

Human Factors Analysis of Consumer Personal Protective Equipment: EMERGENCY ESCAPE MASKS

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Executive Summary

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 are intended to 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. * Five RPEDs were selected for evaluation on the basis of availability (all available online) and price (covering a range of prices). In 2005, CPSC Division of Human Factors (ESHF) staff conducted a human factors analysis of these RPEDs. This report presents the results of the staff analysis, which included an evaluation of fit; filter-related factors; behavioral factors; instructions, warnings, and general usability; and a donning test.

In general, the RPEDs followed several good human factors practices, such as considering a wide range of anthropometric dimensions and designing so that they are intuitive to don. None of the RPEDs evaluated conformed to all aspects of the labeling requirements of the voluntary standard, nor did any RPED pass the donning test in the standard. For all five RPEDs evaluated, improvements in marking and labeling for ease of reading in emergency situations would be beneficial.

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TABLE OF CONTENTS

1	<i>Introduction</i>	4
1.1	Background	4
1.2	Objective	4
1.3	Product Description	4
1.3.1	Model A	6
1.3.2	Model B	6
1.3.3	Model C	6
1.3.4	Model D	6
1.3.5	Model E	6
2	<i>Fit Analysis</i>	7
2.1	Anthropometry	7
2.2	Seal Formation	8
3	<i>Filter Analysis</i>	10
3.1	Filter selection	10
3.2	Filter installation	10
3.3	Filter service life while in use	10
4	<i>Behavioral Analysis</i>	11
4.1	Training and Practice	11
4.2	Psychological/Psychophysical Problems	11
4.3	Communication	12
5	<i>Instructions, Warnings, and General Usability</i>	12
5.1.1	Model A	13
5.1.2	Model B	14
5.1.3	Model C	14
5.1.4	Model D	15
5.1.5	Model E	15
6	<i>Donning Test</i>	16
6.1	Materials and Method	16
6.2	Results	16
7	<i>Conclusion</i>	18
8	<i>References</i>	19
10	<i>Appendix A – Summary Table</i>	20

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 are intended to 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 2005, the U.S. Consumer Product Safety Commission (CPSC) staff began a human factors analysis of RPED performance to determine if RPEDs have the potential to reduce fire-related residential deaths and injuries. Five RPEDs were selected for analysis on the basis of availability (all available online) and price (covering a range of prices). This report presents the results of the CPSC staff analysis.

1.2 Objective

This report presents the results of a CPSC human factors staff analysis of five models of RPEDs. The staff analysis included an evaluation of fit; filter-related factors; behavioral factors; instructions, warnings, and general usability; and a donning test. The donning test was conducted in accordance with the voluntary standard, *Standard for Air-Purifying Respiratory Protective Smoke Escape Devices* (ANSI/ISEA 110).*

1.3 Product Description

All sample RPED models (see Figure 1) are air-purifying respirators, which use filters to remove harmful substances from the air. As the consumer wearing the air-purifying device breathes in and out, air is drawn through the filters. The filters are intended to cleanse the air of particulates, gases, vapors, and aerosols. Because these devices simply scrub the air, their use is limited to situations where the ambient oxygen level is sufficient to support breathing and where the contaminate level is within the rating levels of the filter. Since each filter can only remove a certain amount of contaminants before it ceases to effectively clean the air, the RPED’s service life is limited by the level of contaminant, breathing rate of the consumer, temperature and humidity levels in the area (Colton, 1996).

* American National Standard/International Safety Equipment Association 110-2003, *Standard for Air-Purifying Respiratory Protective Smoke Escape Devices*



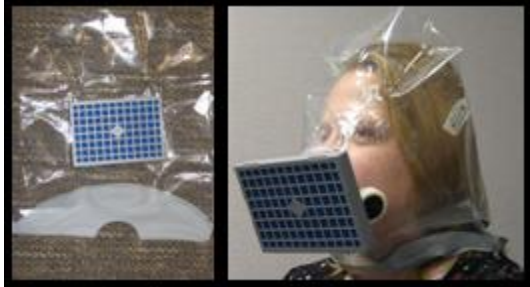
Model A, ~\$70



Model B, ~\$130



Model C, under \$50



Model D, ~\$150



Model E, ~\$75

Figure 1. RPED Models

1.3.1 Model A

Model A was packaged in a bright green canister with a red translucent top. The 5.25 inch long x 2.5 inch diameter canister fits into a wall-mount holder. The canister contained a yellow, polyamide hood approximately 16 inches long x 14 inches wide with two red ribbons at the bottom. A mouthpiece and nose clip were attached to the canister and remained inside the hood. The RPED is worn by placing the hood over the head, placing the mouthpiece between the teeth, placing the nose clip on the nose, and then pulling the red ribbons so that the bottom of the hood is tight around the neck.

