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The Role of PIAF in The Testing of Air Purifying Respirators.

NIOSH Full Face CBRN Standard meeting October 2002

Introduction:

When writing standards for RPE (Respiratory Protective Equipment), it is most important to have the main objective clearly understood.

- That the equipment perform as expected.
- That the equipment are designed so it can be used 100% of the time it is needed to be used.

How do we get someone to wear a RPE 100% of the time?

- RPE must not cause any hindrance to the user in doing his or her task.
- This includes both physiological and psychological restrictions.
- It also includes the speech capability, it is of most importance to be able to communicate with others.

L. Silverman Fundamental Factors in the Design of Protective Respiratory Equipment. Inspiratory air flow measurements on human subjects with and without resistance

- I believe we have not followed his recommendations with regard to how to test RPEs.

First Responders and other personal attending to the 9/11 incident, there was a clear message saying:

- We can't wear those respirators *and* do what we have to do!

The Test Program

- Eight five minute sections.
- The tree first minutes pedaling no talk.
- The fourth minute reading *When the sunlight strikes raindrops etc.*
- The fifth minute pedaling.
- Starting with an external work load of 50 Watts.

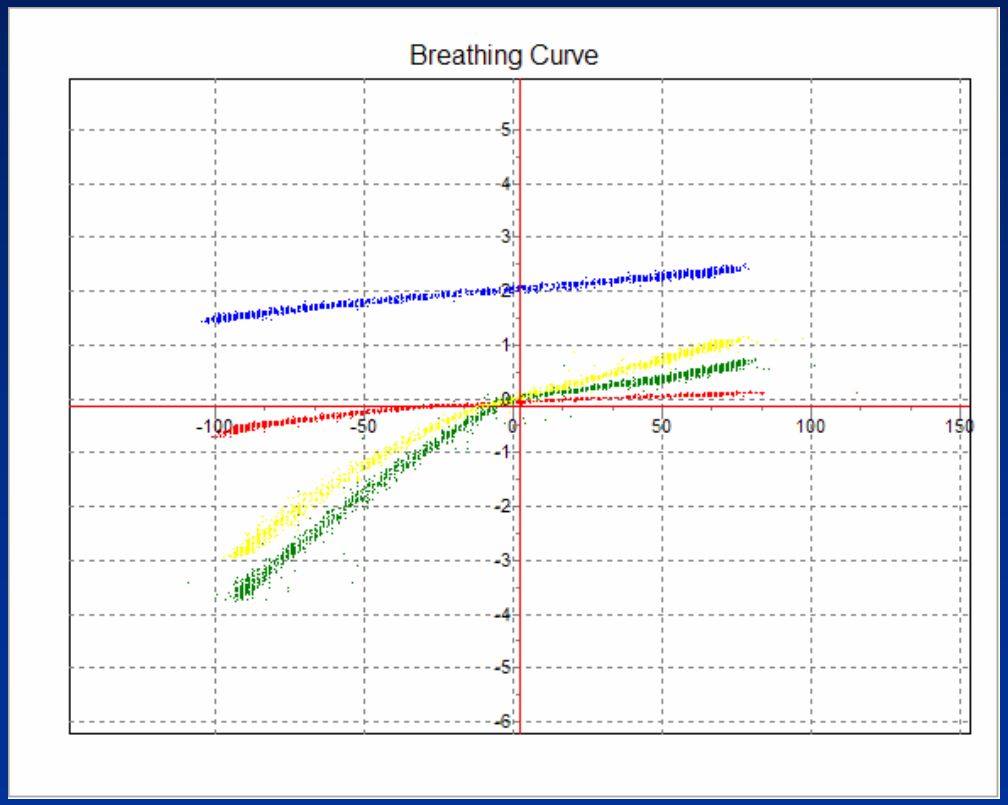
The Test Program

- Increased every five minutes with 25 Watts.
- Test finished when test subject reached 85% of Max heart rate or,
- Subject for whatever reason don't want to continue or,
- %SpO_2 (blood oxygen content) went below 92% or,
- After 40 minutes (225 W).

Equipment tested

- M40 US Military service mask with C2A1 NBC filter.
- Two commercial available Full Face mask's, one with multipurpose DP filter, and one with only the Flow meter. The last one have two exhalation valves.
- And a SE400AT Positive Pressure demand PAPR.

The pressure drop of those Mask's.



