Evaluation of Consumer Personal Protective Equipment: EMERGENCY ESCAPE MASKS

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Rohit Khanna
Division of Combustion and Fire Sciences
Directorate for Engineering Sciences

U.S. Consumer Product Safety Commission
4330 East West Highway
Bethesda, Maryland 20814

FEMA

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EXECUTIVE SUMMARY

In 2004, the U.S. Consumer Product Safety Commission (CPSC) staff began an evaluation of respiratory protective escape device (RPED) performance to determine if RPEDs have the potential to reduce fire-related residential deaths and injuries. Three RPED models were tested in accordance with provisions of the voluntary standard, American National Standard for *Air-Purifying Respiratory Protective Smoke Escape Devices* (ANSI/ISEA 110). The tests that were determined by CPSC staff to be most important in evaluating effectiveness were conducted. Testing focused on function, human factors issues, durability, and flammability.

The test results showed that the RPEDs selected for evaluation did not meet standard requirements associated with donning. These results indicate that improvements may be needed in operational packaging to allow novice users to quickly determine correct RPED donning procedures. All of the models tested complied with requirements to assess field of vision, and two of the three models met requirements to evaluate leakage.

For all three RPED models evaluated, there were failures associated with tests to assess breathing resistance, either initially or after conditioning. There were also failures associated with total inward leakage (fit) and soot particulate performance. These results indicate a need to improve factors that influence breathing resistance, such as filter design and seal integrity.

The RPEDS met requirements for flammability, molten polymeric drip, and radiant heat resistance; however, they did not meet requirements associated with corrosion resistance performance.

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1 INTRODUCTION

1.1 Background

There is a variety of fire/emergency escape devices, commonly called "smoke hoods" or "smoke masks," marketed to assist consumers in safe egress from fire emergencies. They provide head, eye, and respiratory protection from particulate matter, eye irritants, carbon monoxide, and other toxic gases commonly produced by structural fires. This report refers to these products as respiratory protective emergency escape devices (RPEDs).

In 2004, the U.S. Consumer Product Safety Commission (CPSC) staff began an evaluation of RPED performance to determine if RPEDs have the potential to reduce fire-related residential deaths and injuries.[*] Three RPED models were tested in accordance with provisions of the voluntary standard, *Air-Purifying Respiratory Protective Smoke Escape Devices.* The tests that were determined by CPSC staff to be most important in evaluating effectiveness were conducted. This report presents the results of those tests.[**] As part of this study, an evaluation of RPED human factors issues including respirator fit, filter-related factors, behavioral factors, instructions, warnings, general usability, and donning was conducted and the analysis is presented in a separate report.[***]

1.2 Voluntary Standards

In October 2003, the International Safety Equipment Association (ISEA) published the first voluntary standard for RPEDs, American National Standard for *Air-Purifying Respiratory Protective Smoke Escape Devices* (ANSI/ISEA 110). This standard provides design guidance to manufacturers in the form of detailed performance requirements and test procedures. The standard also requires that an RPED have a minimum service life of 15 minutes.

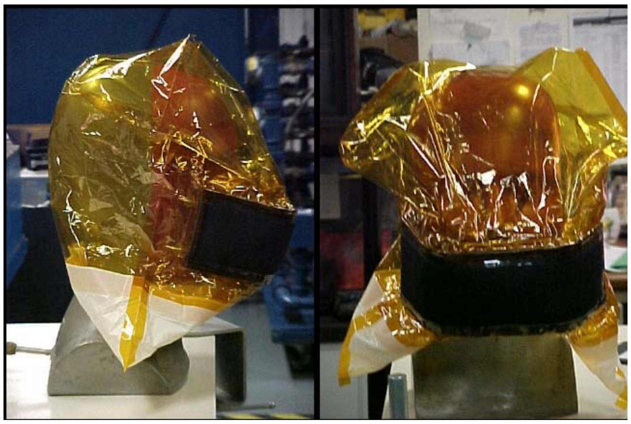
2 PERFORMANCE TESTING

Three models of commercially available consumer RPEDs (designated A, B, and C) were selected for testing and evaluation in accordance with the standard for *Air-Purifying Respiratory Protective Smoke Escape Devices* (ANSI/ISEA 110); see Figure 1.