1.3.2 Model B

Model B was packaged in a large yellow-orange box. Inside the box, the RPED and its two filters were stored in a brown fabric bag with a shoulder strap approximately 10 inches wide x 10 inches high x 4 inches thick. Inside the bag were two vacuum-sealed filters and a large orange hood with a 7 inch x 4.5 inch viewing lens. The RPED measures about 13 inches from top to neck and has a 7 inch long neck and shoulder cover. The seal around the neck is an elastic band. The filter canister is placed in an exterior holder with a clear screw top. Inside the RPED, there is a breathing cup that is placed over the nose and mouth. The bright orange RPED has two reflective strips, one on the front and one on the rear.

1.3.3 Model C

Model C was encased in a vacuum-sealed package approximately 5 inches wide x 8.5 inches long x 1 inch thick. It opened to a 14 inch wide x 15 inch high bag-like hood made of yellow polyamide film with a rubber-like collar to stretch around the neck. There were 2.5 inch x 12 inch black rectangular filters on each side of the hood. The RPED is worn by placing the hood over the head and breathing normally. According to marketing information available online, the polyamide film resists sparks and temperatures up to 800° F (425 °C).

1.3.4 Model D

Model D was packaged in a silver foil vacuum-sealed package that was stored inside a blue, zippered case approximately 5.5 inches tall x 8 inches wide x 1 inch thick. The foil packet contained a clear, polyamide hood approximately 13 inches wide x 15 inches tall, with a 6.25 inch wide x 4.25 inch high rectangular filter. The bottom of the hood is made of a flexible, polymeric material with an expandable neck hole.

1.3.5 Model E

Model E was packaged in a box approximately 6 inches x 6.5 inches x 2 inches. The box was sealed along one edge with a large sticker containing the name of the product, a warning message, and a list of six properties of the RPED. Inside the box, there was a single page brochure and a vacuum-sealed foil package containing the RPED. When opened, the RPED unfolded to a clear, yellow, polyamide hood approximately 15.5 inches wide and 18 inches from

top to bottom. The expandable neck hole has an initial diameter of 3 inches. The outside front of the RPED has a 2.5 inch tall cylindrical filter (3.5 inch diameter) that enters into the polyamide material and is attached to a mouthpiece inside the RPED. A plastic nose clip with an elastic band is attached to the reverse side of the RPED.

2 Fit Analysis

There are several features that are essential to the proper fit of any respirator. The RPED must form an airtight seal to prevent contaminated air from entering the breathing region around the nose and mouth. Essential factors to consider in design include anthropometry, facial hair, and eyeglass use to ensure proper fit and creation of an airtight seal.

2.1 Anthropometry

The ANSI/ISEA standard contains an anthropometric performance section requiring leakage testing using ten test subjects that fit in three anthropometric ranges. Test subjects must meet certain anthropometric characteristics to test each size RPED (small, medium, or large). The anthropometric dimensions specified in the standard and the corresponding percentiles for each size are shown in Table 1 (AdultData). The sizes specified in the standard appear to account for approximately 99% and 95% of the female and male population, respectively.

Table 1. Face, neck, and head dimensions

	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	34.5 – 43.5	44 – 52.5	53 – 61.5

Adult female percentiles

	Small (%-ile)		Medium (%-ile)		Large (%-ile)	
Head circumference	7.3%	50.7%	53.0%	93.2%	93.9%	99.8%
Neck circumference	3.9%	20.9%	21.6%	40.0%	40.9%	69.2%
Face length	3.3%	33.9%	36.6%	99.3%	99.4%	>99.9%
Lip length	0.0%	7.3%	8.9%	69.1%	72.9%	99.3%

