

The Effect of Ambient Aerosol Concentration and Exercise on PortaCount[®] Quantitative Fit Factors

Ziqing Zhuang¹, Christopher C. Coffey², and Robert B. Lawrence²

¹ National Institute for Occupational Safety and Health, National Personal Protective Technology Laboratory, Technology Branch, Pittsburgh, PA 15236, USA
Email: zaz3@cdc.gov

² National Institute for Occupational Safety and Health, Division of Respiratory Disease Studies, Laboratory Research Branch, Morgantown, WV 26505, USA

ABSTRACT

The PortaCount[®] Plus Model 8020 is a quantitative fit test instrument that uses ambient aerosol to estimate respirator fit. Ambient aerosol concentration levels vary greatly among workplaces. The purpose of this study was to determine: (1) if PortaCount Plus fit factors are affected by ambient aerosol concentration; and (2) if any of the exercises are the most critical in determining the overall fit factor. Fit test data for 30 elastomeric and filtering-facepiece respirator models from a companion study were analyzed. Each respirator model was tested on a 25-subject panel using the PortaCount Plus and seven exercises. The analyses were conducted to determine: (1) if fit factor varies among five levels of ambient aerosol concentration; (2) the frequency of each exercise having the lowest within-fit-test fit factor among all exercises; and (3) the mean ratio of each exercise fit factor to the highest within-fit-test fit factor. Ambient aerosol concentration had no practical effect on fit factor. "Talking out loud," "bending," and "moving head up/down" exercises had the lowest fit factor in approximately 66% of the tests. They also had the lowest average within-fit-test ratios of exercise fit factor to the highest fit factor (0.56, 0.62, and 0.67, respectively). Fit factors for each exercise were found to be highly correlated with fit factors for each of the other six exercises. There was no significant fit-factor difference between the first and second normal breathing exercises. We conclude that the fit test pass/fail criterion need not be adjusted for ambient aerosol concentration level and that "talking out loud," "bending," and "moving head up/down" are the three most critical exercises in determining the overall fit factor. These three exercises could be considered for development of a multi-donning protocol using fewer and/or shorter exercises to keep the length of a fit test the same as the current fit test protocol.

Keywords: Quantitative Fit test, Fit Factor, Ambient Aerosol, PortaCount[®] Plus, Exercise

INTRODUCTION

The purpose of the movements (exercises) used in quantitative fit tests is to simulate the type of head and facial movements made during the course of normal respirator use in the workplace. Different sequences of exercises have been used by both researchers and regulatory agencies. The most common sequence of movements prior to the standardization of fit test exercises in 1998 by the Occupational Safety and Health Administration (OSHA) was: 1) normal breathing while the head remains motionless, 2) deep breathing while the head remains motionless, 3) moving the head side to side, 4) moving the head up and down, 5) talking out loud (e.g., reading a prepared passage or reciting the alphabet, etc.), and 6) a second normal breathing (Hyatt, 1976; Murata et al., 1979).

local city newspaper, word of mouth, and from participants in previous NIOSH fit testing studies. Panel members were selected to provide a variety of facial sizes without regard to any particular facial size distribution.

Respirators

The 30 models of NIOSH-certified N95 respirators used in this study are listed in Table I. The 15 filtering-facepiece respirators were selected at random from approximately 33 models which were commercially available at the beginning of the study and had not been tested in previous NIOSH studies (Coffey et al., 1999; Coffey et al., 2004). The 15 N95 elastomeric facepiece respirators were randomly chosen from approximately 40 models available at the time the study started in 2001.