[*] Funding was provided by the U.S. Fire Administration under Interagency Agreement No. HSFEEM-04-X-0375.
[**] Testing was conducted by Intertek Testing Services under Contract No. CPSC-04-1384.
[***] *Human Factors Analysis of Consumer Personal Protective Equipment: Emergency Escape Masks,* H. Johnson, R. Khanna, 2007

Model A

Model B



Model C

Figure 1 – RPED Models

Testing was conducted in accordance with requirements of the standard that focused on function, human factors issues, durability, and flammability. Specifically, testing was conducted for the following requirements:

<u>Functional Tests</u>

- Section 7.2 – Donning
- Section 7.3 – Breathing Resistance
- Section 7.5 – Total Inward Leakage
- Section 7.6 – Optical Properties (Field of Vision only)
- Section 7.7 – Leakage
- Section 7.10 – Soot Particulate

<u>Durability Conditioning</u>

- Section 8.2 – Vibration Conditioning
- Section 8.3 – Puncture and Tear Conditioning
- Section 8.4 – Pressure Conditioning
- Section 8.5 – Temperature Conditioning

<u>Flammability Tests</u>

- Section 7.11 – Flammability
- Section 7.12 – Molten Polymeric Drip Resistance
- Section 7.13 – Radiant Heat Resistance
- Section 7.14 – Corrosion Resistance

These tests, along with the test results, are described in detail below.

2.1 Donning

The purpose of this test is to evaluate the donning effectiveness of an RPED by measuring the time needed to correctly don the device. An essential design feature of the RPED is for it to allow quick and correct donning by novice users from the ready-to-use configuration.

<u>Section 7.2 – Donning</u>

The test procedures for evaluating the donning time of RPEDs are specified in Section 9.2, *Donning Testing*. Test samples are conditioned at room temperature for a period of 24 hours prior to testing. Two physically able test subjects (one male and one female) who have not been trained in the use of RPEDs and who have not previously donned an RPED are required for testing each different model.

The test subjects are given an RPED in the ready-to-use configuration, and they are given 30 seconds to read the donning instructions provided by the manufacturer (separate instructions and any instructions printed on the RPED). After 30 seconds have elapsed, the test subjects are instructed to immediately don the RPED and the time is recorded. At the conclusion of the test, proper fit consistent with the user instructions is confirmed. To pass the requirements of this section, the time required to correctly don the RPED must not exceed 30 seconds. An additional evaluation of RPED donning performance is reported in the human factors report (Johnson and Khanna, 2007).

Donning Time Test Results

RPED Model	Test Subject	Time (sec)	Result
Model A	Male	37.25	Fail
	Female	35.21	Fail
Model B	Male	35.00	Fail
	Female	44.09	Fail
Model C	Male	25.39	Fail*
	Female	45.91	Fail

* RPED not donned correctly

None of the samples tested was successfully donned within the specified time limits. For five of the six test samples, test subjects exceeded the allowable 30 seconds. In one test, the test subject donned the RPED in less than 30 seconds but did so incorrectly.

2.2 Breathing Resistance

The purpose of this test is to evaluate the breathing resistance of an RPED. The breathing resistance is a measure of the difficulty of breathing experienced by a user of the RPED during inhaling and exhaling air. The factors that influence breathing resistance include the size of the filter media, efficiency of the filter media, and exhalation valve design. High breathing resistance requires more effort to be exerted by the user to inhale air sufficient to meet the user's physical needs.

Section 7.3 – Breathing Resistance

The test procedures for evaluating the breathing resistance of RPEDs are specified in Section 9.3, *Air Flow Resistance Testing*. Test samples are secured to a test headform. A pressure probe, consisting of metal tubing with one end open and the other closed, is attached to the test headform. The closed end of the pressure probe extends through the test headform and exits at the center of the mouth. The open end of the pressure probe extends outward from the back of the test headform and is connected to a differential pressure transducer. A breathing machine as specified in National Fire Protection Association (NFPA) 1981, *Standard on Open-Circuit Self Contained Breathing Apparatus for the Fire Service,* is used. The breathing machine uses the Lung Breathing Waveform for 40 litres (L)/minute Volume Work Rate; it is set for 19 breaths per minute, yielding a constant ventilation rate of 31.7 L/minute and a peak inhalation flow of 95 L/minute.

To pass the requirements of this section, the maximum inhalation resistance should be 81.5 mm water column below ambient pressure from the beginning of the test until its conclusion. The maximum exhalation resistance is required to be 30.6 mm water column above ambient pressure from the beginning of the test until its conclusion.