Adult male percentiles

	Small (%-ile)		Medium (%-ile)		Large (%-ile)	
Head circumference	0.1%	5.9%	6.6%	45.8%	48.1%	91.3%
Neck circumference	0.1%	3.5%	3.8%	14.8%	15.6%	50.0%
Face length	0.1%	2.6%	3.0%	70.9%	73.0%	96.4%
Lip length	0.0%	2.0%	2.5%	42.6%	46.7%	95.4%

None of the samples were marked with a size; therefore, ESHF staff assumed they were “one size fits all.” All of the RPEDs evaluated appeared to fit a wide variety of sizes. Although

ESHF staff did not have the equipment to fit-test the hoods according to the standard, ESHF staff measured the width of the hood portion and the maximum circumference allowed by the neck opening for each RPED, shown in Table 2. The maximum circumferences measured would allow the hoods to fit greater than 99% of males and females.

Table 2. Approximate dimension for each device

	Head width (mm)	Neck circumference (mm)
Model A	80	76
Model B	67.5	68
Model C	74	69
Model D	70	73.5
Model E	67.7	63

Models C and D allow free breathing inside the hood; therefore, only the neck and head circumference dimensions are applicable. Models A and E contain a mouthpiece and nose clip, also eliminating the sizing issues around the mouth area. Model B contained an interior mouth and nose cup to direct air from the filter to the user, but this mouth and nose cup requires formation of a proper seal against the face.

2.2 Seal Formation

The seal for model A allows for varying neck sizes and shapes, but it is not likely to be airtight since it simply gathers with string. Neck variations, movement, and bulk formed by gathered material could interfere with this type of seal design.

Models C, D, and E use a flexible, polymeric material to form a seal around the neck of the user, while model B uses an elastic band at the bottom of a neck sleeve. Model A does not provide any type of flexible material; instead, the user pulls strings around the neck “snugly.” ESHF staff did not have the equipment needed to test and quantify the successful formation of a seal; however, a qualitative analysis was performed using one sample of each model.

Models B, C, D, and E use a flexible, rubber-like material that relies on material rebound to form a seal around the neck. This allows for some variation in neck size and shape; however, these types of seals could be affected by the presence of facial hair in the lower neck region, thereby reducing seal quality. Additionally, consumers with large necks may find the tight seal overly constricting. The flexible material at the base of model E did not appear to rebound completely after stretching to fit over the head. Small gaps were left along the neck, which could compromise seal quality.

Models A and E use a mouthpiece and nose clip in lieu of tight seal formation. When a consumer properly uses the mouthpiece and nose clip there is a reduced need for a tight seal to provide respiratory protection, although the eyes may still be affected by contaminants. Reliance on a separately applied nose clip to ensure a proper respiratory seal, however, is not ideal because:

1. Some users may have difficulty applying the nose clip correctly due to the finger strength required for application.
2. The nose clip may cause discomfort to the user, which may encourage removing it.
3. The use of a nose clip relies on the user to take a separate action to apply the nose clip during the donning process.
4. There is no means of protecting the eyes from smoke, fumes, and particulate matter.

The National Ag Safety Database (NASD) was developed with funding from the National Institute of Occupational Safety and Health (NIOSH). The information contained in NASD was contributed by safety professionals and organizations from across the nation. NASD provides detailed information on respiratory protection and recommends the following method for testing seal formation:

Only a secure and snug fit protects you, so make sure you have the right size respirator for your face. The shape of your face, facial hair and condition of your skin can affect your fit. Try various sizes until you find one where air does not leak in around the edges. You can test the respirator fit by placing the palms of your hands over the cartridges and breathing in for 10 seconds... If fit properly, the device should suck in tightly around your face.

<http://www.cdc.gov/nasd/docs/d000101-d000200/d000111/d000111.html>

This test method is not appropriate for models A, C, and E. ESHF staff used this method to test models B and D, substituting a plastic bag for the palms of the tester's hands to test the seal. For model B, the device appeared to form a tight fit and was held tight to the face while inhaling. Since model B uses a mouth cup that must maintain a tight seal against the face, additional testing was conducted to verify if the seal was maintained during facial movement. For this test, ESHF staff read aloud the Rainbow Passage (Fairbanks, 1960), which is a common passage used in respirator fit testing because reading it results in a wide variety of facial movements (Colton, 1998). Although it was impossible to determine quantitatively if the seal was broken during the reading, qualitatively, it appeared some facial movements disrupted the seal.

