece is slightly high. Yet, cost over time is not impacted by any vendor-required maintenance. The CBRN canister is also affordable and features an 8-year shelf life, which makes replacement or non-use reasonable.

4.3 Draeger Safety Inc. CDR 4500

The CDR 4500 (Figure 13) received an overall assessment score of 3.6 and costs $207. The facepiece has a single canister port, weighs 1.1 pounds, and is available in small, medium, large, and a universal size. A neck strap and a 1-year warranty are included with purchase. The CDR 4500 also includes a plastic drawstring bag, manual, and NIOSH approval insert.

Figure 13. Draeger Safety Inc. CDR 4500 Donned

Figure 14. Draeger Safety Inc. CBRN Canister in Packaging

The following sections, broken out by SAVER category, summarize the assessment results.

Capability

The CDR 4500 received a Capability score of 3.5. The following information is based on evaluator comments:

- The facepiece seemed durable. Despite a lack of specific information for scratch or impact resistance (American National Standards Institute, etc.), the facepiece performed well in the field and had no issues.
- The canister attached easily to the facepiece and canister change outs were quick once canisters were out of packaging—after attachment, canister connections were not compromised and held up well during use. Removal tabs on the canister may be difficult to remove with gloves or other PPE. Users must remember to remove the seals on both ends of the canister prior to attaching to facepiece, otherwise they could get caught in threads and prevent attachment or seal.
- The facepiece offered assortment of accessories but lacks communications improvement beyond included speech diaphragm.
- The facepiece is limited for use in multiple different situations and/or configurations—able to be used with PAPR, but not currently approved by NIOSH for CBRN PAPR.

Usability

The CDR 4500 received a Usability score of 3.4. The following information is based on evaluator comments:

- The seal maintained integrity during all operational assessments; no leaks occurred. Breathing was not difficult but most evaluators noticed increased resistance during stair climbing and lifting.

- The facepiece was easily donned both with and without mask carrier—the mask fit neatly in carrier, but evaluators had to be cognizant of the leg pouch sticking out in order not to bump into things. The rubber straps were difficult to tighten at first and two evaluators had difficulty in successfully adjusting the top strap of the facepiece.
- The facepiece was small and light overall, but the integrated nosecup created some discomfort on nose. The seal around the chin was not comfortable—the canister weight pulled the facepiece down in the front and added pressure to the jaw.
- The centered canister placement allowed equal range of motion on both sides; however, some difficulty was experienced looking downward and the facepiece seemed to sway while walking. The canister would tap evaluators' chests while they tilted their heads down, and while going down stairs. The single port and profile of the mask interfered with weapon sighting.

Deployability

The CDR 4500 received a Deployability score of 3.6. The following information is based on evaluator comments:

- Reference documentation was comprehensive; step-by-step instructions were worded so anyone could perform maintenance. The manual was easy to use and had charts for routine maintenance. After finding the English section, material was easily navigated.
- The operating temperature of -22°F to 248°F provides a large functional range, and lower or higher temperatures are permitted with short exposure times. Storage temperature ranges were also wide, and not viewed as restrictive.
- Technical support is available by phone during normal business hours, and after hours calls are handled by an answering service, which then contacts the technical team. Operator or technician training options are available at additional cost, and repairs may only be carried out by trained and qualified service personnel.

Maintainability

The CDR 4500 received a Maintainability score of 3.7. The following information is based on evaluator comments:

- The 12-year canister shelf life exceeded expectations, and facepiece shelf life of at least 10 years was viewed favorably.
- All maintenance was performed quickly and easily. Valve replacement was simple and did not require special tools.
- Decontamination of the facepiece was simple but the opening between the lens and the nosecup was inaccessible during decontamination; this concern would be irrelevant if mask is immersed in disinfectant.

Affordability

The CDR 4500 received an Affordability score of 3.8. The following information is based on evaluator comments:

- The initial cost for the facepiece is well-priced. The canisters are somewhat expensive to replace; however, they have a long shelf life. Without operational necessity, no maintenance-prescribed replacement parts are forecasted until 4 years after purchase.

4.4 Mine Safety Appliances (MSA) Millennium® CBRN Gas Mask

The Millennium (Figure 15) received an overall assessment score of 3.6 and costs $595. The facepiece has twin canister ports and is available in small, medium, and large. The medium-sized facepiece weighs 1.3 pounds. A plastic clamshell storage case, a clear lens outsert, and a 1-year warranty are included with purchase. A drawstring plastic bag, manual, wrench, and NIOSH approval inserts are included.

Figure 15. MSA Millennium Donned

The following sections, broken out by SAVER category, summarize the assessment results.