Breathing Resistance Test Results

RPED Model	Constant Ventilation Rate (L/min)	Peak Inhalation (mm)	Peak Exhalation (mm)	Performance
Model A	95	-228.60	162.56	Fail
	60	-226.06	107.95	Fail
	50	-223.52	92.71	Fail
	40	-217.93	77.47	Fail
	30	-185.42	62.23	Fail
	20	-157.48	55.63	Fail
Model B	95	-182.88	50.80	Fail
	60	-82.55	20.32	Fail
	50	-62.23	15.24	Fail
	40	-43.18	12.70	Fail
	30	-29.21	7.62	Fail
	20	-15.24	5.08	Fail
Model C	95	-208.28	162.56	Fail
	60	-92.71	86.36	Fail
	50	-62.23	15.24	Fail
	40	-41.91	41.91	Fail
	30	-25.40	26.67	Fail
	20	-11.43	14.73	Fail

All of the RPED models failed the performance requirements for this test by exhibiting peak inhalation and exhalation resistance that exceeded the specified limits.

2.3 Total Inward Leakage (Fit Testing)

The purpose of this test is to assess RPED fit quality by measuring leakage. This method specifies a quantitative measure of the ambient particle concentration outside and inside an RPED. These two measures are compared to determine the amount of leakage. Fit testing is essential to RPED performance since gaps can occur with users with a range of head, neck, and face dimensions. These gaps can be sources of leakage that can compromise RPED performance.

Section 7.5 – Total Inward Leakage

The test procedures for evaluating total inward leakage are specified in Section 9.5, *Total Inward Leakage Fit Testing*. A leak-tight sampling probe is installed inside each RPED and connected to a quantitative fit testing device. Leakage tests are performed on ten RPED test subjects with facial, head, and neck dimensions that correspond with the dimensions in the following table:

<u>Facial, Head, and Neck Dimensions for Test Subjects</u>

	Small (mm)	**Medium (mm)**	**Large (mm)**
Head Circumference	525-550	551-575	576-600
Neck Circumference	307-350	351-375	376-409
Face Length	93.5-103.5	104-123.5	124-133.5
Lip Length	34.43-43.5	44-52.5	53-61.5

Test subjects are directed to position their hair so that it does not interfere with the RPED's seal. The test subjects are instructed to don the RPED and perform exercises for 30 seconds while walking on a treadmill that operates at 3 mph. A challenge agent is introduced in the test areas prior to each exercise. The exercises are performed in the following order:

1. Normal breathing
2. Deep breathing
3. Turning head side to side
4. Moving head up and down
5. Normal breathing

A quantitative fit testing device is used to measure ambient particle concentration within the probed space for each exercise. The average concentration of the challenge agent within the probed space is obtained for each exercise. The average values for all five concentrations are calculated (C_i = average concentration calculated for all exercises, and C_o = average concentration outside the RPED). The total inward leakage is determined by the following calculation:

Total Inward Leakage = C_i / C_o

In order to pass the requirements of this section, the maximum inward leakage of the challenge agent should be an average of 2 percent of the inhaled air for any of the test subjects in any of the test exercises.

Total Inward Leakage Test Results

	Model A	**Model B**	**Model C**
	% Inward Leakage	% Inward Leakage	% Inward Leakage
Small	*DNF	8.62	*DNF
Small	*DNF	3.61	*DNF
Sm/Med	0.75	0.23	0.64
Sm/Med	42.56	6.26	1.83
Sm/Med	19.62	1.41	0.78
Med/LG	*DNF	16.00	*DNF
Med/LG	*DNF	2.31	*DNF
Med/LG	*DNF	2.62	*DNF
Large	2.53	0.24	0.20
Large	3.25	4.73	*DNF
Avg. Total Leakage	**N/A	4.60	**/NA
Pass/Fail	Fail	Fail	Fail

* DNF (Did Not Finish): Subjects could not finish testing.
** Averages could not be calculated due to subjects not finishing test.

None of the RPED models met the performance requirements of the standard for this test. The total average leakage for Models A and C could not be calculated because the test subjects could not finish performing the required exercises due to extreme discomfort. The average leakage for Model B was 4.6 percent, which exceeded the allowable 2 percent limit.

