



# What PIAF do we need to assure **Positive Pressure** for **95% of the First Responders**

NIOSH Multifunction PAPR CBRN  
Standard meeting April 10 2003



# Introduction:

The results of this test emphasize that we at present do not test respiratory protective devices (RPD) adequacy to ensure that the user can use the RPD without undue physiological burden (breathing resistance), nor can we with confidence ascertain that the RPD will actually offer the protection the user expects or should be entitled to get from a product which is certified and/or deemed to comply with NIOSH, CE or Australia/NZ standards.



# The Study!

- This study was designed to simulate different work intensities which are common when workers are required to wear RPD when performing their assigned tasks. We decided to use an ergometer (test bicycle) to simulate the different workloads; most people would be comfortable riding a bicycle.

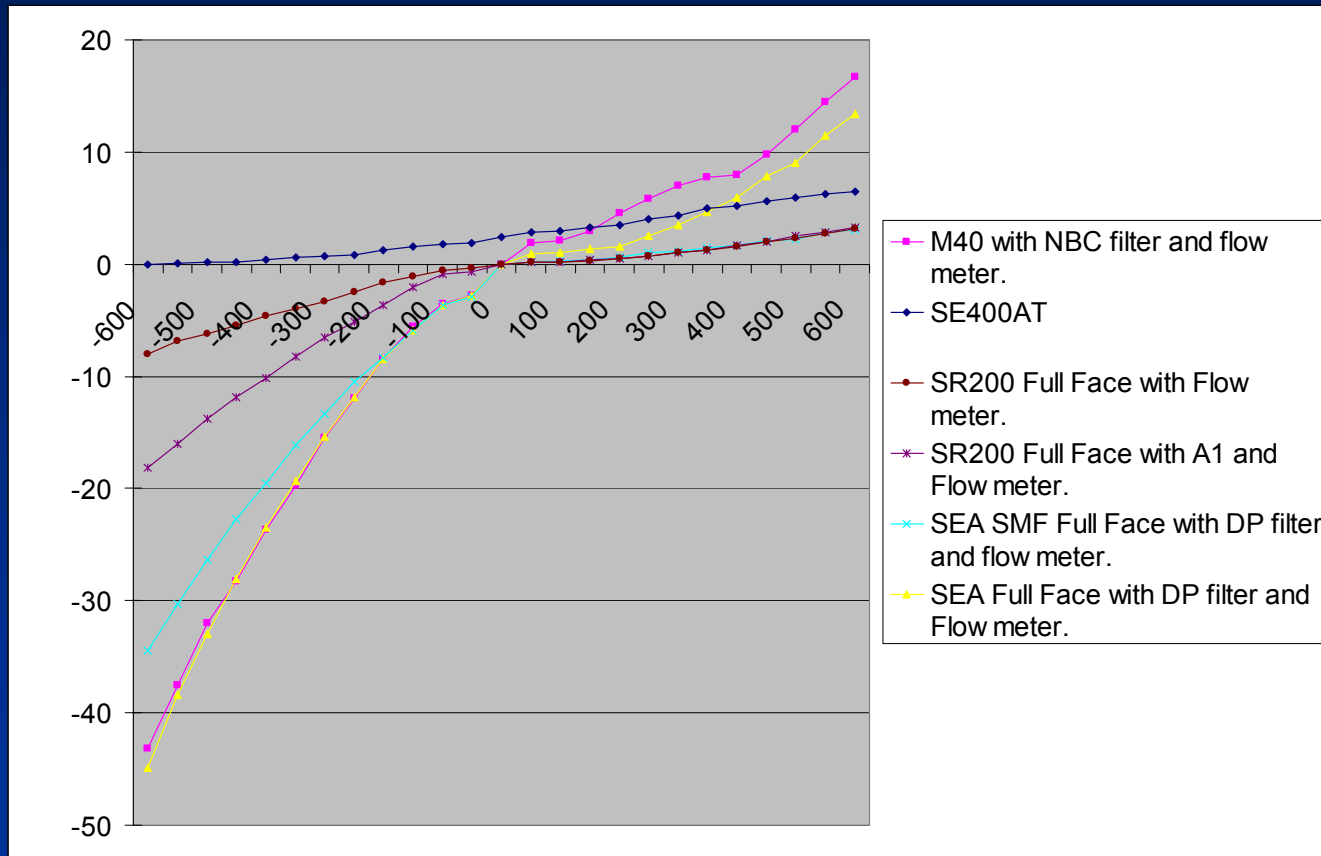


# Material and methods

- The equipment used comprised five negative pressure full face masks and a [PPD-]FPBR ([Positive Pressure Demand]-Fan-supplied Positive pressure Breath Responsive Respirator) model SE400AT



# Pressure Drop in millibar per liter/minute flow



# Subjects

» Ten test subjects (8 male and 2 female) participated in the study.

	<b>Average All Subjects</b>	<b>Standard deviation</b>	<b>Min</b>	<b>Max</b>
<b>Age</b>	<b>34</b>	<b>13.6</b>	<b>17</b>	<b>54</b>
<b>Weight kg</b>	<b>77</b>	<b>12.7</b>	<b>61</b>	<b>96</b>
<b>Height cm</b>	<b>179</b>	<b>7.7</b>	<b>169</b>	<b>193</b>