Capability

The Millennium received a Capability score of 3.8. The following information is based on evaluator comments:

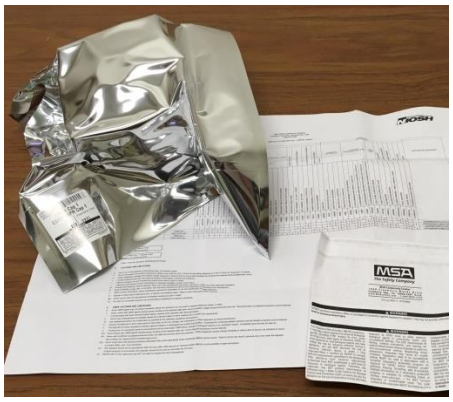


Figure 16. MSA CBRN Canister in Packaging

- The facepiece can be deployed in several alternate configurations and environments, and is NIOSH-approved for CBRN PAPR.
- The canister was very easy to swap out, and there were no tabs or caps to remove when dealing with the canister packaging; this also ensures that canisters would be easy to attach with gloves.
- The facepiece held up well and seemed durable, although the thin material and pliable lens made some evaluators question the overall ruggedness of the equipment. This concern was offset by the included polycarbonate lens outsert that attached to the mask for impact and scratch protection.
- The canister was nearly as large as the mask, and while the canister connection remained tight during all scenarios, it was noted that the canister was only screwed in to the port by a few threads—this could cause issues during rough usage or if the canister experienced a forceful impact.

Usability

The Millennium received a Usability score of 3.7. The following information is based on evaluator comments:

- The Millennium was easily and quickly donned, although the facepiece strap tabs were small and difficult to grab and tighten when they were let all the way out. When stored in the mobile carrier, the combination was slightly bulky but did not feel heavy.

The facepiece fit well inside the carrier, secured to the leg well, and was easily removed and donned from the carrier.

- The seal maintained integrity well. A noticeable amount of breathing resistance was felt during arduous workloads (when climbing stairs and lifting the simulated victim).
- The wide facepiece lens offered great visibility and had a very wide field of view, but a slight glare was noted on the lens and the lens outsert—this could have been impacted by the florescent indoor lighting.
- The facepiece was light and felt comfortable on and around the face, although the integrated nosecup rubbed or dug into a couple of evaluators' noses. The weight distribution of the canister pulled the facepiece slightly to one side and made the facepiece slightly unbalanced, yet this allowed for easy sighting with the weapon.

Deployability

The Millennium received a Deployability score of 3.1. The following information is based on evaluator comments:

- Reference documentation was comprehensive and easy to read and understand. The manual took the form of a booklet and included step-by-step instructions and appropriate photos for demonstration.
- Technical support was offered during normal business hours and an after-hours number was available. Online training was available and included with purchase.
- Storage of the facepiece required a special clamshell to store. While an additional requirement, the clamshell was included with purchase and large enough to fit canisters, the facepiece, and other materials.
- No operating temperature ranges were provided outside of those for NIOSH CBRN approval.

Maintainability

The Millennium received a Maintainability score of 3.9. The following information is based on evaluator comments:

- Decontamination was simple and all parts of the facepiece were easy to access.
- The Millennium's lack of a designated facepiece service-life exceeded expectations, but the 5-year canister shelf life was not viewed as favorably.
- Swapping ports in the field is feasible, and maintenance was not difficult to complete. However, swapping the canister ports requires a special tool and also involves moving the mechanical speech diaphragm or voice emitter from one side of the facepiece to the other, requiring keeping track of a number of small pieces.

Affordability

The Millennium received an Affordability score of 2.9. The following information is based on evaluator comments:

- The initial cost of the facepiece was considered expensive. The Millennium has no scheduled maintenance or part replacement, which was viewed favorably, but the cost of replacing used or expired canisters over time was considered high.

4.5 Honeywell Opti-Fit™ CBRN

The Opti-Fit (Figure 17) received an overall assessment score of 3.5 and costs $284 for the small and medium sizes and $278 for large (with hydration valve, $323 for small and medium sizes, $312 for large). Two canister port caps and a 1-year warranty are included with purchase. A plastic zipper bag, manual, warning insert, and single-use fog eliminator cloth are also included.

Figure 17. Honeywell Opti-Fit Donning

The following sections, broken out by SAVER category, summarize the assessment results.

Capability

The Opti-Fit received a Capability score of 3.5. The following information is based on evaluator comments:

- The facepiece can be deployed in several alternate configurations and environments, and is NIOSH-approved for CBRN PAPR.
- The facepiece appeared durable and met expectations. Canister connections were never compromised.
- The canisters were attached with ease to the facepiece, and port swaps could be easily swapped in the field if necessary using only a quarter as a tool.
- The facepiece offered assortment of accessories, including a hydration tube option, but lacked communications improvements.
- It was difficult to get canisters out of packaging and remove their seal without a knife. The canister pouch packaging also included a gasket on canister cap—users must remember to remove or it can interfere with connection. This gasket is not mentioned in the manual. One canister as received was defective and had a divot in its threading that would not allow for an effective connection.