2.4 Field of Vision

The purpose of this test is to quantify RPED field of vision by measuring the effective visual field. This method uses procedures consistent with European Standard (EN) 136:1998, *Respiratory Protective Devices - Full Face Masks - Requirements, Testing, Marking*, but uses the visual field score method described by the American Medical Association to measure the functional impact of the RPED on the visual field loss. Visual field loss may affect visual orientation and mobility skills of the user.

Section 7.6.2 – Field of Vision

The test procedures for evaluating RPED field of vision are specified in Section 9.6.2, *Field of Vision Testing.* The RPED is mounted according to the manufacturer's instruction on a special headform (apertometer) designed to measure field of vision. The effective field of vision is measured in an apertometer apparatus (See Figure 2) and is transferred to a field of vision scoring grid overlay. The effective field of vision is determined by counting the dots within the effective field of vision for the RPED.

In order to pass the requirements of this section, the RPED field of vision score should be at least 70.

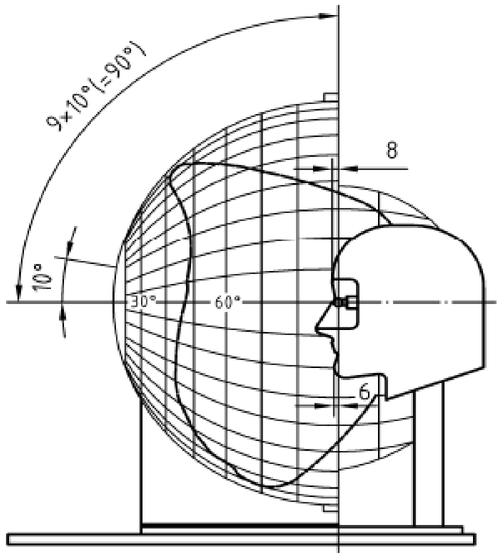


Figure 2 – Apertometer Apparatus Fixture

Field of Vision Test Results

Model A	Fitting Trial	Effective (%)	Pass/Fail
	1	98.2	Pass
	2	99.9	Pass
	3	97.7	Pass
	Average	98.6	Pass
Minimum Permitted		70	

Model B	Fitting Trial	Effective (%)	Pass/Fail
	1	88.3	Pass
	2	84.9	Pass
	3	83.7	Pass
	Average	85.6	Pass
Minimum Permitted		70	

Model C	Fitting Trial	Effective (%)	Pass/Fail
	1	96.6	Pass
	2	96.7	Pass
	3	90.3	Pass
	Average	94.5	Pass
Minimum Permitted		70	

All of the models tested had an effective field of vision score over 70 and, therefore, met the requirements of the standard.

2.5 Leakage

The purpose of this test is to evaluate the operational packaging seal integrity, such that immediately upon opening, the user is able to don the RPED. RPED packaging should be leak-free so that contaminants do not compromise operation and performance during storage and prior to use.

Section 7.7 – Leakage

The test procedures for evaluating RPED leakage in its ready-to-use configuration are specified in Section 9.7, *Leakage Testing*. A tub with dimensions 600 mm length x 600 mm width x 750 mm depth is filled with water to a depth of 600 mm. The RPED in its ready-to-use configuration is completely immersed, without interfering with the operational packaging seal integrity, until it is positioned at the bottom of the tub. The RPED is oriented in the position in which it is normally stored. Once in position, the RPED is held in place for 5 minutes. After immersion for 5 minutes, the exterior is immediately dried and opened.

To pass the requirements of this section, no water should be present in the interior of the RPED.

Leakage Test Results

	Leakage After 5 Min. Immersion	Pass/Fail
Model A	No	Pass
Model B	No	Pass
Model C	Yes*	Fail*

* Note: Outside packaging burst open where the sample was heat sealed, causing failure.

Models A and B met the performance requirements of the standard. Model C failed the leakage test, as the operational packaging burst open at the location where the sample was heat sealed.

2.6 Soot Particulate

The purpose of this test is to evaluate the increase in breathing resistance generated by the RPED after exposure to soot-laden air. The RPED filter media should be designed to limit increased breathing resistance upon exposure to a soot-laden environment, as can be expected during a fire emergency.

Section 7.10 – Soot Particulate

The test procedures to evaluate increased breathing resistance due to exposure to soot particulate are specified in Section 9.10, *Soot Particulate Testing*. A soot test chamber is used, consisting of a metal box equipped with an opening through which room air and soot are introduced, and openings on which test devices can be mounted. A specified breathing machine is modified to yield a tidal volume of 1.7 L. At 18.8 cycles per minute, the modified machine produces 32 ± 2 L/min. Soot-laden air is pulled though the test chamber at a concentration of 200 ± 25 mg/m^3. The RPED is connected to the test fixture and modified breathing machine and placed in the test chamber. After 5 minutes, the RPED is removed from the test chamber and tested for breathing resistance in accordance with Section 9.3, *Breathing Resistance*, to determine if exposure to a soot-laden environment has increased breathing resistance.