TABLE I. List of Respirator Manufacturers and Models

Manufacturer	Model	Facepiece Size(s)	Facepiece Type
3M	8511	OSFA ¹	Filtering
3M	8515	OSFA	Filtering
3M	9210	OSFA	Filtering
3M	9211	OSFA	Filtering
3M	7000 with 7N11 filter	Small/Medium, Medium/Large	Elastomeric
AlphaProtech	695	OSFA	Filtering
AO Safety	5Star with 9500R filter	Small/Medium/Large	Elastomeric
Aswan	M-12	OSFA	Filtering
Draeger	Piccola	OSFA	Filtering
Gerson	1730	OSFA	Filtering
Gerson	2747	OSFA	Filtering
Gerson	3945	OSFA	Filtering
Lab Safety	11291 with 30638 filter	Small/Medium/Large	Elastomeric
Makrite	910-N95	OSFA	Filtering
Moldex-Metrics	2600	Small, Medium/Large	Filtering
Moldex-Metrics	8000 with 8910 filter	Small/Medium/Large	Elastomeric
MSA	AffinityFR200	OSFA	Elastomeric
MSA	Comfo Elite	Small/Medium/Large	Elastomeric
MSA	COMFO with 816291 filter	Small/Medium/Large	Elastomeric
North	7700-30 with 7506N95 filter	Small/Medium/Large	Elastomeric
Pro-Tech	1590 with F200 filter	Small/Medium/Large	Elastomeric
San-M	TN01	Small, Medium/Large	Filtering
Scott	66	Small/Medium/Large	Elastomeric
Sellstrom	Econ-Air	Small/Medium/Large	Elastomeric
Survivair	1913	Small/Medium/Large	Filtering
Survivair	2000 with 1060 filter	Small/Medium/Large	Elastomeric
Survivair	7000 with 7860 filter	Small/Medium/Large	Elastomeric
Willson	1200with GN95	Small/Medium/Large	Elastomeric
Willson	6100	Small/Medium/Large	Elastomeric
Willson	6800	Small/Medium, Medium/Large	Elastomeric

¹OSFA – One Size Fits All

among different ambient aerosol concentration levels and between the two different respirator types. The geometric mean (GM) overall fit factor (35.0) for elastomeric respirators was significantly higher than the GM overall fit factor (20.2) for filtering facepiece respirators. The interaction between ambient aerosol concentration and respirator type was not significant (p -value > 0.05). The geometric mean (GM) fit factors are summarized by ambient level and respirator type in Table III. With the exception of one ambient aerosol concentration level (i.e., >12000 particles/cm³), the GM fit factor was not significantly different among ambient aerosol concentration levels. No trends such as the GM fit factor increasing with ambient aerosol concentration were observed in the data.

TABLE II. Analysis of Variance Table for Log-Transformed Overall Simulated Workplace Protection Factors Using a Two-Factor Statistical Model

Source of Variation	Degrees of Freedom	Mean Square	F-ratio	p-value
Ambient Aerosol Concentration Level (ACL)	4	0.697	3.51	0.0072
Respirator Type (RT)	1	61.8	311.56	< 0.0001
ACL x RT	4	0.317	1.60	0.1718
Errors	4324	0.198		
Total	4333			

TABLE III. Summary of Geometric Mean FFs by Ambient Aerosol Concentration Level and Respirator Type

Respirator Type		Ambient Aerosol Concentration Level (particles/cm ³)				
		< 5000	5000 - 6500	6500 - 8500	8500 - 12000	> 12000
Elastomeric	N	503	408	451	356	466
	GM	31.1 ^B	35.3 ^B	35.1 ^B	33.8 ^B	40.3 ^A
	GSD	2.4	2.6	2.4	2.7	2.9
Filtering Facepiece	N	377	411	446	460	456
	GM	20.8 ^A	19.5 ^A	19.7 ^A	19.5 ^A	21.5 ^A
	GSD	2.8	3.2	3.1	3.0	2.8
Both	N	880	819	897	816	922
	GM	26.2 ^B	26.2 ^B	26.4 ^B	24.8 ^B	29.6 ^A
	GSD	2.6	3.0	2.9	3.0	3.0

Note: Statistical comparisons were made for each respirator type and both respirator types combined, and means with the same superscript letter (A or B) are not significantly different among different ambient aerosol concentration levels (p -value > 0.05).

Thus, it can be concluded that fit factors around the pass/fail criterion of 100 for half-facepiece respirators are not affected by ambient aerosol concentration.

