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Sent: Thursday, February 19, 2004 4:24 AM
To: NIOSH Docket Office
Cc: Leroy Garey; Robert Lingo
Subject: NIOSH DOCKET -010 Comments on the CBRN PAPR concept paper of Feb06,2004

Ref. NIOSH DOCKET -010

Dear MS. / Mr.
Please find in the attachment our comments on the CBRN PAPR concept paper of Feb06,2004. The comments refer to breathing performance requirements.
Best regards,
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CBRN PAPR

NIOSH Concept Paper of February 6th, 2004

Comments on Breathing Performance

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17 February 2004

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General

1. The new concept paper for CBRN PAPR defines two types of systems according to breathing rate, as presented in the following table:

System Type	Minute volume (lpm)	Frequency (min^{-1})	Tidal volume (lit)	Standard
Moderate Rate	40.000	24	1.667	42 CFR Part 84H
High Rate	103.000	30	3.433	NFPA 1981, 2000 edition, Table 8.1.4.10.7(a)

2. The Breathing Performance requirements given in the new concept paper are listed below:
   a. During operation of the breathing machine, described in the table above, the PAPR shall be mounted on a manikin head equipped to continuously monitor pressure in the breathing zone of the respirator.
   b. During operation the pressure shall be maintained in the range of 0 to 3.5" (88.9 mm) H2O.
   c. Duration of test – Specified operational battery life plus 20 minutes.
3. It should be emphasized that the requirement for high breathing rate is based on the requirements for Open- Circuit Self Contained Breathing Apparatus for Fire and Emergency Service.

Theoretical Background

4. The breathing machine generates a sine wave of airflow vs. time according to the following equation:

   Q = A* sin (2¶ft)

   Where:

   Q - the instantaneous airflow rate (lpm)
   A -the waveform amplitude = Peak Flow (lpm)
   f-frequency of respiration (min^{-1})
   t- time (min)

5. Integrating this equation over the time interval between t=0 and t=1/4f , i.e. half of the inspiration, (2¶ft from 0 to ¶/2) we will get:

   A = ¶ * Q

6. The meaning of the integration is that the peak airflow values at the required breathing rates are:
   a. Moderate rate – 125.7 lpm
   b. High rate – 323.6 lpm
   c. Any blower that is used as a part of a PAPR system should be able to deliver the relevant peak flow rate at a pressure drop equal or greater than zero.

Analysis of system parameters

7. Basic assumptions:

   a. A PAPR system uses 2 or 3 filters in parallel.
   b. Filter resistance is 50 mm H2O @ 85 lpm (NIOSH maximum in previous PAPR and APR requirements) and changes linearly with the air flow rate.
   c. The hose (air tube) has relatively low flow resistance.
   d. As a consequence the blower must deliver the peak flow @ at least the filters resistance.

8. Based on these assumptions the minimal pressure drop that should be delivered by the blower should be as follows:

Breathing Rate	No. of Filters	Airflow Rate across individual filter (lpm)	Pressure Drop across filters (mm H2O)
Medium	2	62.85	36.97
	3	41.90	24.65
High	3	107.87	63.45

9. The expected values of pressure drop delivered by common PAPR blowers at the relevant air flow rates , with fully charged battery pack are:
   a. 65 – 70 mm H2O at 125.7 lpm.
   b. Airflow rate of 323.6 is higher than the maximal airflow of common PAPR blower. Expected pressure drop is 0.

10. These data mean that blowers are capable to work at moderate rate with 2 or 3 filters. They cannot be used for high respiratory rate because negative hood pressure will occur.

11. One should remember that the high flow resistance of the filters at high respiratory rate dictates the use of much bigger blowers, i.e. increased dimension, higher voltage, higher required battery capacity, increased system weight etc.

12. With these extremely high flow rates one should also expect very high exhalation resistance due to the exhalation valve, etc.

13. It seems that no commercial PAPR system can meet these requirements, taken from NFPA standard for open circuit SCBA.

Experimental

14. A male subject with relatively large tidal volume was tested without and with PAPR system as described in the following paragraphs.

15. Breathing without a protective system:

    The subject was connected to a mass flow meter.

    The subject inspired extremely deeply and quickly.

    Inspiratory peak airflow rate was 250 lpm.

16. Donning a PAPR respirator:

The mass flow meter was connected to a PAPR blower and to a tight fitting hood system. The mass flow meter was inline.

The blower was connected to 3 C90 filters in parallel.

A differential manometer was introduced into the hood to measure the pressure difference between the hood and the ambient atmosphere.

In normal breathing the blower's air delivery was ca. 140 lpm and the overpressure in the tight fitting hood was 14 – 20 mm H2O.

During extremely deep and sharp inspiration the pressure peak inside the hood was negative and reached –60 mm H2O. Human subjects cannot hold this respiratory regime for extended periods of time.

Conclusion

17. Based on our theoretical calculations and laboratory measurements we think that adopting NFPA standard for SCBA's to the area of PAPR's is mistaken.

18. The respiratory regime, defined in the NFPA standard (Based on a breathing pump) is not applicable to human subjects. A human being does not have the ability to breathe with a combination of very high frequency (30-40 min^{-1}) and extreme tidal volumes of more than 3 liters for extended periods of time.

19. Based on the paragraphs above the NFP standard for SCBA's is completely irrelevant to the area of PAPR's.

20. A long term experience in research and development of personal respiratory protective systems shows the following facts:

    a. Mask/tight fitting hood systems - protection factors of at least 10,000 can be achieved at flow rates higher than 115 lpm.
    b. Open hood systems - same protection factors (>= 10,000) can be achieved at flow rates higher than 170 lpm.

21. These PF data apply for subjects, performing high physiological workloads. (PF tests under physiological load are performed as a part of the EN standards).

22. The requirement for an extreme peak flow, higher than 300 lpm, will lead to enlargement of filter dimensions (cross section and bed depth) in order to meet service life requirements. This, in turn, will increase filter's flow resistance and will lead to a further increase of blower size, weight and energy needs.

23. The consequences of these extremal requirements will be:

    a. Bigger blowers.
    b. Bigger energy packs.
    c. Heavy, bulky and more expensive PAPR's.

24. There is no real need for that since the application of the NFPA standard for SCBA's to PAPR's is wrong.