For model D, the bag was not held tightly to the filter and the hood portions expanded and contracted with breathing. Movement of the bag placed over the filter indicated that some air was passing through the filter; however, when the filter was not blocked, the RPED's clear material fogged up quickly raising concerns that some of the exhaled breath was remaining inside the RPED.

Eyeglasses

ESHF staff tried on all five RPEDs while wearing eyeglasses. The presence of eyeglasses increased the difficulty in donning models B, C, D, and E due to the tight, flexible neckband; but it was still possible to don the devices. The eyeglasses did not appear to interfere with any seal.

3 Filter Analysis

3.1 Filter selection

When using a respirator, the selection of the proper filter is essential for effectiveness. Models A, C, D, and E are designed for fire situations only and contain an integral filter. Model B is packaged with two different filters, one intended for fire and the other intended for nuclear, biological, or chemical (NBC) situations. The filter packaging is color-coded (red=fire, blue=NBC). ESHF staff believes the fire filter color coding is appropriate as red is commonly associated with fire; ESHF staff is not aware of any common color association with NBC agents. The packaging for each filter is marked indicating which filter is contained within; however, the packaging is difficult to read due to wrinkles created by the vacuum-sealed packaging. When color-coding like this is used, the packaging should contain significant marking to be recognized quickly and in the low-light conditions one may encounter in a fire situation. For example, to ensure the consumer installs the correct filter, the filter packaging for model B could be completely made of the designated color or contain a wide colored stripe around all edges, rather than the few words printed in the designated color as it is currently marked.

3.2 Filter installation

The filter selection process required by model B may increase the time needed to fully don the RPED since the user will need time to make the selection decision, open the filter packaging, unscrew the filter cap on the RPED, install the filter in the proper orientation, and then reinstall the filter cap. The filter cap does not allow the filter to be installed upside down, reducing the likelihood of installation errors. Models A, C, D, and E do not require filter selection or installation.

3.3 Filter service life while in use

Each RPED model contained a reference to the expected useful service life of the filter. For models A, C, D, and E the escape times listed are 20, 20, 10, and 20 minutes, respectively. The filter on model B is marked with capacities for three gasses (hydrogen chloride (HCl), sulfur dioxide (SO₂), and hydrogen cyanide (HCN)) with capacity listed as 17, 97, and 260 minutes, respectively. This information may cause confusion with consumers, as most will not be aware which chemical compound is in the atmosphere and, therefore, which escape time applies for their situation. To avoid user confusion, ESHF staff recommends that only the shortest escape time should be stated. Additionally, if there is any method other than time in use for the user to determine if the filter is effective, this information should be included.

4 Behavioral Analysis

4.1 Training and Practice

Training is important for proper respirator use. Military personnel and workers in an occupational setting receive training for gas masks and other respirator use. Colton (1998) recommends training for all respirator users. The RPEDs evaluated in this study are intended for general consumers who typically may not be formally trained in their use. Many of the training elements recommended by Colton are suited toward occupational use only; however, the following subset of elements is appropriate for any respirator user:

- An explanation of ... what happens if the respirator is not used properly
 - A discussion of the function, capabilities, and limitations of the respirator
 - Instructions on how to put the respirator on and check its fit and operation
 - Instructions on maintenance
 - Instructions on emergency procedures and the use of emergency escape devices
- (Colton, 1998, pg 621)

Since there is currently no method of training users to use the RPED respirator, the instructions for these products attempt to address some of these points. Although ESHF staff found the RPEDs reasonably intuitive to don and wear, staff is concerned that there is no way to practice or test the fit on models A, C, D, and E. Since consumers who purchase these units will have to learn to use the device under highly stressful emergency situations, their first use will likely be preceded by a sense of fear and panic. This is not an ideal situation in which to learn to use an unfamiliar, new product and will likely lengthen the donning process and reduce a consumer's ability to don the RPED properly. Since model B uses separate canisters that are opened at the time of use, consumers could practice donning and fitting the hood. The instructions, however, do not mention this.

