



Respiratory Protection for Firefighters during Overhaul Operations

Operational Field Assessment Report

February 2019



**Homeland
Security**

Science and Technology



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FOREWORD

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Visit the [NUSTL website, https://www.dhs.gov/science-and-technology/national-urban-security-technology-laboratory](https://www.dhs.gov/science-and-technology/national-urban-security-technology-laboratory), for more information on NUSTL programs and projects.

POINT OF CONTACT

National Urban Security Technology Laboratory (NUSTL)
U.S. Department of Homeland Security (DHS)
Science and Technology Directorate (S&T)
201 Varick Street, Suite 900
New York, NY 10014

E-mail: NUSTL@hq.dhs.gov

Website: www.dhs.gov/science-and-technology/national-urban-security-technology-laboratory

Author:

Brian Albert, Test Director, Electrical Engineer, NUSTL

EXECUTIVE SUMMARY

After extinguishing structural fires, firefighters carry out fire overhaul operations to locate and extinguish smoldering hot spots. Early on in the overhaul operations, firefighters wear self-contained breathing apparatus (SCBA); although, it is common practice to remove the SCBA when the carbon monoxide (CO) concentration drops to a safe level. Studies have shown, however, that after CO dissipates, particulate matter and harmful chemicals are still present during overhaul environments. As a result, firefighters must continue to wear heavy SCBA equipment throughout overhaul operations or risk breathing in the hazardous material present in the overhaul environment. To address this hazard, the Respiratory Protection for Firefighters during Overhaul Operations project developed a filter module that is designed to be used in passive air-purifying respirators (APRs) and powered APRs (PAPRs) to protect firefighters from particulate and chemical hazards while being lighter and more comfortable than the traditional SCBA.

The filter module was developed by TDA Research Inc. in partnership with Avon Protection Systems Inc. The module's main component is a plastic canister that contains a high-efficiency particulate air filter that removes fine particles as well as an activated carbon mixture that removes chemical hazards commonly found in overhaul environments. The disposable canister has a 4-hour lifespan and a standard threaded connection that can be attached to commercially available facemasks and respirators. A rubber boot with a washable foam pre-filter that removes large particles, such as ash and soot, fits over the canister. An optional CO filter can be attached to the canister.

The U.S. Department of Homeland Security, Science and Technology Directorate, National Urban Security Technology Laboratory (NUSTL) conducted an operational field assessment (OFA) of the filter module deployed in an APR, an EZ-Air® PAPR system that uses a single filter module, and a Multi-Position PAPR (MP-PAPR™) that uses two filter modules. The OFA was held on October 17, 2018, at the Federal Emergency Management Agency's National Fire Academy in Emmitsburg, Maryland. Six individuals from fire departments in Colorado, Maryland and Virginia served as evaluators, and wore the filter modules in each of the three system configurations while performing operational activities.

The majority of evaluators believed that each system configuration was an improvement over the much heavier and more cumbersome SCBA. The most positive feedback was for the MP-PAPR, which evaluators found to be very comfortable and to provide the necessary amount of air for strenuous overhaul work. Evaluators preferred this system to an SCBA, and said they could work comfortably for hours. The EZ-Air system did not provide as much air as evaluators needed for strenuous activity, was less comfortable than the MP-PAPR, and had problems with Velcro® straps coming loose. The APR system—in which the filter module is connected directly to the firefighter's facemask—was found to be acceptable for jobs of approximately 30 minutes or less because breathing resistance and the weight of the filter pulling on the facemask became increasingly problematic during use. The optional CO module made it more difficult to breathe and exacerbated the issue of facemask weight in the APR system. The increased breathing resistance and weight would not be a problem in the PAPR systems because they provide powered air and the filters are not attached to firefighters' facemasks.

The various filter module configurations provided enough comfort, maneuverability, and ease of breathing to provide valid alternative options for firefighters performing overhaul work. By eliminating the bulky and heavy SCBA tank, these systems have the potential to make overhaul work easier and faster, while also preventing injuries due to strain and exhaustion.

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1.0 INTRODUCTION

After extinguishing a structural fire, firefighters carry out fire overhaul operations to locate and extinguish smoldering hot spots, while at the same time trying to minimize damage to the structure and its contents. Early on in the overhaul operations, firefighters wear self-contained breathing apparatus (SCBA), but because of the burdensome heavy weight and the need to keep changing tanks to maintain air supply, it is common practice to remove the SCBA when the carbon monoxide (CO) concentration drops below the Occupational Safety and Health Administration (OSHA) permissible exposure limit of 35 parts per million. Unfortunately, CO concentrations do not correlate with the concentrations of other harmful chemicals in overhaul environments, nor do they indicate hazards associated with inhaling particulates. The goal of the Respiratory Protection for Firefighters during Overhaul Operations project is to develop a respiratory protection system that is lighter and more comfortable than the traditional SCBA, and that will protect firefighters against chemical vapor and particulate hazards during fire overhaul operations. This new technology could potentially lead to a reduction in the number of firefighters contracting respiratory illnesses.

To address this technology gap, the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) awarded a contract in 2016 to TDA Research Inc. (TDA)—who partnered with Avon Protection Systems Inc. (Avon)—to develop a stackable filter module that can be used in air-purifying respirators (APRs) as well as various powered air-purifying respirators (PAPRs), which use a blower to force air through the filters to assist in breathing. The filter module developed under this project contains a removable, washable pre-filter that removes large smoke and dust particles, a high-efficiency particulate air (HEPA) filter that removes fine particles, and an activated carbon mixture that removes a wide range of hazardous chemical vapors found to be present in fire overhaul environments in a study conducted by the Oregon Office of the State Fire Marshall [1]. The HEPA and activated carbon filters are encapsulated in a canister that provides 4 hours of protection against challenge concentrations of the hazardous gases identified by the Oregon Study. The canister conforms to the standard 40-millimeter STANAG¹ threaded connection commonly used by many manufacturers of masks and respirators. A rubber boot containing the washable pre-filter insert fits over the canister to complete the filter module.

On October 17, 2018, the National Urban Security Technology Laboratory (NUSTL) and DHS S&T conducted an operational field assessment (OFA) focusing on the comfort, usability, and breathing resistance of the prototype filter module developed under the Respiratory Protection for Firefighters during Overhaul Operations project. The OFA was held at the Federal Emergency Management Agency (FEMA) National Fire Academy in Emmitsburg, Maryland. Five firefighters and one fire investigator from fire departments in Colorado, Maryland, and Virginia served as evaluators. Each evaluator wore his or her department-issued facemask and repeated a set of operationally relevant exercises while wearing the filter module in one APR configuration and two PAPR configurations. After completing the exercises, the evaluators provided feedback on the comfort, usability, and breathing resistance of the filter modules in each of the configurations.

This report describes the OFA activities performed, the results of those activities, and the evaluators' feedback.

¹STANAG refers to standardization for common military equipment agreed on with allied countries.

1.1 PURPOSE

The purpose of the OFA was to assess the suitability of the filter module in various respirator configurations for use during firefighting overhaul operations, and to determine if it is an effective alternative to an SCBA.

1.2 OBJECTIVE

The objective of the OFA was to obtain feedback from firefighting personnel after using the prototype filter module in operationally relevant ways.