Figure 18. Honeywell CBRN Canister

Usability

The Opti-Fit received a Usability score of 3.5. The following information is based on evaluator comments:

- The Opti-Fit's seal maintained integrity and stayed firm even when users perspired. Users experienced low breathing resistance and most did not report an increase over time.

- Triple canister ports allowed for several different canister location options, and even when the canister was attached to one side evaluators reported the CBRN APR still felt balanced. Switching canister ports allowed for clear weapon sighting.
- The wide facepiece lens offered great peripheral vision, although the length of the facepiece lens and nosecup size made looking down difficult for two evaluators.
- The Opti-Fit was easily adjustable and its straps tightened very easily. Three evaluators found that the facepiece's bottom straps needed to be cinched strongly in order to get a good seal, making the straps rub underneath their ears.
- The facepiece was easily and quickly donned, and when using the mobile carrier, the pouch secured nicely and did not move around. However, when donning from the pouch, the facepiece fit in tightly and it was slower to deploy. The canister did not fit well in the designated spot within the carrier, and fell out when the mask was removed.

Deployability

The Opti-Fit received a Deployability score of 3.2. The following information is based on evaluator comments:

- The Opti-Fit storage requirements were not demanding—the facepiece must be stored in the storage bag and cardboard box that are included with the mask.
- The manual came in an easy-to-read booklet format. The reference documentation provided somewhat vague instructions but they were adequate and understandable.
- Minimum operating temperatures outside of NIOSH requirements for CBRN environments were not provided.

Maintainability

The Opti-Fit received a Maintainability score of 3.8. The following information is based on evaluator comments:

- The lack of a designated facepiece service-life for the Opti-Fit exceeded expectations, and the 10-year shelf life for CBRN canisters was also viewed favorably.
- Decontamination was easy and all portions of the facepiece were accessible.
- Maintenance was easy to complete without special tools, although one evaluator mentioned that it was difficult to pull the exhalation valve through the facepiece, noting it would be especially difficult for removal with large fingers.

Affordability

The Opti-Fit received an Affordability score of 3.8. The following information is based on evaluator comments:

- The initial cost of the facepiece was viewed as well-priced and offered different pricing levels with or without the hydration valve. The canisters' cost combined with shelf life was viewed favorably in conjunction with the fact that no maintenance-prescribed replacement parts were forecasted without operational necessity.

4.6 Avon Protection Systems C50™

The C50 (Figure 19) received an overall assessment score of 3.5 and costs $422. The facepiece has twin canister ports, weighs 1.1 pounds, and is available in small, medium, and large. A storage faceform, a protective bag, a storage bag, a canister port insert, and an 18-month warranty, are included with purchase. A manual and NIOSH approvals are included.

Figure 19. Avon Protection Systems C50 Donned

Figure 20. Avon Protection Systems CBRN Canister with Caps

The following sections, broken out by SAVER category, summarize the assessment results.

Capability

The C50 received a Capability score of 3.6. The following information is based on evaluator comments:

- The facepiece felt durable, rugged, and well built—the fact that product met U.S. military standards for battlefield conditions was viewed favorably.
- The facepiece can be deployed in several alternate configurations and environments, and is NIOSH-approved for CBRN PAPR.
- The canister was easily attached, maintained connection, and never compromised; one evaluator noted that the canister was not easy to get out of packaging and that a tab on the foil cover would be useful.
- The range of available accessories and those that come standard (communications port, hydration valve, etc.) was viewed favorably.

Usability

The C50 received a Usability score of 3.6. The following information is based on evaluator comments:

- The C50's seal maintained integrity and no breathing resistance was noticed.
- The facepiece was comfortable overall, although when looking down evaluators noticed a slight discomfort in the chin of the mask with its long neck piece jutting out.
- The range of motion for user head movement was very good and the weight distribution of the facepiece was balanced even when the canister was attached. The CBRN APR did not impact weapon sighting. However, as swapping ports requires a certified technician, the canister port location must be set to the correct side in advance.

- The mask carrier was a little bulky but it did not hamper donning. Facepiece was quick to don, as long as you had already set the temple straps and remembered to lock them. Using the Velcro and lock tabs on the temple straps is time consuming at first.
- The hydration valve straw occasionally twisted around and rubbed against users' upper lips or into their noses. It was noted that you must remember to make sure the hydration straw is secure or at least turned away from your face within the mask if not in use.

Deployability

The C50 received a Deployability score of 3.6. The following information is based on evaluator comments:

- The vendor offers 24/7 support, and operator maintenance was very accessible as described in the booklet manual.
- Expanded operating temperatures for limited time periods were viewed favorably, and the storage requirements, while needing a storage faceform, were not seen as demanding as the faceform was included with purchase.
- Training is available for an additional cost, and technician-level certification training is required for many maintenance procedures.