- M40 Yellow
- F/F Green
- F/F two ex-valve Red
- SE400AT Blue

Result

- It is absolutely clear that humans can breathe very high volumes of air with very high PIAF's.
- The spread of minute liters volume 16.9-132.2 minute liters.
- PIAF's 50-600 liter/minute.

Result

- This indicates that the capability of different people's breathing through an RPE is very different depending on physical size, fitness and willingness to withstand the added load and added discomfort causes by the resistance.

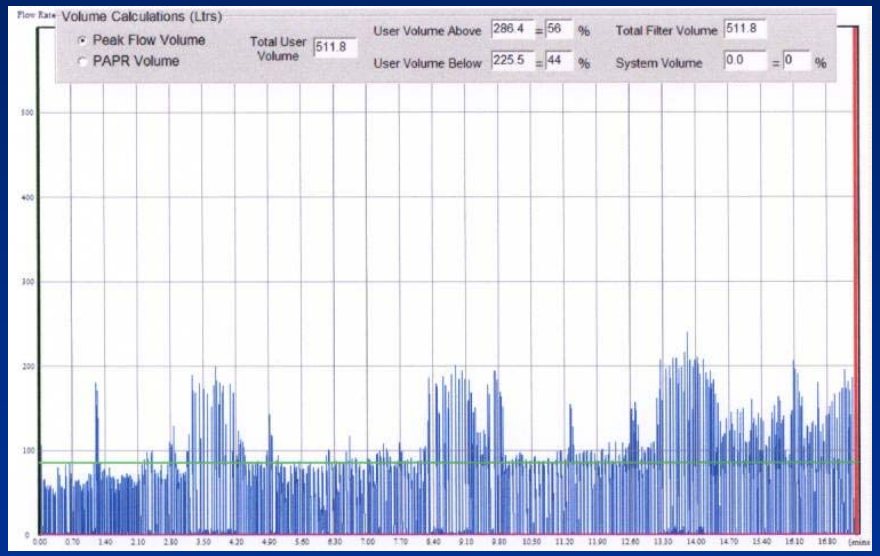
As Cotes said.

- *"A man who knows that he will not see his wife and family again unless he wears a respirator will tolerate much higher pressure drop than, say, a miner who is told that if he wears a dust mask on every shift for the next 10–20 years, his chances of developing pneumoconiosis will be reduced."*
- (modified quote from Cotes: *Physiological Aspects of Respirator Design*.)

Data from the test subjects.

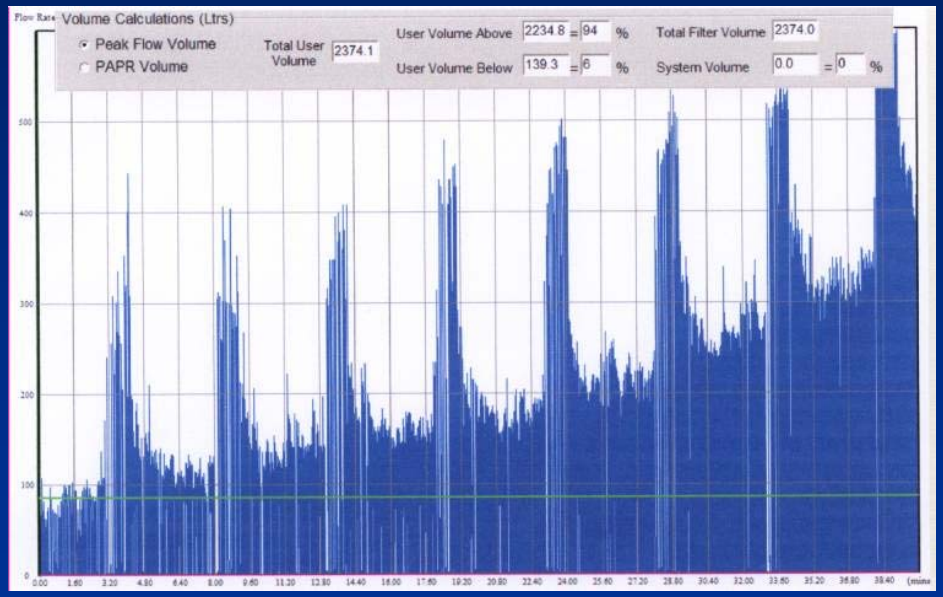
- 8 Subjects 17-55 years of age.
- No-one could continue to 225W and still remain below 85% of Max.
- However we allowed few to go beyond 85% as there fitness level where good.

Woman 38 years old.