The OFA was designed to assess the:

- Comfort, usability, and breathing resistance of the filter module installed in an APR for firefighters during overhaul and other typical field operations
- Comfort, usability, and breathing resistance of the filter modules installed in PAPR configurations for firefighters during overhaul and other typical field operations
- Ease with which firefighters are able to install the filter module in APR and PAPR configurations
- Ease with which firefighters can change and/or clean the washable foam pre-filter contained in the filter module
- Breathing resistance of an optional CO filter that is compatible with the filter module

1.3 REQUIREMENTS

Table 1-1 summarizes the project requirements and how they were assessed during the OFA. These requirements were drawn from the *Respiratory Protection for Firefighters during Overhaul Operations Statement of Objectives* [2], the *TDA Research Technical Proposal Corresponding to Broad Area Announcement 13-012/Call 004* [3], and subsequent design reports.

1.4 COMPLIANCE

The S&T Compliance Assurance Program Office and the New England Independent Review Board reviewed and approved the OFA test protocol and found it compliant with all relevant human subjects research statutes, regulations, and directives [4], [5]. In addition, the DHS Privacy Office approved the collection and storing of personally identifiable information from participants [6].

Table 1-1 Project Requirements and Activities Matrix

Category	Requirement	Test Method
Operational	<ul style="list-style-type: none"> • Must not cause physical fatigue due to breathing resistance in the APR mode; allows user to breathe normally • No reduction in visibility by obstruction of sightline or fogging of facemask • Provide better maneuverability than SCBA; reduce shoulder strain • Equipment does not get caught up with building materials or other potential snag hazards • Simplicity of filter stacking; particulate pre-filter is changeable and re-usable • Integrates with PAPR blower system, while causing minimal interference with overhaul operations 	<ul style="list-style-type: none"> • OFA activities: stair climb, hose drag • OFA activities: stair climb, hose drag, simulated overhaul operations in burn rooms • OFA activities: simulated overhaul in burn rooms • OFA activities: simulated overhaul in burn rooms • OFA activities: setup station • OFA activities: simulated overhaul activities in burn room
Ergonomics	<ul style="list-style-type: none"> • Lightweight (10 to 15 pounds) • Compatible with a wide range of APRs and PAPRs through standard 40-millimeter STANAG connection • Durable • Requires minimum maintenance • Must not cause respirator mask to fog in hot environments 	<ul style="list-style-type: none"> • OFA activities: setup station • OFA activities: setup station • OFA activities: simulated overhaul in burn room • OFA activities: simulated overhaul, stair climb
Respiratory Protection	<ul style="list-style-type: none"> • Protect against chemical vapor and particulate hazards during fire overhaul operations • Protect against challenge concentrations of chemicals identified in Oregon Study: nitrogen dioxide, acrolein, carbon monoxide, arsenic, mercury, hydrochloric acid, benzene, formaldehyde, glutaraldehyde, hydrogen cyanide, ozone • Meet or exceed HEPA standards for particulates • Non-toxic, hypoallergenic 	<ul style="list-style-type: none"> • Vendor presentation of developmental test results and/or plans for certification testing
Standards Compliance	<ul style="list-style-type: none"> • Must have service life indicator or recommended change schedule • High heat resistance 	<ul style="list-style-type: none"> • Vendor presentation
PAPR batteries	<ul style="list-style-type: none"> • Replaceable off the shelf or rechargeable • Adequate run time for overhaul 	<ul style="list-style-type: none"> • Survey

1.5 SYSTEM DESCRIPTION

TDA and Avon partnered to develop a stackable filter module (Figure 1-1) that can be used in commercially available APRs as well as commercially available PAPRs, which use a blower to force air through the filters to assist in breathing. The filter module is also compatible with SCBA facemasks. This is important because most fire departments issue facemasks that are fit tested to individual firefighters to ensure an airtight seal. Firefighters can remove their SCBA and use their fit-tested facemasks with the filter module to form an APR or PAPR.

The filter module protects firefighters from particulate hazards through commercially available particulate filters. It protects against chemical hazards through a carbon filtration mixture specifically designed by TDA to remove the potentially harmful chemicals—identified by the Oregon study—present in overhaul environments. Products presently on the market may not remove all of these chemicals. In all, there are three filters in the module: a washable foam pre-filter for removing large smoke and dust particles, a HEPA filter for removing fine particles, and an activated carbon mixture for removing hazardous chemical vapors. The HEPA and activated carbon filters are encapsulated in a filter canister with a standard 40-millimeter STANAG connection so it can be used with equipment from multiple manufacturers. A rubber boot with the washable pre-filter insert fits over the plastic filter piece to complete the stackable filter module.

The filter canister provides fine particulate removal and protection against chemical vapor hazards. It is designed to be used for 4 hours and then discarded. There is no end-of-life indicator in the canister. The foam pre-filter can be re-used 100 times or more when it is maintained properly with a thorough rinsing in water after each use. If it gets clogged during overhaul work, it can be quickly removed from the rubber boot, rinsed in water, and re-installed. The pre-filter helps prevent clogging of the fine particulate filter in the canister.

The stackable filter module can be used in several configurations. By using an adaptor to attach it to an SCBA facemask, it can be used as a typical APR (Figure 1-2). In this configuration, firefighters inhale unassisted. Other configurations that were tested during the OFA use PAPR systems available from Avon. The EZ-Air® (Figure 1-3) integrates a single filter module with a blower and battery pack, straps onto the firefighter's back, and has a hose connection to the facemask. The battery pack takes four commercially available CR123 batteries and has a run time of over 8 hours per battery pack. A lithium ion rechargeable battery with an 8 hour run time is also available as an option. The Multi-Position PAPR (MP-PAPR™) (Figure 1-4) is a similar product that allows two filter modules to be used and can be mounted on the belt or back of the firefighter. A variety of battery packs with different sizes, weights, and run times are available for the MP-PAPR.



Figure 1-1 Filter Module Consisting of Canister (bottom), Filter (middle) and Rubber Boot (top).

Courtesy of Avon and TDA



Figure 1-2 Filter Module in APR Mode

Courtesy of Avon and TDA



Figure 1-3 EZ-Air PAPR with Single Filter



Figure 1-4 MP-PAPR with Two Filters

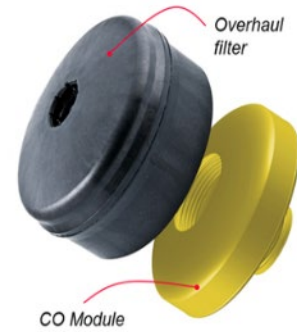


Figure 1-5 Optional Carbon Monoxide Filter

Courtesy of Avon and TDA

An optional CO filter (Figure 1-5) was also developed as part of the Respiratory Protection for Firefighters during Overhaul Operations project. It is designed to be removable because it increases the weight and breathing resistance of the filter system, and it may not be necessary in all overhaul environments. At the time of the OFA, the CO filter was still in development. Avon provided a non-functional mockup to simulate the weight and breathing resistance that the CO filter will have when completed. This device was tested at the OFA for comfort and breathing resistance. Table 1-2 and Table 1-3 list key specifications.