Maintainability

The C50 received a Maintainability score of 3.5. The following information is based on evaluator comments:

- The facepiece's 10-year shelf life was viewed favorably, especially when given the option to recondition the facepiece for additional 10 years. The 5.5-year canister shelf life was thought to be too short.
- The maintenance that evaluators could complete as non-trained technicians was easy and manual instructions were simple to follow. Port swaps and other maintenance procedures require certification from the vendor. Three evaluators considered this an unnecessary training and cost burden, while two wanted those in charge of their facepieces' maintenance to be as well-trained as possible.

Affordability

The C50 received an Affordability score of 2.8. The following information is based on evaluator comments:

- The initial cost for the C50 was viewed as high, although it was noted that the facepiece did include many accessories at base cost.
- The maintenance cost for the C50 was viewed as moderately high: canisters were reasonably priced but a short shelf life meant costs would add up. Additionally, costs for required training were also a factor.

4.7 Avon Protection Systems FM53™

The FM53 (Figure 21) received an overall assessment score of 3.4 and costs $1,117 for the single port model and $1,142 for the twin port model. The facepiece weighs 1.6 pounds and is available in extra-small, small, medium, and large. Purchase of either model includes a storage faceform, a protective bag, a storage bag, and an 18-month warranty. The twin port model also includes a canister port insert and removal tool. For the single port model, port location must be specified at purchase. A manual and NIOSH approval inserts are also included.

Figure 21. Avon Protection Systems FM53 Donned

The following sections, broken out by SAVER category, summarize the assessment results.

Capability

The FM53 received a Capability score of 3.7. The following information is based on evaluator comments:

- The FM53 can be deployed in many alternate configurations and environments, and its hybrid system is unique and could be useful; however, these configurations are pending NIOSH-approved for CBRN use.
- The facepiece comes standard with many accessories, such as an electronic communications port, voice projection unit, and hydration valve. A wide assortment is also available for additional cost.
- The facepiece felt well-built and held up during scenarios. Military standards were viewed favorably. The canister did not budge during use and maintained its connection, although some noted it was difficult to open the canister packaging.

Figure 22. Avon Protection Systems Mask Carriers: Belt (Left) and Leg (Right)

Usability

The FM53 received a Usability score of 3.6. The following information is based on evaluator comments:

- The facepiece maintained seal integrity and little to no breathing resistance was encountered. Resistance did not increase over time.
- The FM53's sizing options were viewed very favorably, offering four different sizes and interchangeable nosecups. The facepiece was considered comfortable, and the material of the mask was especially comfortable; however, the nosecup caused minor discomfort and the hydration tube kept poking the inside of evaluators' noses even when turned away prior to donning.

- The facepiece was balanced and did not impact range of motion. No issues were encountered when sighting the weapon, and the facepiece created little interference. As the FM53 is available as a single port facepiece, care must be taken to decide on port location in relation to the user's right or left sighting preference in advance.
- The CBRN APR was easily donned, but the Velcro harness head assembly was slow to operate and straps had to be adjusted to keep a good seal. The mask carriers were bulky and larger than necessary, but could hold additional canisters, accessories, or other configuration types. The carrier's pouch flap is reversed and can make removing the facepiece from the carrier slightly more difficult, yet the strap for opening the pouch helped.

Deployability

The FM53 received a Deployability score of 3.5. The following information is based on evaluator comments:

- The expanded operating temperatures for limited time periods were viewed favorably, and the storage requirements, while needing a storage faceform, were not seen as demanding. The faceform was included with purchase.
- The vendor offered 24/7 support, and operator maintenance and multiple diagrams were accessible as described in the booklet manual. No alternate ways of retrieving product information or technician maintenance beyond the manual were noted or available.
- Training is available for an additional cost, and technician-level certification training is required for many maintenance procedures.

Maintainability

The FM53 received a Maintainability score of 3.3. The following information is based on evaluator comments:

- The facepiece's 10-year shelf life was viewed favorably, and a reconditioning option exists for an added 10 years. The 5.5-year canister shelf life was considered too short.
- The FM53 had large surface areas to decontaminate, but most were easily accessible.
- The maintenance that evaluators could complete as non-trained technicians was easy and the manual instructions were simple to follow. Port swaps and other maintenance procedures required certification from the vendor. Three evaluators considered this an unnecessary training and cost burden, while two wanted those in charge of their facepieces' maintenance to be as well-trained as possible.

Affordability

The FM53 received an Affordability score of 2.1. The following information is based on evaluator comments:

- The FM53's initial cost was seen as very expensive, even if it included an electronic voice projection unit and other accessories. Maintenance costs were viewed as moderately high: canisters were reasonably priced but a short shelf life meant costs would add up. Costs for training were also a factor.

4.8 3M™ Full Facepiece FR-7800B

The FR-7800B (Figure 23) received an overall assessment score of 3.4 and costs $335. The facepiece has twin-canister ports, weighs 1.3 pounds, and is available in small, medium, and large. A canister port insert and warranty are included with purchase. The duration of the warranty was not provided by the manufacturer. A plastic drawstring bag, manual, facepiece lens warning, and NIOSH approval insert are included.