In order to pass the requirements of this section, the peak inhalation breathing resistance should not exceed 204 mm of water column, and the peak exhalation resistance should not exceed 153 mm of water column.

Soot Particulate Test Results

Airflow Calibration: 31.7 L/min
Soot Calibration #1: 198.13 mg/m^3
Soot Calibration #2: 187.50 mg/m^3

	Constant Vent Rate (L/min)	**Peak Inhalation (mm)**	**Peak Exhalation (mm)**	**Result**
Model A	95	-233.68	180.34	Fail
Model B	95	-218.44	60.96	Fail
Model C	95	-233.68	198.12	Fail

All of the RPED models tested failed to meet the performance requirements of the voluntary standard by exhibiting an increase in breathing resistance exceeding the specified limits.

2.7 Flammability

The purpose of this test is to evaluate the flammability performance of RPED materials using an open-flame ignition source. The duration of afterflame is measured, and the RPED is observed for physical damage after exposure to the test flame. The materials used in RPEDs should be resistant to dripping, melting, or generating holes in components that expose eyes or lungs to gas or smoke. Failure of RPEDs to have resistance to elevated temperatures could severely compromise the user’s ability to egress from a fire emergency.

Section 7.11 – Flammability

The test procedures to evaluate RPED heat and flame resistance are specified in Section 9.11, *Flammability Testing*. The RPED is fitted on a test headform. The test equipment needed is specified in Section 8.5.2, Flammability, EN 136:1998, *Respiratory Protective Devices - Full Face Masks, Requirements, Testing, Marking*. The ignition source is a gas burner with the flame adjusted so that the flame temperature at a position 250 ± 6.4 mm above the flame tip is 800 ± 50^{o}C. The RPED is rotated once through the flame at a velocity of 6 ± 0.5 cm/s. The RPED is observed for any afterflame, and afterflame time is recorded. The RPED is also observed for any dripping, melting, or gap development and any damage to components that exposes eyes and lungs to gas or smoke.

After flame exposure, a test subject having a visual acuity of 20/20 (corrected or uncorrected) in each eye dons the RPED. The test subject is positioned at a distance of 20 ft (6.1 m) in front of a standard 20 ft eye chart illuminated at 100-150 foot-candles. The test subject then attempts to read the 20/100 line.

In order to pass the requirements of this section, the RPED should not exhibit afterflame greater than 5 seconds, none of its components should drip, melt, or develop any gaps visible to the unaided eye, and should allow the test subject to read the 20/100 vision line.

Flammability Test Results

Model A	**Afterflame (sec.)**	**Visual 20/100**	**Pass/Fail**
Sample 1	0.0	Yes	Pass
Sample 2	0.0	Yes	Pass
Sample 3	0.0	Yes	Pass

Model B	**Afterflame (sec.)**	**Visual 20/100**	**Pass/Fail**
Sample 1	0.0	Yes	Pass
Sample 2	0.0	Yes	Pass
Sample 3	0.0	Yes	Pass

Model C	**Afterflame (sec.)**	**Visual 20/100**	**Pass/Fail**
Sample 1	0.0	Yes	Pass
Sample 2	0.0	Yes	Pass
Sample 3	0.0	Yes	Pass

All of the RPED models passed the requirements of the voluntary standard.

2.8 Molten Polymeric Drip

The purpose of this test is to evaluate an RPED's flammability resistance to a molten polymeric drip and its impact on the RPED breathing resistance. RPED materials should be capable of resisting exposure to flame so that the RPED breathing resistance does not increase, as it is reasonable and foreseeable that a user can encounter open flames during egress from a fire emergency.

Section 7.12 – Molten Polymeric Drip Resistance

The test procedures for evaluating RPED resistance to molten drips are specified in Section 9.12, *Molten Polymeric Drip Testing*. The RPED is mounted on a test headform that is connected to a modified breathing machine. A test fixture supporting the test headform in the vertical (upright) position is capable of being moved forward, backward, and left to ensure access to different test locations. The RPED test locations are selected so that each material and material interface exposed during escape is evaluated. The test fixture with the headform in the vertical position is capable of rotating so that the headform can be positioned horizontally, 90 degrees from its original vertical position. The headform in its horizontal position is capable of rotating 360 degrees along the horizontal axis to ensure access to different test locations. The modified breathing machine is turned on and breathing resistance data is recorded.