Table 1-2 Summary of Filter Specifications

Filter Component	Dimensions	Weight	Cost	Filter Life
Filter canister (HEPA and carbon filters)	4.36-inch diameter 2.97-inch height	0.54 pounds	\$20	4 hours
Complete filter module (canister, pre-filter, and rubber boot)	4.72-inch diameter 3.85-inch height	0.88 pounds	\$50	N/A
Optional CO module	4.24-inch diameter 2.07-inch height	0.22 pounds	\$100	8 hours

Table 1-3 Summary of Powered Respirator Specifications

Respirator Component	Blower Dimensions	Flow Rate	Battery Type/Life	Unit Weight	Cost
EZ-Air System	5.8-inch length 4.7-inch width 2.8-inch height	60 liters/ minute	CR123 non-rechargeable lithium (8 hours)	2.4 pounds	\$1,150
			Lithium ion rechargeable (8 hours)	2.7 pounds	\$1,350
MP-PAPR System	16.4-inch length 5.2-inch width 4.3-inch height	120 liters/ minute	CR123 non-rechargeable lithium (4 hours)	3.8 pounds	\$1,450
			Lithium ion rechargeable (8 hours)	4.1 pounds	\$1,650

2.0 OPERATIONAL FIELD ASSESSMENT DESIGN

2.1 EVENT DESIGN

During the OFA, six evaluators from fire departments in Colorado, Maryland, and Virginia participated in operational scenarios to evaluate the filter module developed for the project. The filter modules were assessed in three different configurations. In the APR configuration, a filter module was attached directly to the evaluator’s department-issued facemask and the evaluator inhaled through the filter unassisted. In the EZ-Air configuration, a single filter module was attached to the EZ-Air PAPR system, which used a blower to supply air through the filter to the evaluator’s facemask. In the MP-PAPR configuration, two filter modules were attached to the MP-PAPR, which supplied powered air to the evaluator’s facemask.

The test venue for the OFA was the FEMA National Fire Academy in Emmitsburg, Maryland. Operational scenarios were set up at a burn range that contained many pre-burned single-room burn cells, several large multi-room burn cell complexes, and a large outdoor area. Training and group discussions were held at a nearby conference room. Once training was completed, evaluators proceeded to the burn range and donned their department-issued turnout gear. They were then separated into three groups of two. Group A wore the filter module in the APR configuration, Group B wore the EZ-Air with a single filter module, and Group C wore the MP-PAPR with two filter modules. TDA and Avon representatives were available to help evaluators with the equipment and to answer any questions.

The evaluators then went through the operational scenario circuit listed in Table 2-1. to complete the first rotation. Each activity provided evaluators an opportunity to test the equipment under realistic operational scenarios related to firefighting and fire overhaul duties. After completing each activity, they were debriefed by a NUSTL data collector to obtain activity- and equipment-specific feedback. After all activities were completed, they provided feedback on their overall impressions of the system; this completed the first rotation.

Table 2-1 Operational Scenario Descriptions

Scenario	Locations	Task
Installation	Burn range: outdoors	Evaluators learned how to install the filter module in their facemasks or in powered respirator configurations (EZ-Air, MP-PAPR) aided by the developer presentation and demonstration.
Stair Climb	Burn range: outdoors	Evaluators ascended and descended a concrete staircase with an approximate 50-foot vertical rise. Evaluators repeated this activity with the CO module installed when in APR mode.
Hose Drag	Burn range: outdoors	Evaluators dragged a charged 1¾-inch hose by the nozzle for 70 feet, made a 90-degree turn and proceeded another 20 feet to a point between two burn buildings, then returned to the starting point. Evaluators repeated this activity with the rubber boot and foam pre-filter removed when in APR mode.

Scenario	Locations	Task
Sledgehammer Swing	Burn range: outdoors	Evaluators swung a sledgehammer in overhead fashion several times at wooden pallets.
Ladder Carry and Raise	Burn range: outdoors	Evaluators picked up and shoulder carried a 16-foot extension ladder, raised the ladder against a building, ascended and descended the ladder, then returned it to its original position. The evaluator's partner held the ladder as it was being climbed.
Pike Pull	Burn range: burn cell	Evaluators entered a pre-burned burn cell and used a 6-foot pike pole to pull down ceilings and walls until approximately one-third of the burn cell was demolished.
Search and Rescue	Burn range: large burn cell complex	Evaluators crawled through a section of a pre-burned burn cell complex, then picked up a rescue mannequin, carried the mannequin approximately 10 feet, and returned it to its original position.
Debris Removal	Burn range: burn cell	Evaluators worked for 5 to 10 minutes in a pre-burned burn cell moving furniture, scooping debris into buckets with shovels, and used tools such as saws to probe furniture and other objects for fire. Additionally, evidence gathering tools were available for sifting through debris.

Evaluators then swapped respiratory systems and completed two more rotations, so that each evaluator went through the circuit of activities three times with the filter module installed in the three different configurations: APR, EZ-Air, and MP-PAPR.



Figure 2-1 Stair Climb



Figure 2-2 Hose Drag

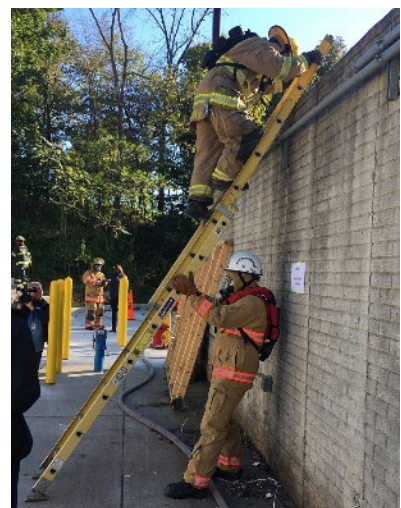


Figure 2-3 Ladder Raise



Figure 2-4 Sledgehammer Swing



Figure 2-5 Pike Pull



Figure 2-6 Search and Rescue



Figure 2-7 Debris Removal

2.2 PARTICIPANTS

Table 2-2 lists the OFA participants. The evaluators who tested and provided feedback on the filter module and related equipment developed under the project included two fire chiefs, three firefighters, and one fire investigator, each having at least 5 years on-the-job experience. Additionally, a retired fire chief observed the OFA and participated in group discussions. Three of the evaluators were men, and three were women. They represented five different fire departments located in the states of Colorado, Maryland, and Virginia.

All evaluators brought their own department-issued turnout gear for use at the OFA: jacket, pants, boots, helmet, gloves and SCBA facemask. Five evaluators wore facemasks that were manufactured by 3M Scott Inc. and one wore a facemask from MSA Safety Inc. Each facemask had an adapter that allowed a filter or hose to attach to the front center of the mask. The evaluators' department-issued facemasks were used because they had been fit tested to the evaluator to form a proper seal when issued.

Table 2-2 OFA Participants

Role	Organization
Evaluator	Colorado Division of Fire Prevention and Control (CO)
Evaluator	Fairfax County Fire and Rescue Department (VA)
Evaluator	Fairfax County Fire and Rescue Department (VA)
Evaluator	Golden Gate Fire Protection District (CO)
Evaluator	Montgomery County Fire and Rescue Service (MD)
Evaluator	Rockville Volunteer Fire Department (MD)
Subject Matter Expert/Observer	International Association of Fire Chiefs
Venue Host	FEMA National Fire Academy
Program Manager and Support Staff	DHS S&T Headquarters
OFA Test Director and Data Collectors	DHS S&T NUSTL
Technology Developer	TDA Research Inc.
Technology Developer Partner	Avon Protection Systems Inc.
DHS Observers	DHS S&T Headquarters
DHS Communications Support	DHS S&T Communications and Outreach Division

2.3 SCOPE

The OFA consisted of three main components:

1. Classroom Presentations and Technology Familiarization: The OFA began with an introductory session that provided evaluators with overviews of DHS S&T technology development, the OFA Test Plan, and a site safety briefing. This was followed by a technology presentation on the development of the filter module by a TDA representative. A hands-on equipment demonstration was then conducted by an Avon representative in which evaluators were trained on how to use the filter module in the APR, EZ-Air, and MP-PAPR configurations.