Figure 23. 3M Full Facepiece FR-7800B

The following sections, broken out by SAVER category, summarize the assessment results.

Capability

The FR-7800B received a Capability score of 3.4. The following information is based on evaluator comments:

- The facepiece seemed durable, rugged, and had no apparent defects. The canister held up in the short amount of time in us; it maintained connection and never compromised the mask.
- Attaching the canister to the facepiece was quick and simple, if the port insert was already removed.
- The FR-7800B does not have any additional configurations, but can operate in riot or crowd control environments with a different canister.
- Voice communications were slightly muffled while wearing the facepiece.

Figure 24. 3M CBRN Canister

Usability

The FR-7800B received a Usability score of 3.2. The following information is based on evaluator comments:

- The FR-7800B maintained seal integrity and no leakage occurred. Breathing resistance was noticeable while performing arduous tasks (climbing stairs, lifting victim) and a slight increase in respiratory effort was noticed over time.
- The canister was wider than it was long and this helped provide a good balance when it was attached to the side of the facepiece. Evaluator range of motion was not impacted; sighting a weapon was only moderately difficult due to the contours of the facepiece.

- The facepiece was moderately comfortable; integrated nosecups seemed slightly undersized and pressed against the nose. A six-strap harness helped ensure a good seal around face, but the CBRN APR did not feel snug around the chin—evaluators were worried that the facepiece would pull away from the jawline.
- The CBRN APR was easily and quickly donned even with a high number of straps; however, there was no mask carrier.
- The FR-7800B's visor slightly limited evaluators' peripheral vision—although this 'tunnel vision' feeling expressed by evaluators was not reflected in the Peripheral Vision data (Appendix C).
- The canister port insert was extremely difficult to remove without tools, and the port insert was placed so securely in the facepiece that almost half of the evaluators were not able to remove the canister port cap even with the use of tools.

Deployability

The FR-7800B received a Deployability score of 3.3. The following information is based on evaluator comments:

- The facepiece's storage requirements were simple and not demanding. Training requirements are standard and provided online and on-site per request at no extra cost.
- The FR-7800B's reference documentation was comprehensive and the wording was easy to read and understand; however, the manual was not in book form and the multifold pamphlet is unwieldy.
- Operating temperatures are not provided beyond NIOSH requirement for CBRN environments.

Maintainability

The FR-7800B received a Maintainability score of 3.4. The following information is based on evaluator comments:

- The no manufacturer-designated facepiece shelf life exceeded expectations, while the canister shelf life was thought to be too short.
- Decontamination was simple but accessing the area behind the nosecup by hand was difficult.
- Maintenance was simple and all steps were easily executed except for the difficulty in removing the canister port insert with and without tools.

Affordability

The FR-7800B received an Affordability score of 3.4. The following information is based on evaluator comments:

- The initial cost of the facepiece was viewed favorably and thought to be well priced.
- The maintenance cost of the FR-7800B was moderately favorable, with no maintenance-prescribed replacement parts forecasted. However, the short canister shelf life would increase maintenance cost.

5. SUMMARY

CBRN APRs are a type of PPE worn by emergency responders to protect them from inhaling harmful contaminants that may be present when responding to CBRN incidents. All CBRN APR overall scores were within a margin of 0.3 points, and all meet strict NIOSH CBRN standards. Scoring differences among the CBRN APRs are more distinct for the individual categories (Capability, Usability, Deployability, Maintainability, and Affordability).

All CBRN APRs feature CBRN canisters for use with the facepieces, and currently all CBRN canisters are rated CAP 1, or NIOSH-approved for a 15 minute operating capacity for escape only (when concentration levels are unknown). All CBRN APRs maintained field-worthy seals and experienced low to moderate breathing resistance throughout the assessment; however, while the assessment sought to create realistic operational scenarios, exercises had to be balanced with safety. It is assumed that arduous environments experienced by emergency responders would require more physical exertion and create added perspiration within facepieces. Comfort is highly user-dependent, and is influenced by user faces of various shapes and sizes.

Evaluators preferred long, indefinite, or non-designated shelf-lives for both facepieces and canisters, which limits costs over time and does not necessitate replacement unless operationally required. Evaluators also preferred CBRN APRs that could be utilized in alternate configurations and environments, both CBRN and otherwise. This freedom in configuration would mean a single facepiece could be deployed with different accessories or canisters for multiple scenarios or environments, and potentially cut maintenance costs and training times. The major advantages and disadvantages for the assessed products are highlighted in Table 5-1.

Emergency responder agencies that consider purchasing CBRN APRs should carefully research each product's overall capabilities, approvals, and limitations in relation to their agency's operational needs, and consider OSHA requirements and regulations under §1910.134.