4.2 Psychological/Psychophysical Problems

Since respirator use is contraindicated for some medical conditions, the Occupational Safety and Health Administration (OSHA) requires a medical questionnaire (29 CFR 1910.134 Appendix C) to be filled out before occupational use of a respirator. Claustrophobia is specifically mentioned, since some respirators can trigger claustrophobia or panic attacks. Claustrophobics generally fear the possible results of a confining situation, such as suffocation, restriction, and entrapment, rather than the confinement itself (Rachman, 1997). ESHF staff feels that all of the RPED models evaluated may be likely to trigger claustrophobia, panic attacks, or other anxiety related conditions, as they all encapsulate a user's head and are made of a plastic-like material that, if not for the filter, may appear to the layman as though they could possibly cause suffocation.

Other factors that may increase anxiety while wearing the device include discomfort, breathing resistance, and the initial situation requiring donning the device (i.e., fire). Anxiety and stress

will increase respiration rate. Increased respiration rate, combined with lower oxygen levels and increased breathing resistance, will lead to early fatigue.

4.3 Communication

In an emergency situation, it is vital to communicate with others. Therefore, it is important that users be able to communicate while wearing the RPED. Evaluation of vocal attenuation and communication degradation while wearing an RPED is difficult without acoustical laboratories simulating the conditions during use. Therefore, ESHF staff only tested the ability to articulate while wearing an RPED. Models A and E did not allow any articulation since the breathing apparatus is held in the mouth. Model B interfered slightly due to the mouth and nose cup, and it is likely the mouth and nose cup attenuates the voice enough to interfere with communication. Models C and D had little interference with articulation.

Although vocal communication may be compromised in an emergency situation, there may be additional factors diminishing vocal communication (e.g., fire alarms or explosions). Therefore, gestures and other non-verbal communication will be important. None of the RPEDs restrict arm motion, which will allow for some basic gesture methods of communication (e.g., “put this on” or “follow me”). These may be sufficient for an escape.

The hood portion of models A, C, and E is a very thin polyamide material. This material makes a significantly loud “crinkling” sound when it is disturbed. Although the material itself may not attenuate sound significantly, the crinkling sound during movement may affect the user’s hearing ability. The hood portion of model D was a thicker polyamide material, which possibly could attenuate sound in addition to creating noise during movement. However, as mentioned above, communication during a fire situation may be possible with gestures.

5 Instructions, Warnings, and General Usability

Section 5 of the ANSI/ISEA standard contains minimal labeling requirements. These requirements* include:

1. A permanent label on the outside of the packaging/storage container
2. A minimum text size of 2 mm for all required text
3. Manufacturer’s name or identification, product identification, month/year of manufacture
4. The statement, “One time use only”
5. The use of symbols to supplement text

* ESHF staff’s numbering system

6. Pre-use info:
 - a. Safety considerations
 - b. Limitations, such as adult use and length of time of protection
 - c. Oxygen-deficient atmosphere information
 - d. A statement about increased breathing resistance
 - e. A statement that the inspired air may be hot
 - f. A statement that the RPED cannot be tested by the user
7. Storage practices
8. Instructions for donning and use
9. Information about periodic inspections, maintenance, and cleaning
10. Service life
11. Shelf life

With regard to the standard, ESHF staff believes that the labeling requirements do not account for the conditions in which the device will be used. The minimum text size of 2 mm is too small to be easily read in low-light conditions, as one may encounter in a fire. While this may be appropriate for some information, in an emergency situation, the most important information for using the RPED should be readily apparent and easily readable given the likely high stress level and low-light level that might be expected in a situation requiring the use of an RPED.

Of particular note is the requirement to state that the RPED is not to be used in an oxygen-deficient environment. This statement will be virtually useless to consumers who will have no way to determine the ambient oxygen level and likely will not fully comprehend the statement. It would be more appropriate to state that the RPED does not provide oxygen and should not be used if the consumer believes there to be a lack of oxygen, although even this statement would be difficult for many consumers to understand and apply appropriately. Additionally, it would be appropriate to state that the RPED should not be used to *enter* burning areas, but only to protect while exiting as quickly and directly as possible.

5.1.1 Model A

The size, shape, and storage method for model A facilitates mounting on a vertical surface. If properly installed in a logical and convenient location, such as by a bed at home or by the fire extinguisher in the office, the RPED would be readily available in an emergency situation. The red lid on the canister draws the user's attention to the part that must be removed.