## **The protocol was as follows:**

- The test was divided in to eight five-minute sections, each with different external workload, starting at 50 Watts external workload, increasing by 25 Watts every 5 minutes. This resulted in the highest section being 225 Watts external workload.



- **Within each section, during the first three minutes, the test subject could pedal the bike with no interference. This allowed the subject's heart rate and breathing pattern to equalize.**
- **During the fourth minute, the test subject was required to read aloud as when talking normal. We used the text applied in testing RPEs, i.e. The Raindrop sentence; "*When the sunlight strikes raindrops in the air [...]*". This reading was repeated for one minute.**
- **During the fifth minute, the subject pedaled before the program automatically increased the resistance by 25 W.**
- **The sequence was then repeated, over and over again, until we reached either forty minutes or 85% of max heart rate.**





# Results

- The spreads of both volume and PIAF were large.
- The average minute volume was 22.20 minute liters (when talking in the first work section) — 61.57 minute liters, and the average PIAF was 99.49 lit/min to 268.02 lit/min (with maximum PIAF reaching 533.73 lit/min ).



# **The results for work level 1**

**( 50 Watt at the test bike) this is a conclusion of 63 test results**

- **Average minute volume at the third minute 26.39 minute liter with an average PIAF of 101.4 lit/min.**



# The results for work level 1

- The fourth minute including speech the volume dropped to 22.20 minute liters; this is a drop of 16% for the volume. The PIAF increased to an average of 177.86 lit/min, an increase of 75% over the PIAF before speech.