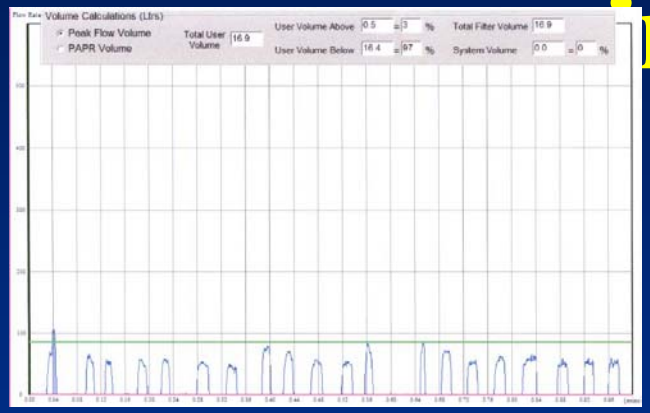
- With an full face mask with only the flow meter consisting of a P100 filter. We can clearly see the 4th minute when the reading occurs. The PIAF reached approximately 235 liters/minute.

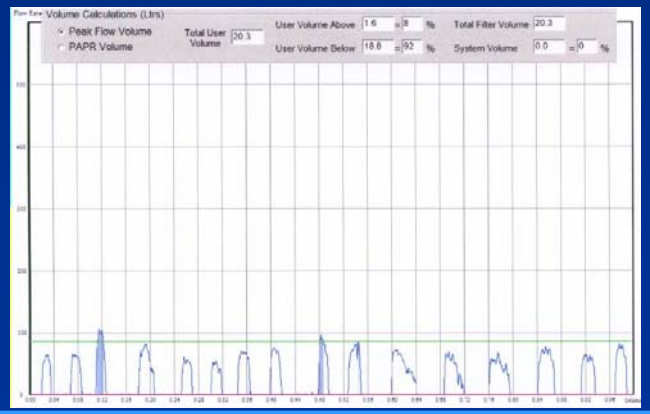
Man 50 years old.



- With the full face mask with only the flow meter. However this person managed to go to 225W and 40 min. At the end the heart rate was on the 92% of max level. The PIAF here reached approximately 600 liters/minutes.

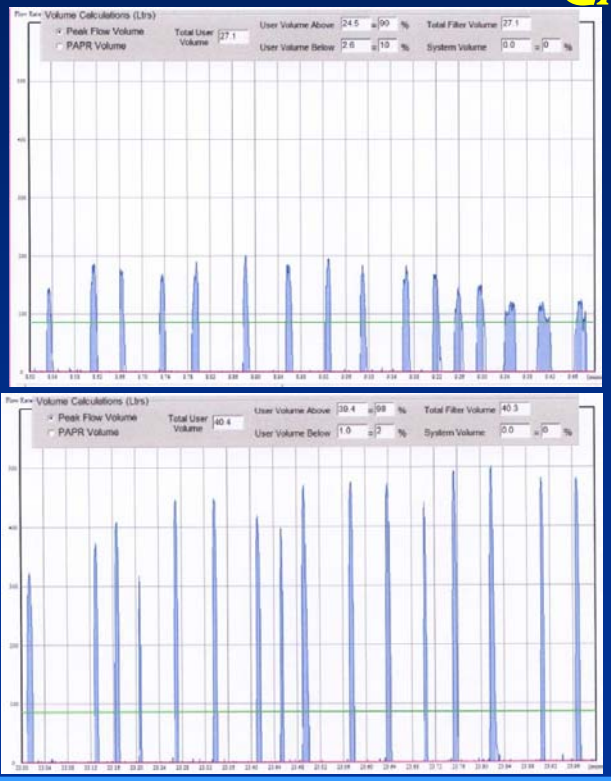
Those where the two extremes. Lets lock at the first minute.





- For the woman total volume being 16.9 minute liters over 20 breaths. Fairly light work as far as we are concerned.
- For the man the total volume 20.3 minute liters over 16 breaths.

The first graph shows the second reading minute, minute 8–9 in the exercise. The second graph shows the fifth reading minute for the man, minute 23–24 in the exercise.