TABLE V. Summary of Mean Ratio of Exercise Fit Factor to the Highest Fit Factor by Exercise Regime and Individual Exercise

Exercise	Mean Ratio	Standard Deviation	Standard Error
All Respirators (n=4334)			
Normal Breathing	0.715	0.235	0.0036
Deep Breathing	0.701	0.236	0.0036
Turning Head Side to Side	0.716	0.249	0.0038
Moving Head up and down	0.666	0.251	0.0038
Talking out loud	0.556	0.275	0.0042
Bending	0.622	0.230	0.0035
Normal Breathing	0.706	0.238	0.0036
Elastomeric (n=2184)			
Normal Breathing	0.723	0.232	0.0050
Deep Breathing	0.699	0.236	0.0050
Turning Head Side to Side	0.777	0.235	0.0050
Moving Head up and down	0.735	0.231	0.0049
Talking out loud	0.486	0.259	0.0055
Bending	0.662	0.225	0.0048
Normal Breathing	0.711	0.238	0.0051
Filtering Facepiece (n=2150)			
Normal Breathing	0.706	0.238	0.0051
Deep Breathing	0.703	0.237	0.0051
Turning Head Side to Side	0.654	0.246	0.0053
Moving Head up and down	0.596	0.252	0.0054
Talking out loud	0.627	0.272	0.0059
Bending	0.582	0.228	0.0049
Normal Breathing	0.701	0.238	0.0051

that talking was the most critical exercise even for air-fed helmets and powered air-purifying respirators. These results are consistent with those from the current study.

Crutchfield and Van Ert (1993) stated that the fundamental or basic fit of a respirator is best described by the normal breathing fit factor. The purpose of the other exercises is to measure the change in fit due to facial or head movements. To prove this, they looked at eleven studies which reported complete fit test data sets: four using the generated aerosol method; four using the ambient aerosol method; and three using the controlled negative pressure (CNP) method.

It should be noted that the exercises are conducted differently for the CNP test since the test subject has to hold his breath and remain motionless while the measurement is being taken. During the CNP test, the subject performs the exercise for one minute, takes a deep breath, and holds the head still in the appropriate position. For example, if the exercise was turning the head side to side, the subject would do this for one minute and then hold his head still while looking left. A measurement would be taken at this time. Then, the subject would look to the right and another measurement would be taken. In the CNP studies, the talking out loud and deep breathing exercises were not done.

Their analysis of the data found 80 to 96% of the total test variation was due to the first normal breathing alone in the generated aerosol tests, 70 to 89% for the ambient aerosol tests, and 65 to 93% for the CNP tests (Crutchfield and Van Ert, 1993). In general for all three methods, there was either no significant difference between the first normal breathing and the rest of the exercise fit factors or the first normal breathing was significantly lower than the rest of the exercises. For the ambient aerosol method, the talking exercise was the exception. In the three studies in which talking exercise was performed, it was found to be significantly lower than the first normal breathing. This is consistent with the findings of this current study. The only exception for the CNP method was found in one study that used induced leakages on a half-facepiece. In this study, the fit factor measured with the head in the down position was lower than the first normal breathing. A 0.05 level of significance was used for all comparisons. The results of the current study generally agree with those from previous studies.

CONCLUSIONS

Fit factor was found to be independent of ambient aerosol concentration. "Talking out loud," "bending," and "moving head up/down" exercises had the lowest fit factor in about 66% of the tests. They also had the lowest average within-fit-test ratios of exercise fit factor to the highest fit factor (0.56, 0.62, and 0.67, respectively). Fit factors for each exercise were found to be highly correlated with fit factors for each of the other six exercises. There was no significant fit-factor difference between the first and second normal breathing exercises. We conclude that the fit test pass/fail criterion need not be adjusted for ambient aerosol concentration level and that "talking out loud," "bending," and "moving head up/down" are the three most critical exercises in determining the overall fit factor. These three exercises could be considered for development of a multi-donning protocol using fewer and/or shorter exercises to keep the length of a fit test the same as the current fit test protocol.

REFERENCES

- Bentley RA, Bostock GJ, Longson DJ and Roff MW. (1983) Determination of the effective protection factor of various types of respiratory protective equipment. IRL/RA/83/21.
- Bentley RA, Bostock, GJ, Longson DJ and Roff MW (1984) Determination of quantitative fit factors of various types of respiratory protective equipment. *J. Int. Soc. Resp. Prot.* 2:313-337.
- Brown RC (1992) Review: protection factors of respirators with special reference to dust respirators. *J. Int. Soc. Resp. Prot.* 10:5- 33.
- Code of Federal Regulations. (1996) *Lead*. U.S. Government Printing Office, Office of the Federal Register, Washington, DC. Title 29, CFR Part 1910.1025.