The test begins with the headform in the vertical position. A polypropylene rod is held in the horizontal position to a location so that the end of the rod is 116 ± 38 mm from the RPED test location. The rod is ignited, and one flaming drip is allowed to fall on each RPED test location until all accessible test locations have been tested. The time taken for the afterflame to begin is recorded when the drip reaches the RPED test location.

Next, the headform and test fixtures are rotated 90 degrees to the horizontal position. The headform is rotated along the horizontal axis as necessary to access the RPED test locations using the flaming drip of the polypropylene rod.

In order to pass the requirements of this section, the RPED must not exhibit afterflame for more than 5 seconds and must not have a decrease in inhalation resistance more than 25 percent.

Molten Polymeric Drip Test Results

Model A						
Drip Location	**Afterflame (sec.)**	**Damage (yes/no)**	**Initial Breathing Resistance (mm)**	**Final Breathing Resistance (mm)**	**% Change**	**Pass/ Fail**
Head Top	0.0	No	-228.60	-233.68	2.22	Pass
Head Side	0.0	No	-228.60	-233.68	2.22	Pass
Filter	0.0	No	-228.60	-233.68	2.22	Pass
Filter/ Cover Seam	0.0	No				

Model B						
Drip Location	**Afterflame (sec.)**	**Damage (yes/no)**	**Initial Breathing Resistance (mm)**	**Final Breathing Resistance (mm)**	**% Change**	**Pass/ Fail**
Head Top	0.0	No	-182.88	-228.60	25.0	Pass
Head Side	0.0	No	-182.88	-233.68	27.0	Pass
Lower Neck			-182.88	-233.68	27.0	Pass
Visor	0.0	No				
Filter	0.0	No				

Model C						
Drip Location	**Afterflame (sec.)**	**Damage (yes/no)**	**Initial Breathing Resistance (mm)**	**Final Breathing Resistance (mm)**	**% Change**	**Pass/ Fail**
Head Top	0.0	No	-208.28	-233.68	12.1	Pass
Head Side	0.0	No	-208.28	-233.68	12.1	Pass
Neck	0.0	No	-208.28	-198.12	4.9	Pass
Filter	0.0	No				

All of the models passed the performance requirements of this aspect of the standard*.

2.9 Radiant Heat Resistance

The purpose of this test is to evaluate an RPED's resistance to radiant heat. RPEDs should be designed to reflect radiant heat so that RPED materials do not lose their rigidity or form, which can cause the user to be exposed to toxic smoke and gases. It is reasonable and foreseeable that high radiant heat can be present during fire emergencies.

Section 7.13 – Radiant Heat Resistance

The test procedures for evaluating RPED resistance to radiant heat are specified in Section 9.13, *Radiant Heat Testing*. In order to pass the requirements of this section, the temperature at the top of a headform and an eyepiece subjected to radiant heat must not exceed 70^{o}C, and the RPED must not exhibit damage in a manner that exposes eyes or lungs to gas or smoke.

In this test, an RPED is mounted over an aluminum fixture, which is attached to a headform, and placed in a radiant heat chamber. The RPED is inflated and connected to a breathing machine to simulate inhalation/exhalation of a user. The RPED is then exposed to a radiant heat source several times for 15-second intervals. Temperatures on the aluminum fixture

* ASTM D 4101, *Standard Specification for Polypropylene Injection and Extrusion Materials, specifies use of a 5 mm polypropylene rod. In this evaluation, the rod used was 0.25 inches (6.35 mm) in diameter; however CPSC staff does not believe that this difference resulted in significant performance differences.*

(corresponding to the head) are continuously recorded, and the condition of the RPED is observed for damage. In a similar set of tests, temperatures at the eye of the headform are recorded, and the condition of the RPED is observed.