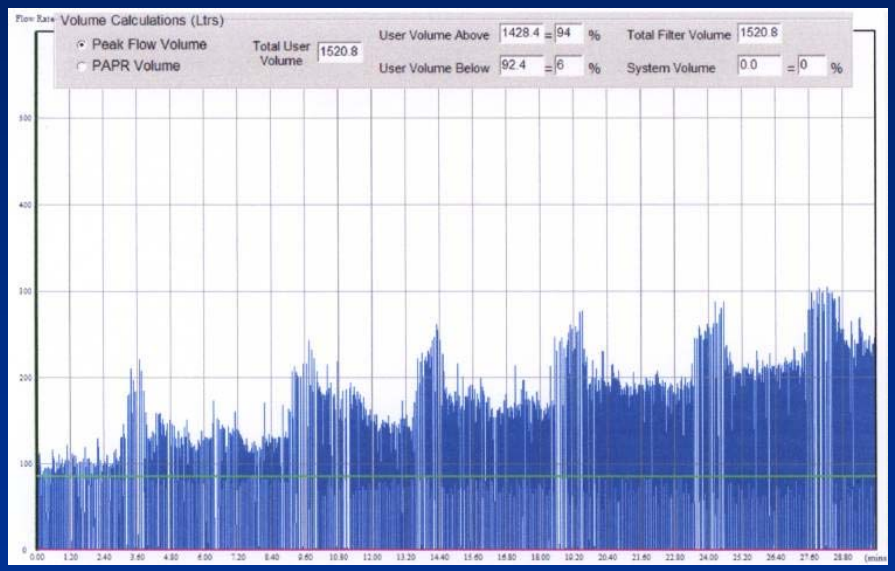


- Total volume of 27.1 minute liters with all breaths having a peak over 110 liters/minutes, the highest being 190 liters/minutes
- Total volume 40.3 minute liters with all breaths having a peak over 310 liters/minutes with the highest being 500 liters/minute

These two persons where the two extremes.

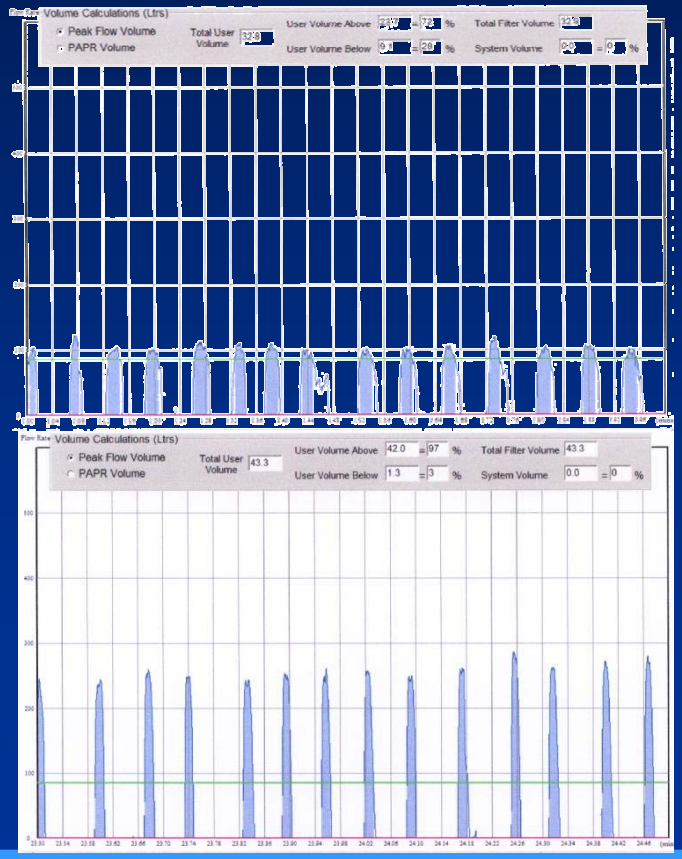
- One thing is very clear: the capability of the breathing has a wide span and can slow down to very low volumes of air in accordance to the task, and equally go very high if that is what the task requires.

The same man, wearing the M40 Full Face mask.



- Pressure drop are 3-5 times higher than the other mask/filter combination.
- Max PIAF 300 lit/min.

Let's have a look at the second minute and a minute in the middle



- The total volume here is 32.8 minute liter, the PIAF 100-120 liters/minute. This is a razia of 3.6 times the volume.
- The total volume in the second graph is 43.3 minute liter and the PIAF is between 250 and 285 liters/minute. 285 divided by 43.3 is 6.6 times the volume when talking.

What we have seen here is just a short description of tests we have dune to verify the data we at SEA have collected for a long time.

- I suppose the question is what is NIOSH going to do to accommodate this in to its test requirement?
- The sad part is that this is not news!