Figure 2-8 Classroom Presentation
An Avon representative provides equipment familiarization training.

2. Operational Assessment Scenarios: After the evaluators gained an understanding of the assessment plan and technology, they performed the operational assessment scenarios described in Table 2-1 which simulated firefighting and fire overhaul tasks.
3. Evaluator Survey and Debrief: Following the scenarios, the evaluators provided feedback based on their experience using the technology. Evaluator feedback included responses to a survey read to them by NUSTL data collectors and participation in a group discussion led by the NUSTL OFA test director. NUSTL data collectors recorded in writing the feedback and comments made by evaluators regarding the breathing resistance, comfort, and usability of the filter module in each of the three test configurations.

Additionally, evaluators were given the opportunity to provide constant verbal feedback to NUSTL staff members who took notes during each portion of the assessment.

The OFA was not intended to test the technical performance or effectiveness of the filter module in removing harmful chemicals and particulates from the air. TDA performed extensive laboratory testing of the filter properties of the module prior to the OFA, and presented those results during the classroom presentation. TDA will also submit the filter design for certification to the National Institute for Occupational Safety and Health (NIOSH). The intent of the OFA was to allow firefighting personnel the opportunity to assess the operational suitability of the filter module to fire overhaul operations.

2.4 DEVIATION FROM THE TEST PLAN

During the OFA there were a few deviations from the original test plan, and they are noted in this section.

There was a general consensus among evaluators and the DHS Project Manager that the CO filter did not need to be tested with a separate stair climb in the EZ-Air and MP-PAPR configurations. Breathing resistance would only be an issue with the CO filter when used in the APR configuration. For this reason, a separate stair climb was only performed with the CO filter added to the filter module in the APR configuration.

During the search and rescue scenario, evaluators were limited to crawling through the burn cell and doing a brief lift of the rescue mannequin without carrying it. This change was necessary because an arson investigation class was scheduled to use the burn complex the following day and a mannequin carry would disturb the scene in the complex to the point where it might affect the ability of the class to determine where and how the fire started.

3.0 RESULTS

This section contains the results of the OFA as reported from survey responses, evaluator comments, and a group discussion. Evaluator ratings from survey responses are presented in Section 3.1 along with a discussion of how the ratings compared between the APR, EZ-Air, and MP-PAPR configurations. Evaluator comments taken by NUSTL data collectors during the operational scenarios are presented in Section 3.2. A summary of the group discussion held in the afternoon is presented in Section 3.3.

3.1 SURVEY RESPONSES

The evaluators assessed the filter modules in three separate configurations or systems. The APR filter system consisted of a filter module attached directly to the firefighter's facemask. The EZ-Air filter system consisted of a single filter module attached to an EZ-Air PAPR device that provided powered air to the evaluator's facemask. The MP-PAPR filter system consisted of two filter modules connected to an MP-PAPR device that provided powered air to the evaluator's facemask.









































































































































Evaluator ratings for the APR filter system are given in Table 3-1. The evaluators were asked to rate certain features and capabilities having to do with breathing resistance, comfort, and usability for each system. Each rating was given as a statement (e.g., 'It was easy to breathe with the APR filter system') to which the evaluators were asked to choose one of four responses: strongly agree, agree, disagree, or strongly disagree—these responses are denoted by filled circular symbols as defined in the first row of the table. Responses for each evaluator are indicated in separate columns labeled 'A' to 'F.' Similarly,





























































































































Table 3-2 and Table 3-3 present the evaluator ratings for the EZ-Air and MP-PAPR filter systems, respectively.

All three systems received mostly positive responses ("strongly agree" or "agree") with a small number of negative responses ("disagree"). The tables show a slight improvement in ratings from the APR filter system to the EZ-Air, and a very noticeable improvement from the EZ-Air to the MP-PAPR. The APR filter system had some negative responses for breathability on the more strenuous activities due to evaluators having to breathe on their own. There were also some negative responses for comfort because of the weight of the filter pulling down on the mask. The EZ-Air filter system had some negative responses for breathability as evaluators believed that it did not provide as much air as they needed. There were also some negative responses for maneuverability due to the Velcro® straps and issues with the breathing tube. In addition, one evaluator's facemask continually fogged while using the EZ-Air and this resulted in several negative ratings for facemask fogging. The MP-PAPR filter system received the highest rating ('strongly agree') in all categories with very few exceptions and did not receive any negative ratings aside from the ease of changing the pre-filter. It should be noted that evaluators C and D believed that changing the pre-filter was not quick and easy, and this was a difference in opinion with the other evaluators.

The issues that were described briefly above are discussed in more detail in Section 3.2.

Table 3-1 APR Filter System Evaluator Ratings

Activity	Statement	A	B	C	D	E	F
Key:		 Strongly Agree	 Agree	 Disagree	 Strongly Disagree	-- = No Response	
Installation	The APR filter system (filter module and facemask) is quick and easy to assemble and don.						
	It is quick and easy to remove the rubber boot, wash or change the foam pre-filter, and replace the boot.						
	The weight of the filter module is satisfactory.						
	The filter module integrates well with, and is easy to connect to, the facemask.						
	The filter module is durable and unlikely to break when installing, changing, or washing the pre-filter.						
Stair Climb	It was easy to breathe with the APR filter system (filter module and facemask).						
	It was easy to breathe with the APR filter system when the optional CO filter is also attached.						
	The APR filter system was comfortable.						
	The APR filter system provided good maneuverability and did not interfere with job performance.						
	The APR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Hose Drag	It was easy to breathe with the APR filter system (filter module and facemask).						
	It was easy to breathe with the rubber boot and pre-filter removed in the APR configuration.						
	The APR filter system was comfortable.						
	The APR filter system provided good maneuverability and did not interfere with job performance.						
	The APR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Sledgehammer	It was easy to breathe with the APR filter system (filter module and facemask).						
	The APR filter system was comfortable.						
	The filter system provided good maneuverability and did not interfere with job performance.						
	The APR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						

Activity	Statement	A	B	C	D	E	F
Key:  Strongly Agree  Agree  Disagree  Strongly Disagree -- = No Response							
Ladder Raise	It was easy to breathe with the APR filter system (filter module and facemask).						
	The APR filter system was comfortable.						
	The APR filter system provided good maneuverability and did not interfere with job performance.						
	The APR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Pike Pull	It was easy to breathe with the APR filter system (filter module and facemask).						
	The APR filter system was comfortable.						
	The APR filter system provided good maneuverability and did not interfere with job performance.						
	The APR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Search and Rescue	It was easy to breathe with the APR filter system (filter module and facemask).						
	The APR filter system was comfortable.						
	The APR filter system provided good maneuverability and did not interfere with job performance.						
	The APR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Debris Removal	It was easy to breathe with the APR filter system (filter module and facemask).						
	The APR filter system was comfortable.						
	The APR filter system provided good maneuverability and did not interfere with job performance.						
	The APR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						






























































































































































































































Activity	Statement	A	B	C	D	E	F
Key:  Strongly Agree  Agree  Disagree  Strongly Disagree -- = No Response							
All Activities (Overall Impression)	The APR filter system allowed performance of fire overhaul operations in an effective manner.						
	The APR filter system is preferable to SCBA for fire overhaul operations.						
	I would recommend the APR filter system to my agency for fire overhaul operations.			--			
	The APR filter system integrated well with turnout gear and other equipment used in overhaul work.						
	The amount of maintenance needed for the APR filter system is acceptable.						