The green RPED canister contained some use and safety information. Specifically, items 1, 2, 3, 4, 5, 6a-c, 7, 8, and 11 from the standard are addressed. Additionally, a user's manual, which addressed all of the items on the green canister and added 6d, 9, and 10, is attached to the wall holder. Three other languages (Spanish, French, and Portuguese) are provided in the user's manual. The directions on the package appeared sufficient for donning the device properly.

The usability of this device is reduced by the difficult-to-apply nose clip, the requirement to insert the mouthpiece and hold it between the teeth, and the need to self-tighten the neck seal. Some adults may have difficulty completing all of these steps properly, and it is unlikely children will be able to don the RPED without adult assistance.

5.1.2 Model B

The carrying case for model B provides a convenient place to store the RPED and both filter canisters together. The large size, however, may interfere with its transportability by preventing transport in a briefcase or suitcase, and the obvious markings may deter some from carrying the RPED in public areas.

ESHF staff had no difficulty opening the filter canister package marked for fire, but the markings on the filter packaging are not conducive for identification in low-light conditions. ESHF staff believes that there is a high likelihood of opening the wrong canister in emergency situations. The canister holder is designed to only accept the canister in the correct orientation, eliminating orientation errors. In addition, since there is only a small (relative to the size of the device) lens and an obvious mouth cup, the likelihood of donning the device incorrectly is low.

The cardboard box packaging for the RPED is printed with instructions for use and several important caution and warning statements; however, because the RPED is contained in a carrying case, it is likely that the device will not be stored or transported with this box. There is also paper product information inside the carrying case; however, ESHF staff does not believe that this meets the intent of the labeling standards since it can easily be separated from the device. The markings on the storage case only include standard items 1, 2, 3, 7, and 11. The packaging for the fire filter contains standard items 2, 3, 4, 6c, 7, and 11. The orange hood contained one label, which contained only Korean text. The instruction leaflet inside adds instructions for use (items 5 and 8) along with items 6a-c.

5.1.3 Model C

The size of the package for model C lends itself to ease of storage and transport. There is a large photo on the packaging of the RPED being worn in a fire situation, and a large amount of marketing information. When assessed by the standard requirements, the RPED label meets requirements 1, 2, 4, 6a, 6b, and 11. Other statements allude to issues mentioned in the standard but are not the direct statements required. The packaging contains four small photos of a child donning the RPED that could be considered symbolic supplements, but there are no written instructions. Donning the RPED, however, is intuitive and should require little instruction. There is only one opening in which to place the head; and the hood itself is clear, allowing clear line of sight no matter the RPED orientation.

The packaging is marked with “open here” and arrows pointing roughly toward a spot in the vacuum packaging that had been notched to facilitate opening. The plastic tore with little effort, and the RPED was easy to remove. This RPED is highly usable, since it is easy to open, intuitive to don, and virtually impossible to don incorrectly.

5.1.4 Model D

The size, shape, and carrying case for model D lend to ease of transport and storage; however, in an emergency, one would need to unzip the storage case, which could lead to a delay in donning. Additionally, ESHF staff found the vacuum packaging extremely difficult to tear open.

Limited information is provided on the foil packet; specifically, items 2, 3 (except manufacture date), 4, 6b-d, and 11 are provided. There are no donning instructions; however, when opened, the donning process should be fairly intuitive to adults. ESHF staff believes that most consumers will understand that the filter must be in front of the user's mouth. It is, however, possible to don this RPED backward. Children, in particular, may not intuitively know the correct orientation.

ESHF staff found that when worn, there are several usability issues with this RPED. First, the RPED tends to expand and contract as one inhales and exhales. This may be disconcerting to some, as they may not realize that some fresh air is coming through the filter. Additionally, the RPED tends to fog after only a few breaths, perhaps due to the recirculation of some portion of the breath. Finally, the large filter on the front of the RPED blocks some vision, particularly restricting vision below eye level despite the marketing claim to provide "360° visibility."

5.1.5 Model E

The box in which model E is packaged is small enough to store in a drawer or briefcase, but the vacuum-sealed package inside the box is more portable. The box, however, is sealed at one end; and the label on the box warns of one time use. It is foreseeable that some consumers may not break the seal on the box to find the smaller package inside. Additionally, the user's manual is stored inside the box, so some consumers may not have the opportunity to read it until they need to use the RPED. The label on the box gives the name of the manufacturer, one-time use warnings, manufacture date, shelf life, and a list of six items the RPED will protect against. When assessed by the standard requirements, the box label meets requirements 1, 3, 4, 6c, and 11. The vacuum-sealed package inside the box has only figures showing the donning process, a "tear open" label, and holographic label written in Russian; therefore, it meets none of the requirements of the standard. The user's manual brochure stored inside the box adds items 2, 5, 6a-c, 7, and 8.