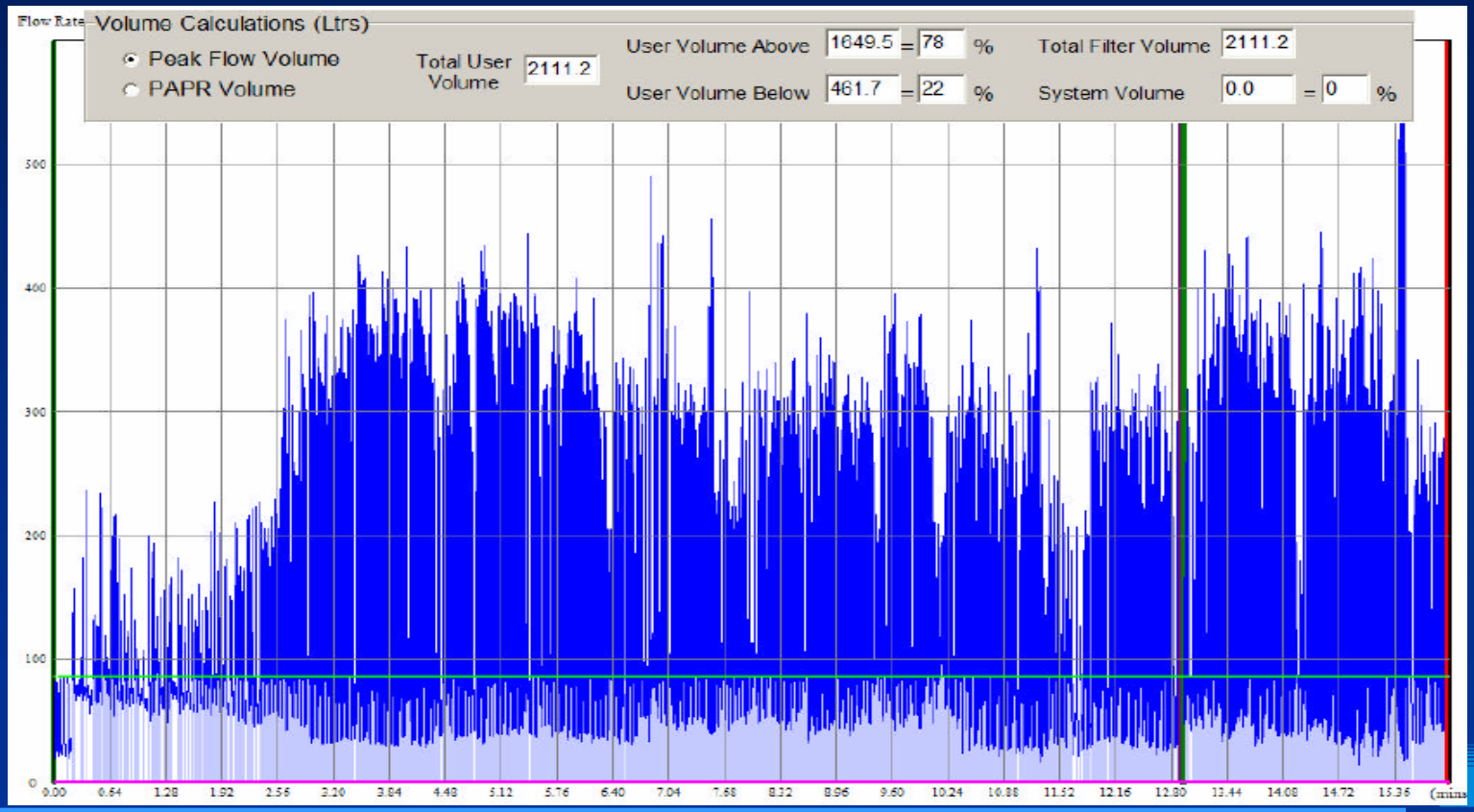
Already 1943 Leslie Silverman said in his paper.