Table 3-2 EZ-Air Configuration Survey Responses

Activity	Statement	A	B	C	D	E	F
Key:  Strongly Agree  Agree  Disagree  Strongly Disagree -- = No Response							
Installation	The EZ-Air filter system (filter module, EZ-Air, and facemask) is quick and easy to assemble and don.						
	It is quick and easy to remove the rubber boot, wash/change the foam pre-filter, and replace the boot.						
	The weight of the EZ-Air filter system is satisfactory.						
	The filter module integrates well with, and is easy to connect to, the EZ-Air.						
	The filter modules are durable and unlikely to break when installing, changing, or washing the pre-filter.						
Stair Climb	It was easy to breathe with the EZ-Air filter system (filter module, EZ-Air, and facemask).						
	The EZ-Air filter system was comfortable.						
	The EZ-Air filter system provided good maneuverability and did not interfere with job performance.						
	The EZ-Air filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						

Activity	Statement	A	B	C	D	E	F
Key:		 Strongly Agree	 Agree	 Disagree	 Strongly Disagree	-- = No Response	
Hose Drag	It was easy to breathe with the EZ-Air filter system (filter module, EZ-Air, and facemask).						
	The EZ-Air filter system was comfortable.						
	The EZ-Air filter system provided good maneuverability and did not interfere with job performance.						
	The EZ-Air filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Sledgehammer	It was easy to breathe with the EZ-Air filter system (filter module, EZ-Air, and facemask).						
	The EZ-Air filter system was comfortable.						
	The EZ-Air filter system provided good maneuverability and did not interfere with job performance.						
	The EZ-Air filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Ladder Raise	It was easy to breathe with the EZ-Air filter system (filter module, EZ-Air, and facemask).						
	The EZ-Air filter system was comfortable.						
	The EZ-Air filter system provided good maneuverability and did not interfere with job performance.						
	The EZ-Air filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Pike Pull	It was easy to breathe with the EZ-Air filter system (filter module, EZ-Air, and facemask).						
	The EZ-Air filter system was comfortable.						
	The EZ-Air filter system provided good maneuverability and did not interfere with job performance.						
	The EZ-Air filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						













































































































































































































































































































































































































Activity	Statement	A	B	C	D	E	F
Key:		 Strongly Agree	 Agree	 Disagree	 Strongly Disagree	-- = No Response	
Search and Rescue	It was easy to breathe with the EZ-Air filter system (filter module, EZ-Air, and facemask).						
	The EZ-Air filter system was comfortable.						
	The EZ-Air filter system provided good maneuverability and did not interfere with job performance.						
	The EZ-Air filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Debris Removal	It was easy to breathe with the EZ-Air filter system (filter module, EZ-Air, and facemask).						
	The EZ-Air filter system was comfortable.						
	The EZ-Air filter system provided good maneuverability and did not interfere with job performance.						
	The EZ-Air filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
All Activities (Overall Impression)	The EZ-Air filter system allowed performance of fire overhaul operations in an effective manner.						
	The EZ-Air filter system is preferable to SCBA for fire overhaul operations.						
	I would recommend the EZ-Air filter system to my agency for fire overhaul operations.						
	The EZ-Air filter system integrated well with turnout gear and other equipment used in overhaul work.						
	The EZ-Air had batteries that were easily replaceable/rechargeable.			--	--		
	The battery lifetime quoted by the vendor would provide adequate run time for overhaul operations.						
	The amount of maintenance needed for the EZ-Air filter system is acceptable.						

Table 3-3 MP-PAPR Configuration Survey Responses

Activity	Statement	A	B	C	D	E	F
Key:		 Strongly Agree	 Agree	 Disagree	 Strongly Disagree	-- = No Response	
Installation	The MP-PAPR filter system (filter module, MP-PAPR, and facemask) is quick and easy to assemble and don.						
	It is quick and easy to remove the rubber boot, wash/change the foam pre-filter, and replace the boot.						
	The weight of the MP-PAPR filter system is satisfactory.						
	The filter module integrates well with, and is easy to connect to, the MP-PAPR.						
	The filter modules are durable and unlikely to break when installing, changing, or washing the pre-filter.						
Stair Climb	It was easy to breathe with the MP-PAPR filter system (filter module, MP-PAPR, and facemask).						
	The MP-PAPR filter system was comfortable.						
	The MP-PAPR filter system provided good maneuverability and did not interfere with job performance.						
	The MP-PAPR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Hose Drag	It was easy to breathe with the MP-PAPR filter system (filter module, MP-PAPR, and facemask).						
	The MP-PAPR filter system was comfortable.						
	The MP-PAPR filter system provided good maneuverability and did not interfere with job performance.						
	The MP-PAPR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Sledgehammer	It was easy to breathe with the MP-PAPR filter system (filter module, MP-PAPR, and facemask).						
	The MP-PAPR filter system was comfortable.						
	The MP-PAPR filter system provided good maneuverability and did not interfere with job performance.						
	The MP-PAPR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						

Activity	Statement	A	B	C	D	E	F
Key:		 Strongly Agree	 Agree	 Disagree	 Strongly Disagree	-- = No Response	
Ladder Raise	It was easy to breathe with the MP-PAPR filter system (filter module, MP-PAPR, and facemask).						
	The MP-PAPR filter system was comfortable.						
	The MP-PAPR filter system provided good maneuverability and did not interfere with job performance.						
	The MP-PAPR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Pike Pull	It was easy to breathe with the MP-PAPR filter system (filter module, MP-PAPR, and facemask).						
	The MP-PAPR filter system was comfortable.						
	The MP-PAPR filter system provided good maneuverability and did not interfere with job performance.						
	The MP-PAPR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Search and Rescue	It was easy to breathe with the MP-PAPR filter system (filter module, MP-PAPR, and facemask).						
	The MP-PAPR filter system was comfortable.						
	The MP-PAPR filter system provided good maneuverability and did not interfere with job performance.						
	The MP-PAPR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						
Debris Removal	It was easy to breathe with the MP-PAPR filter system (filter module, MP-PAPR, and facemask).						
	The MP-PAPR filter system was comfortable.						
	The MP-PAPR filter system provided good maneuverability and did not interfere with job performance.						
	The MP-PAPR filter system did not block field of view.						
	Vision was not impaired by facemask fogging.						

Activity	Statement	A	B	C	D	E	F
Key:		 Strongly Agree	 Agree	 Disagree	 Strongly Disagree	-- = No Response	
All Activities (Overall Impression)	The MP-PAPR filter system allowed performance of fire overhaul operations in an effective manner.						
	The MP-PAPR filter system is preferable to SCBA for fire overhaul operations.						
	I would recommend the MP-PAPR filter system to my agency for fire overhaul operations.						
	The MP-PAPR filter system integrated well with turnout gear and other equipment used in overhaul work.						
	The MP-PAPR had batteries that were easily replaceable/rechargeable.			--	--		
	The battery lifetime quoted by the vendor would provide adequate run time for overhaul operations.						
	The amount of maintenance needed for the MP-PAPR filter system is acceptable.						