Since there is only one opening in which to place the head and one mouthpiece, donning the RPED is reasonably intuitive and should require little instruction for the average adult. The nose clip, however, is taped to the side of the RPED opposite the filter and is likely to be overlooked in a panic situation. Additionally, it is possible that some consumers will not realize that they should grip the mouthpiece between their teeth. It appears that without the mouthpiece in use, the RPED will still filter air that is drawn through the filter, but it is not clear how much air turnover will occur in such a situation.

The packaging is marked "open here" with arrows pointing roughly toward a spot in the vacuum packaging that was notched to facilitate opening. The plastic tore with little effort, and the RPED was easy to remove. With the exception of the nose clip, this RPED is very usable, since it is easy to open and intuitive to don.

6 Donning Test

6.1 Materials and Method

Four of the five RPED samples (Models A, B, C, and E) were tested by CPSC staff* (4 males and 4 females) as specified in section 9.2 of the ANSI/ISEA standard:

9.2 Donning Testing

9.2.2 There shall be two test subjects who have not been trained in RPED use and who have not previously donned an RPED. The test subjects shall be one female and one male. Neither test subject shall have any obvious mental or physical disabilities that prevent donning of the RPED.

9.2.3 The test subject shall be given an RPED in the ready-to-use-configuration. The test subjects shall be given 30 seconds to view the donning instructions that are supplied by the manufacturer and printed on the RPED.

9.2.4 After the 30 seconds required in Section 9.2.3 has passed, the test subject shall be instructed to immediately don the RPED without any further instruction and the timer shall be started.

9.2.5 The donning time shall be measured and recorded.

The fifth RPED could not be tested due to an insufficient number of samples. A short survey was added after the test to obtain additional behavioral data.

Each session began by the investigator explaining what an air purifying respirator protective smoke escape device is, outlining the general test procedure, and then completing the informed consent process. Participants were screened for prior RPED use and claustrophobia. After each participant was deemed appropriate and informed consent obtained, the test was conducted as in sections 9.2.2 – 9.2.5 (shown above).** Donning time was recorded as the time between opening the package and when the participant indicated he or she believed the task was completed. At the conclusion of the testing, ESHF staff evaluated whether the subject had donned the mask properly, and the participant was asked to verbally respond to a series of questions.

6.2 Results

Only one participant successfully donned his RPED in under 30 seconds (29.9 seconds). The remaining seven participants had donning times between 41 and 117 seconds. Three of the eight participants indicated they had completed the donning task but had not donned the RPED exactly

* Approval from the CPSC Human Subjects Committee was obtained.

** Section 9.2.1 was not applicable to CPSC staff testing.

as directed. Full tabulation of the results is shown in Table 3. According to the qualifications set forth in the standard, none of the RPEDs met the criteria to pass the donning tests in section 7.2.1:

7.2 Donning

7.2.1 RPED shall be tested for donning ability as specified in Section 9.2, Donning Testing. The time needed to don the RPED shall not exceed 30 seconds.

Table 3. Results of Donning Test

Model	Gender	Age Group	Donning time (sec)	Successful	Notes
A	male	41-50	44	no	nose clip not used, neck not gathered
A	female	41-50	74	no	neck not gathered
B	male	51-60	63	yes	
B	female	21-30	67	yes	
C	male	51-60	30	yes	
C	female	31-40	80	yes	
E	male	41-50	118	yes	
E	female	21-30	56	no	did not place mouthpiece in mouth

In addition to the donning test, participants were interviewed about their experience using the RPED. Six of the eight participants reported they felt they could breathe easily, while one reported holding her breath and another commented that there was some breathing resistance. Three participants reported feeling reasonably comfortable wearing the RPED. Discomfort ranged from physical discomfort (such as eyeglasses making the RPED a little tight, “funky” smells, nose clips were uncomfortable, and mouthpieces were uncomfortable) to mental discomforts (such as the noise created by the polyamide film and general discomfort with the idea of “a bag over your head”).