- *Fundamental Factors in the Design of Protective Respiratory Equipment.*
- In his introduction, Silverman says: *"It is well known among Physiologists that during hard work or maximum exertion minute volume of 65 to 100 liters are not uncommon. If these minute volumes should be approached in the actual use of protective devices, the present standards would not provide a satisfactory basis on which to evaluate protection."*

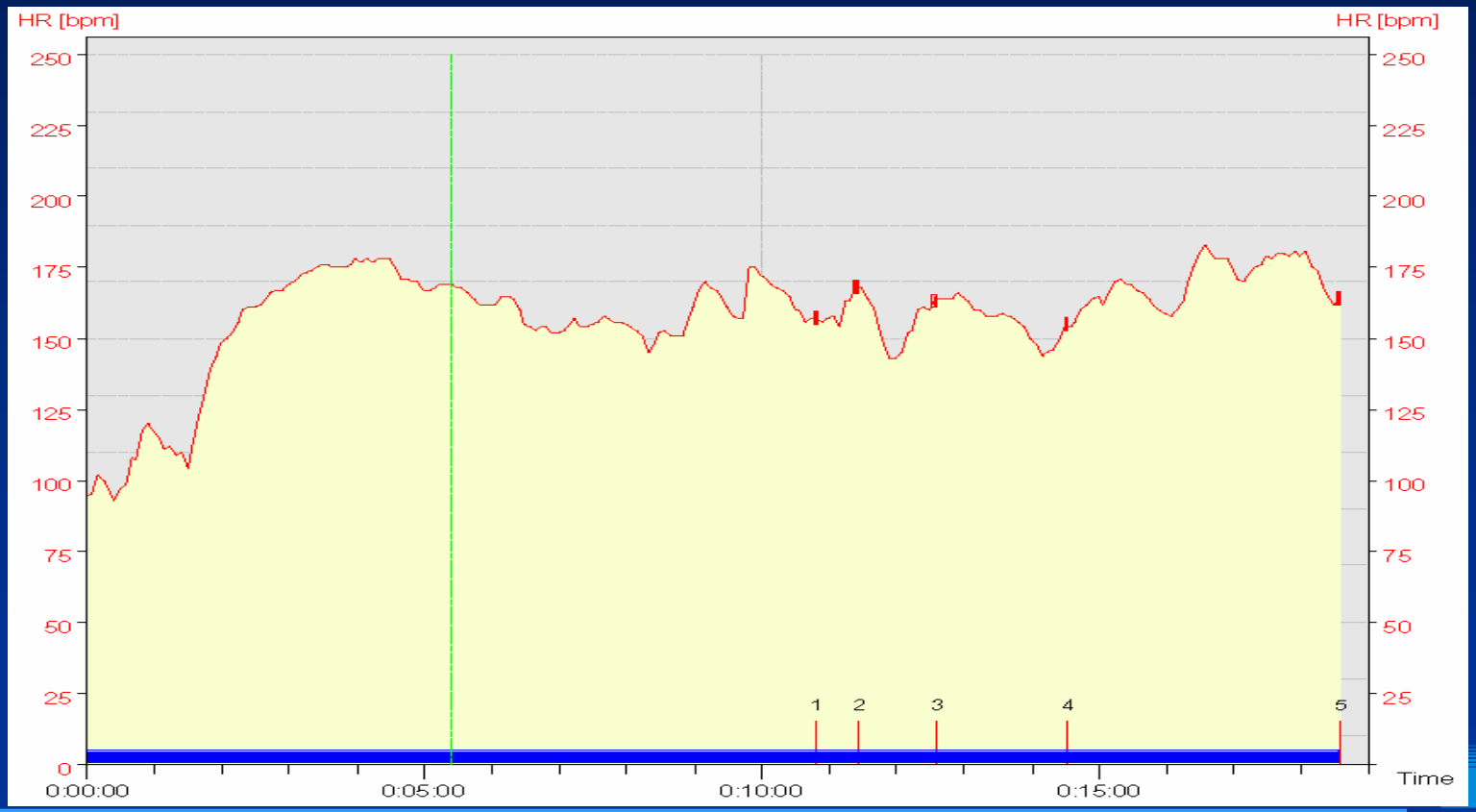
Last month a evaluation was performed using US Marines in various levels of protection, and that evaluation indicated respiratory levels as follows.

- 45 Marines exercised an Fire Fighter Agility Test.
- SE400AT with Data logger where used to collect volume and PIAF.