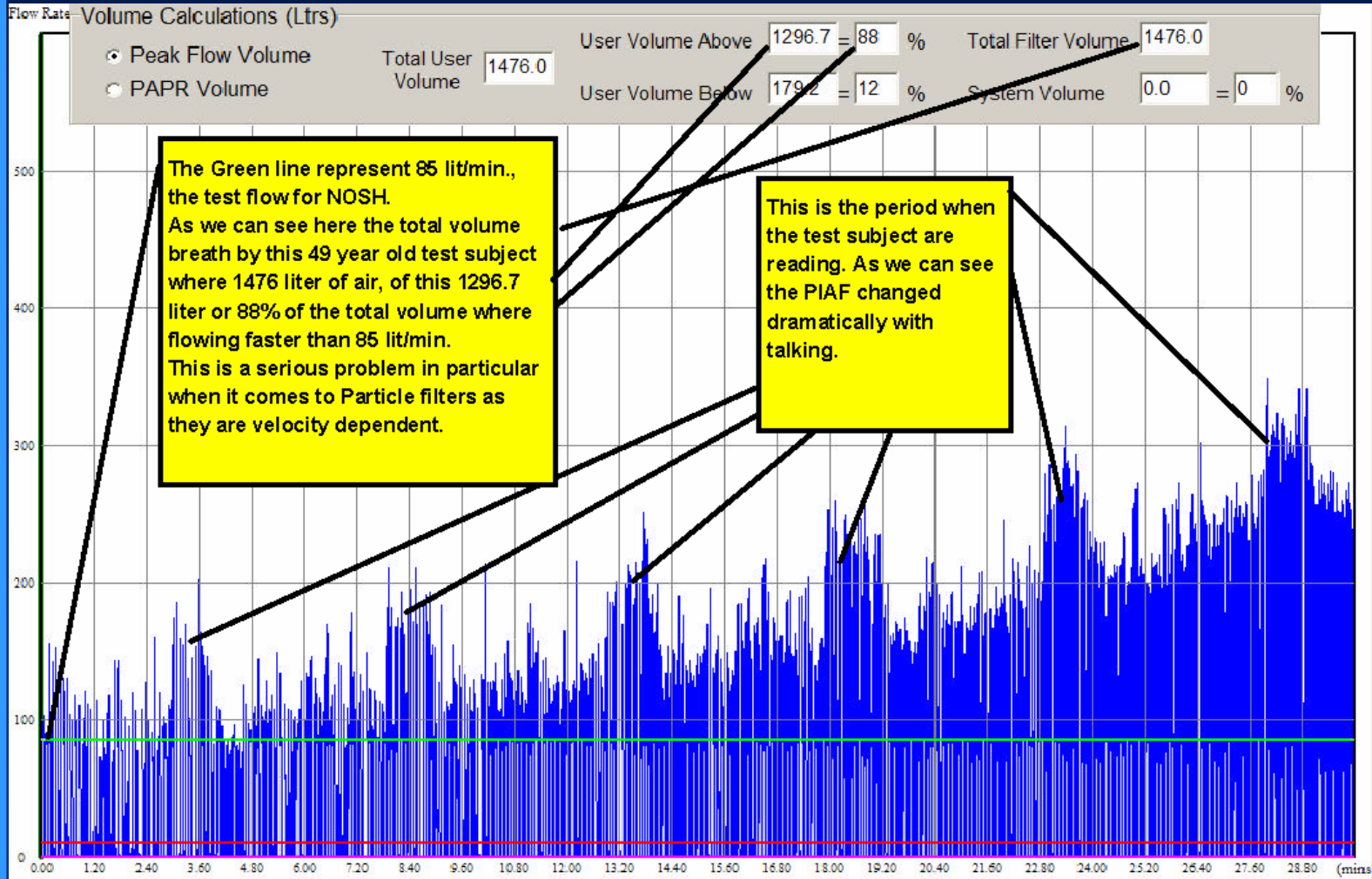


## **The results for work level 1**

- **In the fifth minute, the recovery minute before workload increased by 25 Watt, the volume rose to 30.10 minute liter — an increase of 14% compared with the minute just before speech.**



# typical graph of 30 minutes



# Low External Work Load 50 Watt

	Number of tests	Volume of air (minute liters)	Average PIAF	Max	Volume of air minute liter flowing faster than test speed 85 liter.
Minute before speech (50 Watt external work load)	63	26.39	99.49	252.68	11.79 liter (44.7%)
Speech	63	22.20	174.05	402.13	20.14 liter (90.7%)
Consolidated the minute before and speech.	63	24.295	131.25	402.13	



# What does 50 Watts of external work represent?

- **Sitting at ease; light manual work (writing, typing, drawing, sewing, book-keeping); hand and arm work (small bench tools, inspection, assembly or sorting of light material); arm and leg work (driving vehicle in normal conditions, operating foot switch or pedal).**
- **Standing: drill (small parts); milling machine (small parts); coil winding; small armature winding; machining with low power tools;**
- **Casual walking; (speed up to 3.5 km/h or 2.2 mph).**



# **Is this representative for a First Responder?**

- **This is not hard work and possibly not representative for the first responders, so lets have a look on work load more representative for this user group.**





## **Is this representative for a First Responder?**

- **A more appropriate work level would possibly be what we in the new ISO working group refer to as Very High Work Load (ISO 8996:1990 Annex A Very High Metabolic rate of 520Watt)**



# Very High Work Level 150 Watt External Work

- This translates to approximately 150 Watt external work. We can describe this as:
- Very intense activity at fast to maximum pace; working with an axe; **intense shovelling or digging; climbing stairs, ramp or ladder**; walking quickly with small steps, running, or walking at a speed greater than 7 km/h or 4.4 mph.