Radiant Heat Resistance Test Results

TOP OF HEAD:

Model	**Temperature (^oC)**	**Damage (yes/no)**	**Pass/Fail**
A #1	49.9	No	Pass
A #2	49.2	No	Pass
A #3	50.8	No	Pass
B #1	28.3	No	Pass
B #2	31.9	No	Pass
B #3	29.4	No	Pass
C #1	52.8	No	Pass
C #2	46.2	No	Pass
C #3	53.6	No	Pass

EYE:

Model	**Temperature (^oC)**	**Damage (yes/no)**	**Pass/Fail**
A #1	40.9	No	Pass
A #2	46.2	No	Pass
A #3	53.9	No	Pass
B #1	44.1	No	Pass
B #2	44.4	No	Pass
B #3	45.4	No	Pass
C #1	49.1	No	Pass
C #2	46.6	No	Pass
C #3	51.5	No	Pass

All of the RPED models tested passed the performance requirements of this aspect of the standard. Temperatures at the top of the headform and in the eye remained below 70^oC and none of the units showed any physical damage after the test.

2.10 Corrosion Resistance

The purpose of this test is to evaluate RPED resistance to corrosion. A salt spray test chamber is used to simulate an accelerated corrosive environment. After exposure to salt spray, the RPED is evaluated for increased breathing resistance. An RPED should be designed to maintain operational effectiveness after storage for prolonged periods.

<u>Section 7.14 – Corrosion Resistance</u>

The test procedures for evaluating RPED resistance to corrosion are specified in Section 9.14, *Corrosion Resistance Testing*. The RPED is tested in a salt spray test chamber in accordance with ASTM B 117, *Standard Method of Salt Spray (Fog) Testing.* The test chamber temperature is adjusted to 35 ± 2 ^{o}C. The RPED is placed in the chamber for 2 hours prior to introduction of the salt solution. The salt spray concentration is 5 percent saline solution, and the test duration is 48 hours. After exposure, the RPED is stored in an environment that has a temperature of 22 ± 3 ^{o}C and a relative humidity (RH) of 50 ± 5 percent for 48 hours.

Following the test exposure and storage, and prior to examination, the RPED is rinsed under warm tap water and dried with compressed air. The RPED is next tested in accordance to Section 9.3, *Air Flow Resistance Testing*.

In order to pass the requirements of this section, the RPED inhalation resistance must not exceed 85 mm water column <u>below</u> ambient pressure, and the exhalation resistance must not exceed 30.6 mm water column <u>above</u> ambient pressure after exposure to the salt spray.

<u>Corrosion Resistance Test Results</u>

TYPE OF SALT: NaCl
CONCENTRATION: 5%
CHAMBER TEMP: 95^{O}C
EXPOSURE PERIOD: 48 hours

TYPE OF WATER: Deionized
SALT VOLUME: 28 ml
SOLUTION pH: 6.72

Model	**Vent. Rate (L/min)**	**Peak Inhalation (mm)**	**Peak Exhalation (mm)**	**Pass/Fail**
A #1	95	-231.14	154.94	Fail
A #2	95	-233.68	162.56	Fail
A #3	95	-233.68	154.94	Fail
B #1	95	-233.68	228.60	Fail
B #2	95	-236.22	227.33	Fail
B #3	95	-233.68	227.33	Fail
C #1	95	-233.68	213.36	Fail
C #2	95	-220.98	210.82	Fail
C #3	95	-208.78	165.10	Fail

All of the models tested failed the performance requirements of this aspect of the standard.

3 SUMMARY/CONCLUSIONS

In 2004, the U.S. Consumer Product Safety Commission (CPSC) staff began an evaluation of RPED performance to determine if RPEDs have the potential to reduce fire-related residential deaths and injuries. Three RPED models were tested in accordance with provisions of the voluntary standard, *Air-Purifying Respiratory Protective Smoke Escape Devices.* The tests that were determined by CPSC staff to be most important in evaluating effectiveness were conducted. Testing focused on function, human factors issues, durability, and flammability.

The test results showed that the RPEDs selected for evaluation did not meet standard requirements associated with donning. These results indicate that improvements may be needed in operational packaging to allow novice users to quickly determine correct RPED donning procedures. All of the models tested complied with requirements to assess field of vision, and two of the three models met requirements to evaluate leakage.

For all three RPED models evaluated, there were failures associated with tests to assess breathing resistance, either initially or after conditioning. There were also failures associated with total inward leakage (fit) and soot particulate performance. These results indicate a need to improve factors that influence breathing resistance, such as filter design and seal integrity.

The RPEDS met requirements for flammability, molten polymeric drip, and radiant heat resistance; however, they did not meet requirements associated with corrosion resistance performance.