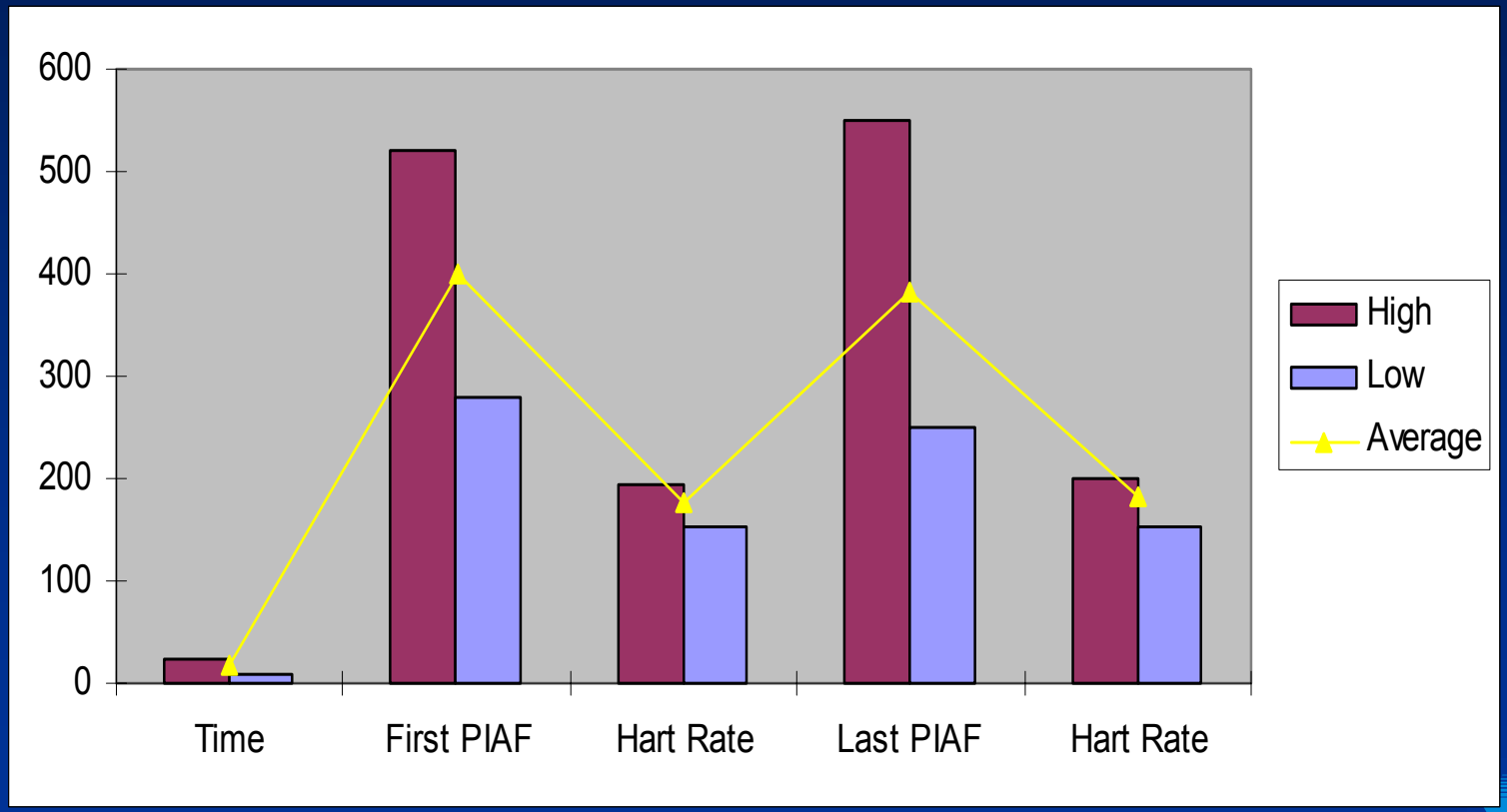
A typical PIAF graph for this test.



Typical hart rate for this test.