Table 5-1. Product Advantages and Disadvantages

Vendor/Product		Advantages	Disadvantages
 MSRP: $416	Scott Safety AV-3000 HT Overall Score: 3.7	• Multiple alternate configurations • Large operating and storage temperature ranges • No manufacturer-designated service life • Multiple training offerings at no extra cost	• Requires First Responder Adapter for CBRN use • Weight of canister caused slight tilt downward • Certification and training required for some maintenance • Peripheral vision slightly impaired
 MSRP: $385	Scott Safety First Responder Respirator (FRR) Overall Score: 3.7	• Multiple alternate configurations • Full range of motion and ease with weapon sighting • Long 15-year facepiece shelf life • Multiple training offerings at no extra cost • Versatile mask carrier	• Defect in one unit's chin and another facepiece's strap broke on first pull • Certification and training required for some maintenance • Somewhat uncomfortable; discomfort in the chin and nose areas

Vendor/Product		Advantages	Disadvantages
 MSRP: $207	Draeger Safety Inc. CDR 4500 Overall Score: 3.6	• Overall small and light facepiece • Long facepiece shelf life, very long canister shelf life • Accessible reference documentation • Maintenance performed easily and quickly	• Lack of communication improvement accessories • Moderate discomfort around chin and nose • Centrally placed canister sways facepiece during movement and interferes with weapon sighting
 MSRP: $595	Mine Safety Appliances Millennium Overall Score: 3.6	• Canisters easily removed from packaging and attached • Good assortment of included accessories • No manufacturer-designated service life	• Large, heavy canister compared to small, light facepiece; slight unbalance • Maintenance may require special tools and involve many small pieces • Short canister shelf life
 MSRP: $278 to $323	Honeywell Opti-Fit Overall Score: 3.5	• No manufacturer-designated service life for facepiece and long canister shelf life • Three canister port options, no interference with weapon sighting • Includes hydration tube	• Gasket on canister cap could interfere if not removed • Facepiece's bottom straps rubbed underneath ears • Difficult to remove canisters from packaging • No communication improvement accessories
 MSRP: $422	Avon Protection Systems C50 Overall Score: 3.5	• Good range of motion, no interference with weapon sighting • Hydration tube and electronic communications port included • Facepiece felt durable, rugged, and well-built	• Velcro and lock tabs on straps difficult • Technician-level certification required for non-routine maintenance • Slight discomfort in chin, long neck piece • Hydration valve poked nose
 MSRP: $1117 to $1142	Avon Protection Systems FM53 Overall Score: 3.4	• Hybrid system, multiple alternate configurations • Communications port, hydration tube, and voice amplification included • Pliable but rugged, comfortable material • No issues sighting weapon	• Costly • Velcro and lock tabs on straps difficult • Technician-level certification required for non-routine maintenance • Hydration valve pokes user even when spun prior to use
 MSRP: $335	3M FR-7800B Overall Score: 3.4	• No manufacturer-designated service life • Simple storage requirements • Good range of motion • Canister was wider than long, providing balance when wearing facepiece	• No mask carrier • Some canister port inserts unable to be removed even with tools • Slightly muffled communications • Breathing resistance during moderate work

APPENDIX A. EVALUATION CRITERIA DEFINITIONS

The focus group identified 27 evaluator criteria, which are defined as follows.

Capability

Facepiece Durability refers to the Chemical, Biological, Radiological, and Nuclear (CBRN) Air-Purifying Respirator's (APR) overall ruggedness, including the sturdiness of its straps, lenses, and other appendages. Durability could also include the product's water resistance, flammability, tensile strength, impact resilience, and scratch resistance.

Canister Durability refers to the ability of the canister to withstand operational impacts during deployment and still maintain a field-worthy connection with the CBRN APR.

Convertibility refers to the possibility of converting the CBRN APR for use in different situations and/or configurations (Air-Purifying Respirator [APR], Powered Air-Purifying Respirator [PAPR], Self-Contained Breathing Apparatus [SCBA], and Supplied-Air Respirator [SAR]).

Communications refers to a user's voice clarity with communications features that come standard with the CBRN APR while wearing the facepiece. This can be evidenced by the ability for consistent and clear vocal interaction to and from the user at a set distance over operationally comparable background noise.

Adaptability refers to the ease of attaching a CBRN canister to a CBRN APR and switching a CBRN canister between ports (dual or triple port) based on operational use and/or user preference, if more than one port is available.

Canister Longevity refers to the National Institute for Occupational Safety and Health (NIOSH) approved capacity of the CBRN APR's corresponding CBRN canister.

Available Accessories refers to availability of accessories for the CBRN APR. Accessories may include hydration features, electronic communications accessories available from the CBRN APR manufacturer, removable film visor protectors, visor outserts, vision correction assemblies, and more.

Usability

Seal Integrity refers to not having to continually reseal the facepiece during operation, evidenced by effective straps and a continuous seal, as well as its ability to maintain a seal after impact. Seal Integrity also refers to whether any liquid leaks from the facepiece and/or exhalation valve and the capacity for this leakage to impact operations (specifically sampling).

Breathing Resistance refers to how easily the user can inhale and exhale while wearing the CBRN APR and using an attached CBRN canister.