Additional questions were asked about use and usability. Most reported the instructions were easy to follow, although both participants testing model C commented on the lack of written instructions and one participant commented that he never reads instructions beforehand. Three participants recalled seeing warnings, but only one could recall what the warning said (technically what he reported recalling was an instruction and not a warning). Two participants recalled an escape time (20 minutes), while the others guessed. Guesses ranged from “maybe a minute, tops” to 30 minutes. Some additional comments from participants are listed below:

“If I was panicked, I would not put this on my head. It’s a *bag*.”

“I wasn’t sure what to do with my glasses.”

“This would be really good for sanding and drywall dust.”

Both participants testing model E commented that they were afraid that removing the nose clip, which was taped to the RPED, would tear the RPED.

Conclusion

In general, the respiratory protective emergency escape devices (RPEDs) examined in this CPSC staff analysis followed several good human factors practices, such as considering a wide range of anthropometric dimensions and designing so that they are intuitive to don. For all five RPEDs evaluated, improvements in marking and labeling for ease of reading in emergency situations would be beneficial.

None of the RPEDs evaluated conformed to all aspects of the labeling requirements (section 5) of the voluntary standard, ANSI/ISEA 110, *Air-Purifying Respiratory Protective Smoke Escape Devices*, nor did any RPED pass the donning test in sections 7.2 and 9.2.

A summary table of the CPSC staff analysis of the five RPEDs is provided in Appendix A.

7 References

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8 Appendix A – Summary Table

	A	B	C	D	E
Anthropometric percentile fit	99th male & female	99th male & female	99th male & female	99th male & female	99th male & female
Mouth seal mechanism	Mouthpiece	Nose-mouth cup	none	none	Mouthpiece
Nose seal mechanism	Nose clip	Nose-mouth cup	none	none	Nose clip
Neck seal mechanism	Ribbon	Elasticized band	Flexible neck ring	Flexible neck ring	Flexible neck ring
Qualitative assessment of mouth seal quality	Appeared acceptable when mouthpiece is properly used	Appeared acceptable	n/a	n/a	Appeared acceptable when mouthpiece is properly used
Qualitative assessment of nose seal quality	Appeared acceptable when clip used	Appeared acceptable	n/a	n/a	Appeared acceptable when clip used
Qualitative assessment of neck seal quality	Material bunching and possible air gaps	No noticeable air gaps	No noticeable air gaps	No noticeable air gaps	Material did not completely rebound, leaving possible air gaps
NASD seal test results	n/a	Tight	n/a	Not tight	n/a
Possible seal compromising issues	Facial hair	Facial hair, facial movements	Facial hair	Facial hair	Facial hair
Other seal/breathing concerns	Bunching of material when using ribbon for neck seal leaving air gaps	n/a	n/a	Possible rebreathing of air	Poor rebound of material forming neck seal left air gaps
Filter type	External	External (replaceable)	In-hood	External	External
Filter selection process	n/a	May be difficult to read labels	n/a	n/a	n/a
Filter installation process	n/a	May delay user donning	n/a	n/a	n/a
Training/practice	Impossible	Possible, but not suggested by instructions	Impossible	Impossible	Impossible
Verbal communication	Impossible	May be compromised	Possible	Possible	Impossible
ANSI/ISEA instruction conformance	No	No	No	No	No

Qualitative vision observation	Very little obscuring of vision by filter	Field of vision may be limited by hood material	Very little obscuring of vision by filter	Some vision obscuring by large filter	Very little obscuring of vision by filter
General ease of use when donning	Moderate	Moderate (filter selection not included)	Good	Good	Moderate
ANSI/ISEA donning test conformance (under 30 seconds)	No	No	No (one under 30 second, one over 30 seconds)	n/a	No
ANSI/ISEA donning test - successful donning	No	Yes	Yes	n/a	Mixed
Subject comfort comments	Both subjects were uncomfortable, one with the nose clip and the mouthpiece, the other with the material	One subject had difficulty with hair in her eyes and perceived a "funny smell"	One subject expressed mental discomfort because "you aren't supposed to put a bag on your head"	n/a	One subject disliked nose clip
Subject perceptions of breathing resistance	One subject expressed breathing felt restricted	low	low	n/a	low
	A	B	C	D	E