This is the data of the 45 Marines



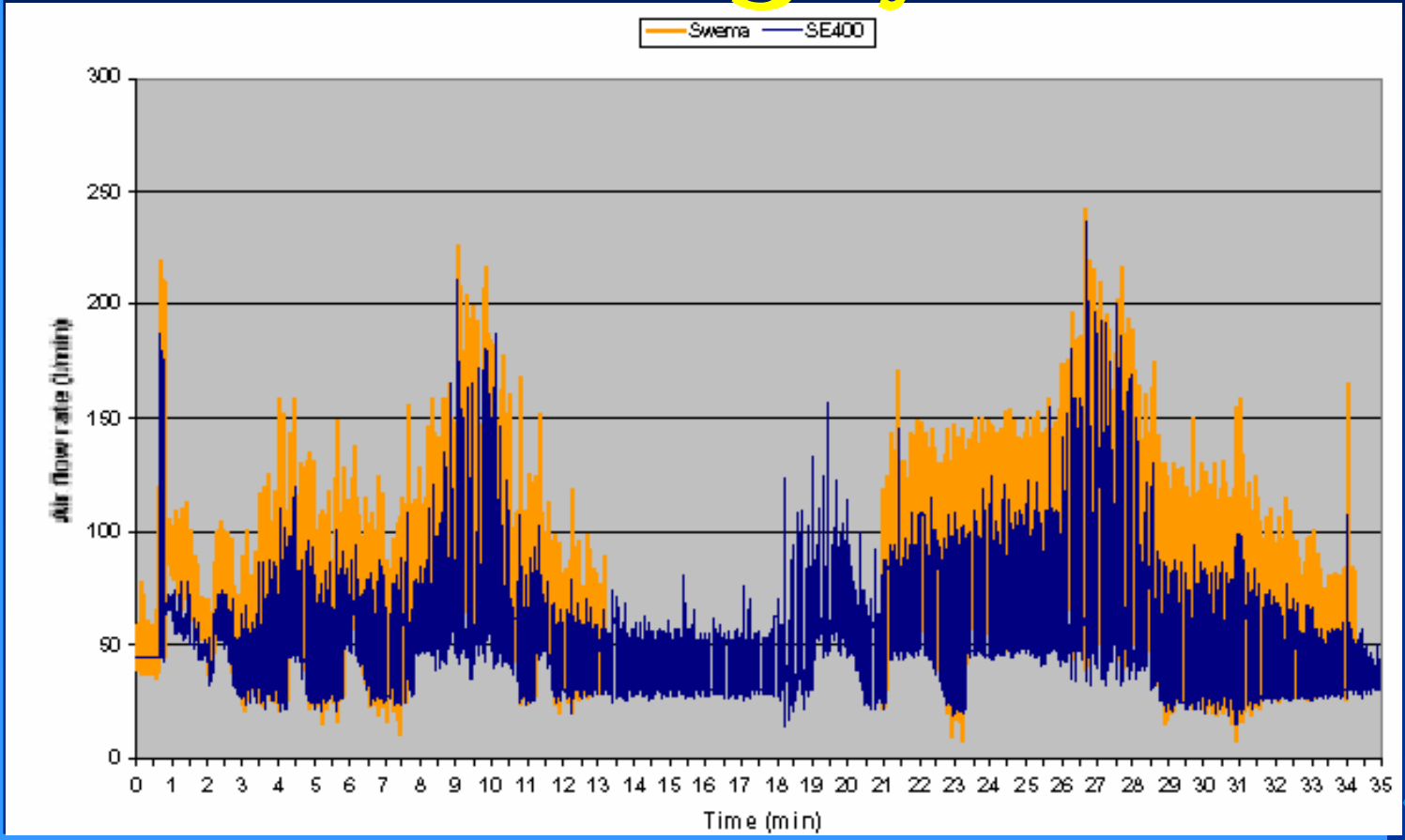
Earlier this year The Swedish National Work Environment Authority, contracted

- Kalev Kuklane and Ingvar Holm'er Department of Ergonomics National Institute for Working Life Solna Sweden.
- The task where to verify The SEA Group's data in regards to volume and flow.

Air flow module with sensor

House with fan, filters and built-in flow meter

Comparing the two flow measuring system.



Conclusions

1. Inspiratory air flow rates have been measured with an independent sensor in the tubing of a fan assisted positive pressure respirator.
2. Dynamics of the flow response pattern was very similar to the built-in sensor.
3. Values for the tube sensor were higher than the built-in sensor at low flow rates, but become close to each other at large flow rates (150-300 l/min).
4. High activity produces high inspiratory peak flow rates often in excess of 95 l/min.
5. Talking during the inspiration cycle increases flow rates by abut 50 % for the given activity level.
6. The fraction of the inhalation cycles that flow rate exceeds 95 l/min vary between almost none at very light work to 90-95 % during heavy work in combination with talking.
7. The protection offered by the respirator for this part of the inhalation cycle when flow rate exceeds 95 l/min has not been tested.
8. Performance of filters at least for this type of respirators should be tested at higher flow rates. A value of 200 l/min appears to be reasonable in order to accommodate the vast majority of flow rates that are expected to occur during use.

CEN Standard

- Ingvar Holm'er will present this on the next CEN meeting next week, the Swedish National Work Environment Authority, can not ignore this and will work hard to correct how we test RPE's in Europe.
- The Question is can NIOSH write a NEW Standard for First Responders and not correct the test flows?

Questions?
Thank you for your attention.

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