Comfort refers to the highly user-dependent notion that the equipment affords physical comfort to the wearer. Comfort takes into account the propensity of straps and buckles to cause discomfort, the ability to wear the equipment for an extended operational period, the available sizing and fit of facepieces, and the interchangeability of nosecups.

Visibility refers to the field of view of the facepiece, as well as the propensity of the lens to fog or acquire condensation.

Material refers to the composition of the facepiece and nosecup.

Mobility/Ergonomics refers to the weight balance and profile of the facepiece with an attached CBRN canister while worn on the user's face. Mobility/Ergonomics also includes the user's range of motion or ease of moving user's head from side to side while wearing the CBRN APR.

Accessibility refers to the ease and speed of donning the CBRN APR with a corresponding CBRN canister.

Stored Facepiece Portability refers to the bulkiness of the facepiece while inserted in a carrier, pouch, or case (and its combined weight) while worn on the user.

Deployability

Training Requirements refers to what CBRN APR training is offered, what training is required for operational use and end-user maintenance, the length of training, and the training requalification intervals, if any are required in addition to OSHA annual training requirements for operational use, maintenance, and storage under OSHA 1910.134(k).

Reference Documentation refers to the ease of accessibility and comprehensiveness of reference documentation. This may include certifications, approvals, user manuals, quick-reference guides, and/or online resources.

Storage Requirements refers to the ability for the facepiece to be deployed after being stored for extended periods of time without deterioration or changing shape. This also refers to the manufacturers' suggested or required storage recommendations.

Operating Temperature refers to the ability of the CBRN APR and its material composition to maintain seal integrity in extreme operating temperatures, evidenced by the minimum and maximum operating temperatures of the equipment.

Maintainability

Ease of End-User Maintenance refers to the ease of performing routine maintenance and whether users can self-service the CBRN APR or the manufacturer is required.

Decontamination refers to the ability to easily decontaminate the CBRN APR facepiece or parts.

Warranty refers to the duration and terms of the CBRN APR's warranty included with purchase. This duration will be provided as information only.

Technical Support refers to the availability of knowledgeable representatives, hours of availability, the availability of on-site support, and the quality of assistance. These hours of availability will be provided as information only.

Facepiece Shelf Life refers to the length of time or date from manufacture that the CBRN APR is field-worthy with recommended storage and maintenance.

Canister Shelf Life refers to the length of time or date from manufacture that the CBRN canister corresponding to the CBRN APR is field-worthy and within date for use.

Affordability

Initial Cost refers to the cost of purchasing the CBRN APR, as evidenced by MSRP.

Maintenance Cost refers to the cost of the CBRN APR's corresponding CBRN canisters, replacement parts, training, and extended warranties over a span of three years.

APPENDIX B. ASSESSMENT SCORING FORMULAS

The overall score for each product was calculated using the product's averaged criterion ratings and category scores. An average rating for each criterion was calculated by summing the evaluators' ratings and dividing the sum by the number of responses. Category scores for each product were calculated by multiplying the average criterion rating by the weight assigned to the criterion by the focus group, resulting in a weighted criterion score. The sum of the weighted criterion scores was then divided by the sum of the weights for each criterion in the category as seen in the formula and example below.

Category Score Formula

$$\frac{\sum\left(Average\ Criterion\ Rating \times Criterion Weight\right)}{\sum\left(Criterion Weights\right)} = \begin{matrix} Category \\ Score \end{matrix}$$

Category Score Example[2]

$$\frac{(4.3\times 4)+(5\times 4)+(4\times 3)+(4.5\times 3)+(4.5\times 3)}{4+4+3+3+3} = 4.5$$

To determine the overall assessment score for each product, each category score was multiplied by the percentage assigned to the category by the focus group. The resulting weighted category scores were summed to determine an overall assessment score as seen in the formula and example below.

Overall Score Formula

$$\sum\left(Category\ Score \times Category\ Percentage\right) = \begin{matrix} Overall\ Assessment \\ Score \end{matrix}$$

Overall Score Example[1]

$$\underset{Capability}{(4.0\times 33\%)} + \underset{Usability}{(4.2\times 27\%)} + \underset{Affordability}{(4.2\times 20\%)} + \underset{Maintainability}{(3.8\times 10\%)} + \underset{Deployability}{(4.5\times 10\%)} = 4.1$$

[2]Examples are for illustration purposes only. Formulas will vary depending on the number of criteria and categories assessed and the criteria and category weights.