3.2 EVALUATOR COMMENTS

Evaluator comments were collected by NUSTL data collectors before, during, and after the evaluators participated in the operational assessment scenarios. Each data collector shadowed a two-person team of evaluators throughout the assessment process and debriefed them after they installed the equipment, after they completed each operational scenario, and after they completed the operational scenario circuit. As evaluators gave ratings, they were encouraged to provide comments that elaborated upon their responses. This was repeated for each rotation so that evaluators commented on each of the three filter system configurations.

3.2.1 APR FILTER SYSTEM

Installation: Evaluators found it very easy to screw the filter module into their facemask.

Breathing Resistance: While there were some difficulties breathing through the unpowered APR filter system, ratings were generally positive for breathing resistance, but less so for the more strenuous activities of the stair climb and hose drag. Evaluators commented that it felt normal to breathe during non-strenuous activity, but that they felt more restricted the harder they worked. One evaluator commented that the breathing ability was ok, but not nearly as good as with the MP-PAPR.



Figure 3-1 APR Filter Installation

An evaluator attaches the filter canister to his facemask adapter.

Breathing Resistance without the Pre-filter: Evaluators wearing the APR filter system performed the hose drag twice, once with the full filter module and once with the washable pre-filter and rubber boot removed. After removing the pre-filter, four evaluators kept the same rating, while one evaluator gave a more positive rating and another gave a more negative rating. Three evaluators provided comments: one said that it felt easier to breathe; another said that it felt a little more difficult to breathe; while the third said there was no noticeable difference.

Breathing Resistance with the Optional CO Filter: Five of the six evaluators gave a more negative rating for breathing resistance with the optional CO filter added to the APR system. Evaluators commented that the CO filter smelled foulⁱⁱ, that there was definitely more breathing resistance with it attached, and that the added weight was an annoyance as it pulled down on the facemask. One evaluator commented that using the APR system with the CO filter was acceptable for short time periods, but an SCBA would be preferable for longer jobs. Another evaluator believed that while the CO filter added more difficulty, the APR filter system was still preferable to an SCBA for overhaul work.

Comfort: The main issue with comfort for the APR filter system was the weight of the filter module tugging on the nose of the evaluators' facemasks, which tended to pull their heads down. Evaluators thought it was comfortable for the most part, but they were "bothered" and "annoyed" by the weight at times, and more so as the scenario circuit went on. It was particularly bothersome on the stair climb and during the crawling part of the search and rescue scenario because it made it difficult for evaluators to look straight ahead. They stated that it would be more comfortable if it was smaller, lighter, and closer to the face. One evaluator suggested having a strap on the shoulder/sleeve area that the filter could be clipped to when not in use to alleviate weight on the nose. Another evaluator found that he could lessen the weight a little by readjusting the filter module.

Maneuverability: The APR filter system mainly received positive ratings and comments for maneuverability. Evaluators believed that it allowed them to maneuver well and it did not interfere with their job performance. The one exception was that two evaluators mentioned having the filter module bump or get snagged on the rescue mannequin. One stated that this was not a big deal because it was unlikely that they would do a search and rescue during overhaul work. The weight of the filter module was more of an annoyance than a hindrance to maneuverability.

Blocked Vision: Evaluators believed that vision was not impaired with the APR filter system and nothing was blocked from their field of view throughout the scenarios. They could look in all directions with clear vision. One evaluator stated that the device was well designed with a low profile for field of view. Although it was mostly a comfort issue, evaluators stated that the weight of the filter sometimes made it difficult to look straight ahead, but that they could do so with effort.

ⁱⁱBecause the CO filter product development was incomplete at the time of the OFA, the module tested was a non-functional mockup that simulated the product's weight and breathing resistance. Whether or not the foul odor that evaluators described would apply to the final product is unclear. It should be noted that all evaluators said that it smelled foul even though they used a new module that came in a sealed package.

Facemask Fogging: Five of the six evaluators had either no problem or very minor issues with facemask fogging. Evaluator E had significant facemask fogging with the APR filter system, reporting that his facemask was 100 percent fogged during the search and rescue and 90 percent fogged during the pike pull. The only time his mask did not fog was on the stair climb. This evaluator indicated that the problem was likely caused by a problem with the nosecup on his facemask being loose and not making a proper seal. It should also be noted that this evaluator had fogging in all three configurations.

Overall Impression: Five of the six evaluators agreed or strongly agreed that they could perform overhaul operations effectively with the APR filter system, and four of the six preferred it to an SCBA for overhaul work. The dissenting evaluators believed that effectiveness would drop off after 30 minutes due to fatigue from the weight of the filter and breathing resistance, and that neck strain could occur with prolonged use. For these reasons they could not recommend the filter system or would prefer an SCBA for long overhaul jobs. All evaluators agreed that they could recommend the APR filter system for jobs of 30 minutes or less.

Other: One evaluator does not believe that volunteer fire departments will buy this product if they had to throw away the filter after each fire due to cost.

3.2.2 EZ-AIR FILTER SYSTEM

Installation: Evaluators thought that the EZ-Air filter system was quick and easy to assemble and don. It was easy to attach the filter module to the EZ-Air, and the breathing tube fit well with their facemasks. Most evaluators tried having the breathing tube go under and over their shoulder. This took a little longer, but allowed them to find a more comfortable position. Two evaluators commented that the shoulder strap was helpful and allowed them to install the EZ-Air system over their left or right shoulder. One evaluator could not find the switch to turn on the air until instructed by the vendor, but noted that the problem would be resolved with familiarity.



Figure 3-2 Evaluators are Fitted with the EZ-Air System

Breathing Resistance: While most evaluators strongly agreed that it was easy to breathe for most activities, two evaluators disagreed during the hose drag and search and rescue activities, and one evaluator disagreed during the debris removal. Evaluators commented that the blower often did not provide enough air, and that it would get increasingly harder to breathe as strenuous activities went on. One evaluator stated that part of the breathing difficulty was from feeling restrained by the breathing tube, which did not allow full head motion.

Another evaluator said that it felt like he was fighting the blower motor as he tried to breathe in more air and that this was a “terrible feeling.” Evaluators believed that the EZ-Air filter system was better than the APR, but not as good as the MP-PAPR.

Comfort: Two of the six evaluators had issues with comfort. One evaluator at times had the feeling of being restrained by the breathing tube as if being on a leash. This happened while still, during the stair climb, and intermittently during some of the other scenarios. An alternative design with the breathing tube better anchored to the body or the retention straps would likely solve the problem. Another evaluator said that the Velcro attachment strap was a source of discomfort, coming loose at times and not feeling secure. This evaluator thought that the product should have buckles or retention snaps instead of Velcro. An evaluator who felt comfortable throughout stated that having the breathing tube under the arm provided more comfort than having it over the arm.