# **Very High Work Level 150 Watt External Work**

- This work is more applicable to a first responder, for instance, who needs a respirator for CBRN protection.



# PIAF for Very High External Work Load (150 Watt)

	Number Of tests	Volume of air minute liter	Average PIAF	MAX	Volume of air minute liter flowing faster than test speed 85 liter.
Minute before Speech 150Watt external work load	43	57.34	176.52	320.05	52.94 liter 92.33 %
Speech	43	49.58	268.02	533.73	48.02 liter 96.88 %
Consolidated the minute before and speech.	43	53.46	217.96	533.73	



- **What Percentile do we want?**



# Negative Pressure Full Face Mask 150 Watt work Load

	Lit/min peak flow
95 <sup>th</sup> Percentile	367
87 <sup>th</sup> Percentile	296
80 <sup>th</sup> Percentile	265
70 <sup>th</sup> Percentile	237
60 <sup>th</sup> Percentile	217
50 <sup>th</sup> Percentile	201
40 <sup>th</sup> Percentile	188
30 <sup>th</sup> Percentile	175
20 <sup>th</sup> Percentile	161
10 <sup>th</sup> Percentile	147



# Agility Test Performed by the US Marine Corps

	Lit/min peak flow
95 <sup>th</sup> Percentile	427
87 <sup>th</sup> Percentile	390
80 <sup>th</sup> Percentile	368
70 <sup>th</sup> Percentile	338
60 <sup>th</sup> Percentile	314
50 <sup>th</sup> Percentile	290
40 <sup>th</sup> Percentile	265
30 <sup>th</sup> Percentile	243
20 <sup>th</sup> Percentile	217
10 <sup>th</sup> Percentile	175



# Conclusions:

- **Inspiratory air flow rates are high for all exercises. This concurs with earlier findings by the author as well as by Dr. J. Kaufman, *Respiratory Airflow in Working Individuals Wearing Chemical Protection*, Mr. I. Holmér, *Respiratory flow patterns during physical work with respirators*, and Dr. P-O. Åstrand, *Textbook of Work Physiology*.**





# Conclusions:

- The work which best represent a first responder's typical work (150 Watt external work) generates high PIAF rates, all in excess of the typical test flows, raising the question, how well will the first responder be protected if we don't test at a typical flow rate for this type of work?



## Conclusions:

- **At 150 Watts external work, a full 90% of the inhalation sequence is made up of air that flows faster than 115 lit/min without speech. A whole 42% flows faster than 200 lit/min.**



# Conclusions:

- In order to maintain positive pressure for 95% of all first responders, an air flow of 427 lit/min is required.



# Recommendations

- Based on this data and data collected and presented by Dr. J. Kaufman, (*Respiratory Airflow in Working Individuals Wearing Chemical Protection*), and Professor I. Holmér, (*Respiratory flow patterns during physical work with respirators*) as well as what's published in all modern text books in Physiology in particular Sport Physiology.
- I propose the following recommendations for the New Standards for RPD for use by First Responders and other who need protection in CBRN situations.



# Recommendations

- To maintain the level of protection required when exposed to hazards typically classified as CBRN compound's, we need a performance level which will assure that a so called Positive Pressure respirator really maintain Positive Pressure. Based on the Data collected and presented recently (*“Peak Inhalation Air Flow during an Agility Test Performed by the US Marine Corps”*), and if we want to protect the 95% tale, then we need RPD's to maintain Positive Pressure at 427 lit/min.



# Recommendations

- The RPD shall have an alarm to warn the user when Positive Pressure can no longer be maintained during a substantial portion of the inhalation cycle (filter clogged, battery voltage low or work rate too high).



• **Questions?**



# Thank you for your attention.

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