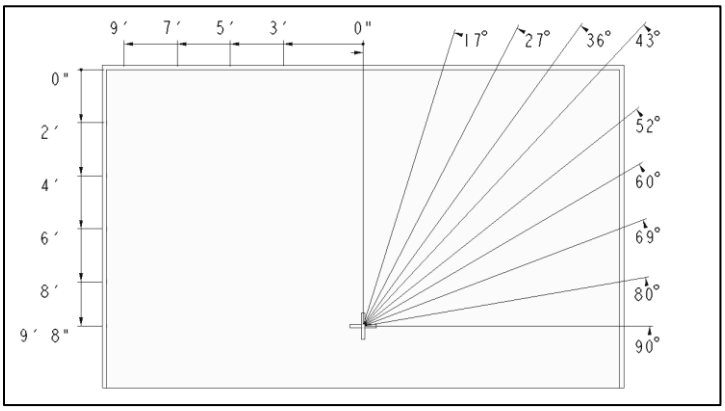
APPENDIX C. PERIPHERAL VISION DATA

This Appendix provides peripheral vision data for each CBRN APR, for each evaluator. As noted in Section 3.3.2, during the Donning, Use, and Decontamination Trial evaluators centered themselves on a marker within the room, aligned their toes on a designated line, and reported, with assistance from assessment facilitators, the furthest angle marker visible while having each CBRN APR donned. Baseline vision data was also collected prior to assessing any CBRN APR.

The below table shows the total peripheral field of view when adding the two angles (left and right) from the center point, in both bright and dim testing iterations. A graphic representing the distances measured and their corresponding angles are shown in the figure below.

Peripheral Vision Data

Evaluator #	Room Lighting	Baseline	AV-3000 HT	FRR	CDR 4500	Millennium	Opti-Fit	C50	FM53	FR-7800B
1	Bright	180	149	180	180	180	160	170	160	180
	Dim	180	129	170	180	180	160	160	149	180
2	Bright	180	160	180	180	180	180	180	180	180
	Dim	160	149	160	180	180	160	180	180	180
3	Bright	180	138	180	180	180	160	180	180	180
	Dim	160	138	160	180	170	160	180	180	180
4	Bright	180	149	180	180	180	170	180	180	180
	Dim	180	138	170	180	180	170	180	180	160
5	Bright	180	159	180	180	180	180	180	180	180
	Dim	160	149	160	160	170	180	160	160	160
Compiled Average	Bright	180	151	180	180	180	170	178	176	180
	Dim	168	141	164	176	176	166	172	170	172



Peripheral Vision Assessment Representation

APPENDIX D. COMMUNICATIONS REPEAT DATA

The table below provides the communications success rate data for each CBRN APR, for each evaluator. As noted in Section 3.3.2, during the Donning, Use, and Decontamination Trial each evaluator read aloud a randomized phrase and the paired evaluator had to repeat the phrase back to confirm successful communication through the CBRN APR.

In the table below, the numbers noted reflect the amount of times a phrase needed to be repeated to be understood with the respective CBRN APR donned. While subjective, this means that a rating of '1' is superior to a rating of '2.' This data set may have irregularities due to the differences in randomized phrases and the potential for any vocal accents of evaluators, rather than a direct effect of CBRN APRs. The overall Communication evaluation criteria included evaluator experience across all operation scenarios—this data is just a snapshot.

Communications Repeat Data

Evaluator #	AV-3000 HT	FRR	CDR 4500	Millennium	Opti-Fit	C50	FM53	FR-7800B
1	2	2	1	1	1	2	1	1
2	1	1	1	1	1	1	1	1
3	2	3	1	2	1	1	1	1
4	1	1	1	1	1	1	1	1
5	2	2	1	1	1	1	2	1
Compiled Average	1.6	1.8	1	1.2	1	1.2	1.2	1

APPENDIX E. FIT FACTOR DATA

As noted in Section 3.1, all evaluators completed fit tests for each CBRN APR. The table below provides each evaluator's fit factor for each individual CBRN APR.

A higher fit factor is indicative of less leakage of outside air into the facepiece. OSHA Respiratory Protection Standard 29 CFR 1910.134 requires workers to achieve a fit factor of 500 or greater to pass for operational use, and the standard does not distinguish between different environments for deployment (i.e., CBRN).

However, most manufacturers recommend a pass level of 2,000 or 2,500 for CBRN environments. While this higher pass level would provide an added safety factor, obtaining such a score—or anything higher than the minimum requirement of 500—does not increase the OSHA-assigned protection factor for the respirator, nor does it condone the use of the respirator in a more toxic atmosphere.

All evaluators exceeded OSHA-required fit factors in all cases.

Fit Factor Data

Evaluator #	AV-3000 HT	FRR	CDR 4500	Millennium	Opti-Fit	C50	FM53	FR-7800B
1	9,521	5,359	7,937	9,364	12,750	11,859	5,397	40,730
2	3,571	7,283	7,666	7,374	3,518	7,963	3,679	24,078
3	15,279	6,754	8,571	9,402	11,377	5,064	6,056	35,529
4	5,096	5,154	3,901	5,055	6,710	2,550	6,623	15,765
5	2,319	3,196	1,901	2,609	4,531	2,779	3,134	27,947
Compiled Average	7,157.2	5,549.2	5,995.2	6,760.8	7,777.2	6,043	4,977.8	28,809.8