Maneuverability: Evaluators found it was easy to maneuver while using the EZ-Air filter system. Not having the filter attached to the facemask as with the APR system alleviated a lot of weight and made it easier to maneuver. One evaluator stated that because of the reduced weight on the facemask and not needing an air tank, reaching up during the pike pull was very easy and much easier than with the APR or with an SCBA. Another commented that it was easy to maneuver whether the breathing tube was over or under the arm. There were some negative comments as well. One evaluator was bothered by the Velcro attachment straps not working well, and also reported that the ladder briefly got caught on the shoulder strap while carrying it. Another evaluator felt a little restricted by the breathing tube as if being on a leash and this had an effect on maneuverability.

Blocked Vision: All evaluators strongly agreed that their field of view was not impeded with the EZ-Air filter system.

Facemask Fogging: Five of the six evaluators had no fog on their facemasks at all. Evaluator E reported having “some fog” or having a mask that was “beginning to fog” on four of the seven activities. This was an improvement over that evaluator’s experience with the APR filter system.

Batteries: The four evaluators who tried agreed that the batteries were easy to replace (two evaluators did not answer the question because they were unable to complete the task due to time constraints). Evaluators thought that the 8-hour battery life was sufficient for overhaul work; however, they would like to see a visual battery life indicator added as a feature.

Overall Impression: All evaluators agreed or strongly agreed that they could perform overhaul operations effectively with the EZ-Air filter system, and five of six evaluators would prefer it to an SCBA for overhaul work. The dissenting evaluator stated that you tend to get air-hungry working with the EZ-Air, and you have to do the work more slowly so that you do not get over-exerted. This evaluator would recommend the system only if the fan speed is increased to provide more air.

3.2.3 MP-PAPR FILTER SYSTEM

Installation: Evaluators found the MP-PAPR filter system to be quick and easy to assemble and don. It was easy to screw in the two filter modules, and the breathing tube fit well with their facemasks. Evaluators appreciated the option of installing it over their shoulder or under their arm. Two evaluators commented that they preferred the over-the-shoulder position because they could not look down properly in the under-the-arm position.



Figure 3-3 Evaluators are Fitted with the MP-PAPR Filter System

Breathing Resistance: All evaluators believed strongly that it was easiest to breathe with the MP-PAPR filter system. All evaluators strongly agreed that it was easy to breathe during each of the seven operational scenarios. Evaluators commented that it was “very easy to breathe,” and “so easy to breathe.” While they became winded during the stair climb and hose drag, it was much easier to catch their breath with the MP-PAPR than with the other systems.

Comfort: All evaluators strongly agreed that the MP-PAPR filter system was comfortable throughout the scenarios and commented that it felt “quite comfortable,” “very comfortable,” and that it was more comfortable than the other systems they tried. One evaluator—who is a fire investigator—after crawling and sifting through debris using evidence gathering tools during the debris removal scenario, stated that it was much easier to do this work with the MP-PAPR than with an SCBA or a hose lineⁱⁱⁱ.

Maneuverability: Evaluators commented that the MP-PAPR filter system was very maneuverable and provided the best maneuverability of the three systems tested. After the search and rescue scenario, an evaluator commented that it is much easier to balance and go underneath things than with an SCBA, and also that you feel less crowded in a tight space. After the debris removal scenario, another evaluator said that it was easier to pick up heavy things with the MP-PAPR as opposed to an SCBA. None of the evaluators found any interference with their job performance with the MP-PAPR.



Figure 3-4 Fire Investigator Examining Debris while Wearing the MP-PAPR System

ⁱⁱⁱMany fire investigators use air line systems with 300 feet or more of hose in place of SCBAs. Some departments have firefighters use hose lines for confined space in which the bulky SCBA tank may not fit.

Blocked Vision: All evaluators strongly agreed that their field of view was good with the MP-PAPR filter system and that their vision was not blocked in any way by the equipment during all scenarios.

Facemask Fogging: There were no problems with facemask fogging except for evaluator E, who had some slight fogging on two of the seven scenarios. This evaluator noted that he was very happy not to have fog during most of the scenarios because it allowed him to be careful and methodical and that it saved time by not having to take breaks to clean his mask.

Batteries: Evaluators were pleased with the multiple battery options in the MP-PAPR filter system, and thought that the battery lifetimes quoted were sufficient. As with the EZ-Air, they would like to see a battery life indicator added as a feature. They stated that it was unlikely that they would hear an audible chirp. Instead they would prefer an LED that would not need to stay on but that they could see during installation. They also noted that it is not a critical failure if batteries run out because without power, the system functions as an APR.

Overall Impression: All evaluators strongly agreed that they could perform overhaul operations effectively with the MP-PAPR filter system, and they strongly agreed that it was preferable to an SCBA for overhaul work. SCBAs take up a lot of space and cause firefighters to bump into walls and each other in tight spaces. SCBAs are also very heavy and put a lot of strain on the upper body, especially when pulling down drywall or moving objects. One evaluator discussed an overhaul job in which five tanks of SCBA air were used. All this is eliminated with the MP-PAPR filter system, which is lightweight, has a small footprint and provides plenty of air. With the MP-PAPR filter system, evaluators felt that it was very easy to breathe, provided the best mobility, and could prevent injury and save time.

3.2.4 FILTER MODULE

Changing/Washing the Pre-filter: Four evaluators strongly agreed that it was quick and easy to change/wash the pre-filter, but two evaluators disagreed. One had some trouble unscrewing the plastic case that held the pre-filter and needed some instruction on how to do it. That evaluator and a subject matter expert observer stated that having arrows on the case would be helpful to show where the notches are and which direction they should be turned. Another evaluator thought it would work better with two side buttons to lock and unlock the filter in place instead of having to use your fingers to grasp and slide the cover to open and close it.



Figure 3-5 Foam Pre-filter and Case

An evaluator points out the tab in the pre-filter case that unlocks it so it can be unscrewed.

Filter Module Construction: Evaluators thought that the rubber boot was easy to work with and easy to grasp when installing and removing the filter modules. One evaluator commented, however, that the rubber might stick to the plastic canister in cold weather. The evaluators thought the plastic filter canister seemed durable and was unlikely to break unless it got badly snagged on something.

3.3 GROUP DISCUSSION SUMMARY

After evaluators completed all rotations of the operational scenarios and were debriefed, they reconvened in the classroom for a group discussion led by the OFA test director. The subject matter expert observer, DHS S&T managers, and representatives from TDA and Avon also participated. Evaluators discussed advantages and disadvantages of the systems that they assessed and offered ideas for future improvements to the products. Consensus opinions of the evaluators are presented in this section.



Figure 3-6 Opened Pre-filter Case

The foam pre-filter that removes large particles of smoke and dust can be washed or replaced.

3.3.1 APR FILTER SYSTEM FEEDBACK

Breathing:

- Working with the APR filter system becomes difficult after 30 minutes.
- Breathing resistance is moderate, but it gets harder to breathe as activity becomes more strenuous.
- There was no difference in breathing resistance with the pre-filter and rubber boot removed.

Weight and Comfort:

- There is a lot of weight pulling on the facemask from the filter module.
- This is especially true when used with the Scott facemask, which is long and moves the center of gravity far in front of the face.
- The weight tends to pull your head down and forward and makes it difficult to look straight ahead.

Use with CO Filter:

- The optional CO filter made it more difficult to breathe and weighed down the mask more, pushing the limits of what is acceptable.
- Wearing it for too long could cause neck strain, but this is still preferable to an SCBA, which can cause full body strain.
- Although the filter assessed was a non-functional mockup of a CO filter, it had a bad smell and taste to it.
- One evaluator felt anxious to finish the stair climb quickly so that the mask could be removed.

Facemask Fogging:

- Most evaluators did not experience facemask fogging with the APR filter system.
- One evaluator had constant fog on the facemask that had to be periodically wiped off; however, this may have been caused or exacerbated by a nosecup problem on the evaluator's facemask.
- Another evaluator noted some fogging when going up the stairs and had sweat dripping in his eyes.

Overall Impression:

- Despite the disadvantages of the APR filter system, it is still preferable to SCBA due to reduced weight and strain on the back and shoulders.

3.3.2 EZ-AIR FILTER SYSTEM FEEDBACK

Breathing:

- Evaluators said that the 60 liters per minute of air provided to the facemask by the EZ-Air was not enough for firefighting and overhaul work. As they worked harder, they became more air-hungry.
- Work would have to be adjusted to a slower pace to accommodate the air flow and not cause over-exertion.

Installation:

- The EZ-Air was a little harder to put on than the MP-PAPR as the main attachment is a waist strap that has to be adjusted to the proper size.

Comfort:

- The Velcro fastener on the waist strap can easily come loose. This happened repeatedly with one evaluator and caused problems with discomfort and mobility.
- Evaluators suggested having a buckle instead of Velcro, and a design that keeps the blower higher on the body and more centrally located on the body.
- The Velcro straps do not hold the air hose in place well and when the hose comes loose, it is no longer anchored to the body and pulls on the facemask. One evaluator suggested having shoulder straps with channels that the hose can clamp to.

Suggested Improvements:

- Evaluators suggested adding an on/off indicator for the blower because they found it hard to tell whether it was on or off, especially during strenuous activity.
- Evaluators also wanted an indicator for battery life, which should at least be visible at startup but would preferably be either constantly visible or displayed as a heads-up indicator.
- Evaluators suggested using a higher quality component for the filter adapter. The membrane seemed flimsy to them, and they stated that it could tear during filter installation or break if dropped on a table.

3.3.3 MP-PAPR FILTER SYSTEM FEEDBACK

Breathing:

- The MP-PAPR never interferes with breathing, provides all the air that is needed for strenuous overhaul work, and makes breathing very easy.
- Evaluators said that they could work for hours with it.
- The air felt cool and pleasant. However, they noted that this may have been because of the cool autumn day and may be different in warm humid weather.

Comfort/Maneuverability:

- The MP-PAPR is light and very comfortable.
- The weight is distributed well and it fits snugly and close to the body, allowing for unimpeded motion.
- Evaluators felt that having the light-weight MP-PAPR instead of the heavy SCBA made them able to do the work more effectively.
- The webbing on the straps were a little hard to adjust, but the problem might alleviate over time as the fabric loosens.
- The breathing tube initially interfered with the sledgehammer swing for one evaluator, who was able to quickly and easily switch the tube to the other side without help from another person, and this solved the problem.

Battery Life/Indicator:

- The 4 hours of battery life (8 hours for rechargeable option) is good for overhaul.
- Evaluators stated a strong desire for adding a low-battery indicator to the product.
- It currently has a chirp, but this will not be heard during fire overhaul operations.
- Evaluators suggested an LED indicator that can be checked at times and does not have to stay on continuously.
- They noted that the system becomes an APR if the battery runs out, which is not as critical as with an SCBA.

Overall Impression:

- Evaluators believed the MP-PAPR filter system performed best.

3.3.4 USEFULNESS OF CARBON MONOXIDE FILTER

Necessity:

- Evaluators thought that a CO filter is needed because in most departments only the safety officer carries the CO monitor, and an instrument reading is not a guarantee that there will not be a problem because CO can exist in pockets.
- Firefighters can easily walk into a pocket of CO without realizing it.
- The more protection for firefighters the better.

Use as a Separate Module:

- The vendor explained that there were three reasons for keeping the CO filter as an optional module separate from other filters:
 - It adds significant cost to the filter system.
 - It will have a longer usage life than the filter canister and therefore can be re-used for multiple overhaul operations.
 - It works as a catalyst and must be kept downstream of other filters because other agents can poison the catalyst.

End of Life:

- Although it can be used for approximately twice as long as the filter canister, most evaluators did not like the idea of re-using the CO filter, and thought it should be a single-use item from a sealed package.
- The vendor plans to include a CO detector past the filter to alert on 35 parts per million as an end-of-life indicator. Evaluators thought that this would be an excellent feature.

4.0 CONCLUSION

In this OFA, six evaluators from fire departments located in Colorado, Maryland, and Virginia assessed a filter module designed for overhaul work in three different configurations. The APR filter system consisted of a filter module attached to the firefighter's facemask and provided no powered assistance with breathing. The EZ-Air filter system used a single filter module with a powered blower that provided 60 liters per minute of air. The MP-PAPR filter system used two filter modules with a powered blower that provided 120 liters per minute of air.

Evaluators preferred the MP-PAPR filter system because they found it to be light, comfortable, and very easy to breathe. They found that they could more effectively do overhaul work with the MP-PAPR than with the much heavier and bulky SCBA air system. With the MP-PAPR, they did not have to worry about having an SCBA tank bumping into walls and other objects and putting strain on their upper body during strenuous activities such as pulling walls and ceilings. They stated that they could work for hours while wearing the MP-PAPR without the need for changing air tanks or getting exhausted due to the weight of the tank. A fire investigator, who served as an evaluator, stated that it is much easier to crawl and sift through debris with the MP-PAPR compared to an SCBA and other air systems such as hose lines. Evaluators would like to see a visual battery indicator added as a feature to the MP-PAPR.

The EZ-Air filter system was also preferable to an SCBA, but was not as comfortable and did not provide as much air as evaluators needed for strenuous activities. Evaluators pointed out problems with the Velcro straps coming loose, the hose line getting detached from the straps and pulling on the facemask, and what they thought was a low-quality filter adapter that is susceptible to breaking when installing a filter module. The evaluator consensus was that while the EZ-Air was acceptable, it should provide more air and have an improved fastening system. Otherwise, the MP-PAPR is the much better option for using the filter module with powered air.

The APR filter system is a viable option for fire departments that cannot afford PAPRs for their overhaul crews. Evaluators stated that the APR filter system would be sufficient for approximately 30 minutes, but after that breathing resistance would become an issue and cause firefighters to begin struggling for air. The weight of the filter module pulling down on the facemask was also found to be bothersome by the evaluators, who stated that it became difficult to keep their head up and look straight ahead after working with the APR filter system for extended periods of time.

The evaluators also tested a non-functional mockup of a CO filter that simulated the product's weight and breathing resistance. In the APR mode, evaluators found that adding the CO filter had a significant effect on weight and breathing resistance. All evaluators thought that it was more difficult to breathe, and some thought that it pushed breathing resistance to unacceptable limits, while also exacerbating the facemask's weight. Evaluators liked the idea of having an optional CO filter because during overhaul, they sometimes run into pockets of CO, not detected with a meter. The weight and breathing resistance would not be an issue when used with the PAPR systems.

The filter module system in its various configurations provided enough comfort, maneuverability, and ease of breathing to be considered valid options for performing overhaul work. By eliminating the bulky and heavy SCBA tank, these systems have the potential to make overhaul work easier and faster, while also preventing injuries due to strain and exhaustion.

5.0 REFERENCES

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