Workplace Breathing Rates: Defining Anticipated Values and Ranges

David Caretti

Research Physiologist

Edgewood Chemical Biological Center

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Background

- **Objectives**
  - Define ventilatory parameters based on real-world work rates
  - Examine both non-respirator and respirator conditions
  - Establish flow rates for assessing filter/respirator performance

- **Approach**
  - Literature review
  - Compile/analyze data from government/non-government sources
  - Human use testing (lab and/or worksite)

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Literature Review

- **Objectives**
  - Review concepts of respiration pertinent to respirator certification
  - Evaluate methods for quantifying ventilation
  - Define maximal ventilation rates
  - Address speech ventilation rates
  - Describe ventilation rates reported for occupational activities
  - Review the impacts of respirator wear on ventilation

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Literature Review

- **Summary Information**
  - 155 papers reviewed/cited
    - 9 with workplace or simulated workplace data
    - 7 with workplace data during respirator wear
  - Limited empirical data to meet objectives
  - Adopted approach for estimating minute volumes from energy expenditure literature
    - Relationship between ventilation and oxygen usage
    - 2 exponential functions utilized to derive a range of predicted volumes
    - Assumptions and limitations defined

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Literature Review

- **Summary Information (continued)**
  - Peak inspiratory flow literature
    - Determined prediction intervals for peak flows based on limited empirical data
    - Estimates of upper and lower boundaries for PIF for any given minute volume
    - Defined assumptions and limitations
  - Respirator wear and ventilation
    - Changes from non-masked conditions
    - Addressed for broad respirator categories
      - APR
      - Supplied air/PAPR
      - SCBA
  - Initial paper draft provided to NIOSH for review Mar 04

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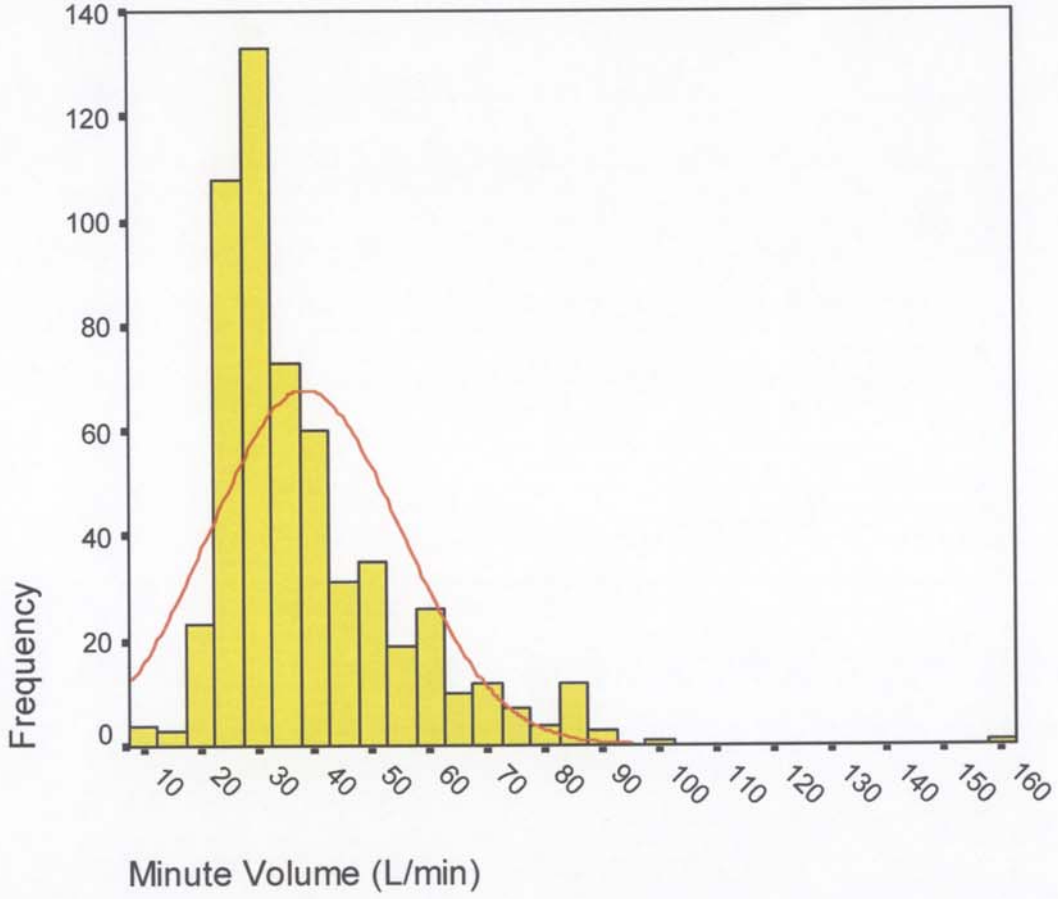
Literature Review: Results



Distribution of ventilation rates measured or estimated from occupational activity literature fitted with a normal distribution.

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Literature Review: Results

Occupational activities:

- **Minute volume distribution**
  - Mean = 38.5 ± 16.6 $L \cdot min^{-1}$ (n = 565)
  - Median = 33.6 $L \cdot min^{-1}$
  - 95th percentile = 73.3 $L \cdot min^{-1}$
  - Peak = 162 $L \cdot min^{-1}$

- **Peak flow ranges based on minute volumes**
  - Mean V_E : 72 to 183 $L \cdot min^{-1}$
  - 95th percentile V_E : 182 to 295 $L \cdot min^{-1}$
  - Peak V_E : Estimation not valid for V_E over ~120 $L \cdot min^{-1}$

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Literature Review: Results

Human performance literature:

- **Maximal V_E**
  - Males (20-29 yr) = 114 ± 23 $L \cdot min^{-1}$
  - Females (20-29 yr) = 87 ± 17 $L \cdot min^{-1}$
  - Extremes of 180 to 200 $L \cdot min^{-1}$

- **Peak flow rates**
  - Maximum exercise values as high as ~ 300 $L \cdot min^{-1}$
  - Peak in-house value ~ 485 $L \cdot min^{-1}$ during hard work
  - Speech values not substantially different

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Conclusions

- **Occupational V_E rarely approach V_E max values**
  - 73 $L \cdot min^{-1}$ sufficiently represents the upper limit of minute volumes anticipated in the workplace
  - 114 $L \cdot min^{-1}$ reasonable estimate for V_E max
- **Peak inspiratory flows**
  - High end predictions based on V_E correspond with literature
  - Suggest upper limit of 430 $L \cdot min^{-1}$ based on V_E max of 114 ± 23 $L \cdot min^{-1}$
- **Higher V_E and peak flows will occur!**
  - Literature suggests such instances are not the norm

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Conclusions

- **Respirator wear**
  - Minute volumes and peak flows generally lower during intense work for APR and SCBA
  - SAR/PAPR impact ventilation to a lesser degree

- **Implications toward respirator standards**
  - Better representation of occupational ventilation rates:
    - Adopt values based on 95th percentile V_E (73 L·min^{-1})
  - Greater range of human ventilation:
    - Adopt values based on V_E max of 114 L·min^{-1}
  - Other factors involved:
    - Cyclic flows vs. constant flows?
    - Contaminant exposure levels?

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Data Compilation

- **Objectives**
  - Obtained raw ventilation data from recent respirator studies
  - Validate/update current knowledge on ventilation during respirator wear
  - Identify data gaps for further research

- **Status**
  - Data obtained from 3 sources; anticipate input from 1 additional investigator
  - Database variables defined; database partially populated
  - Currently reviewing new dataset
  - Analysis of data will be initiated once database is complete

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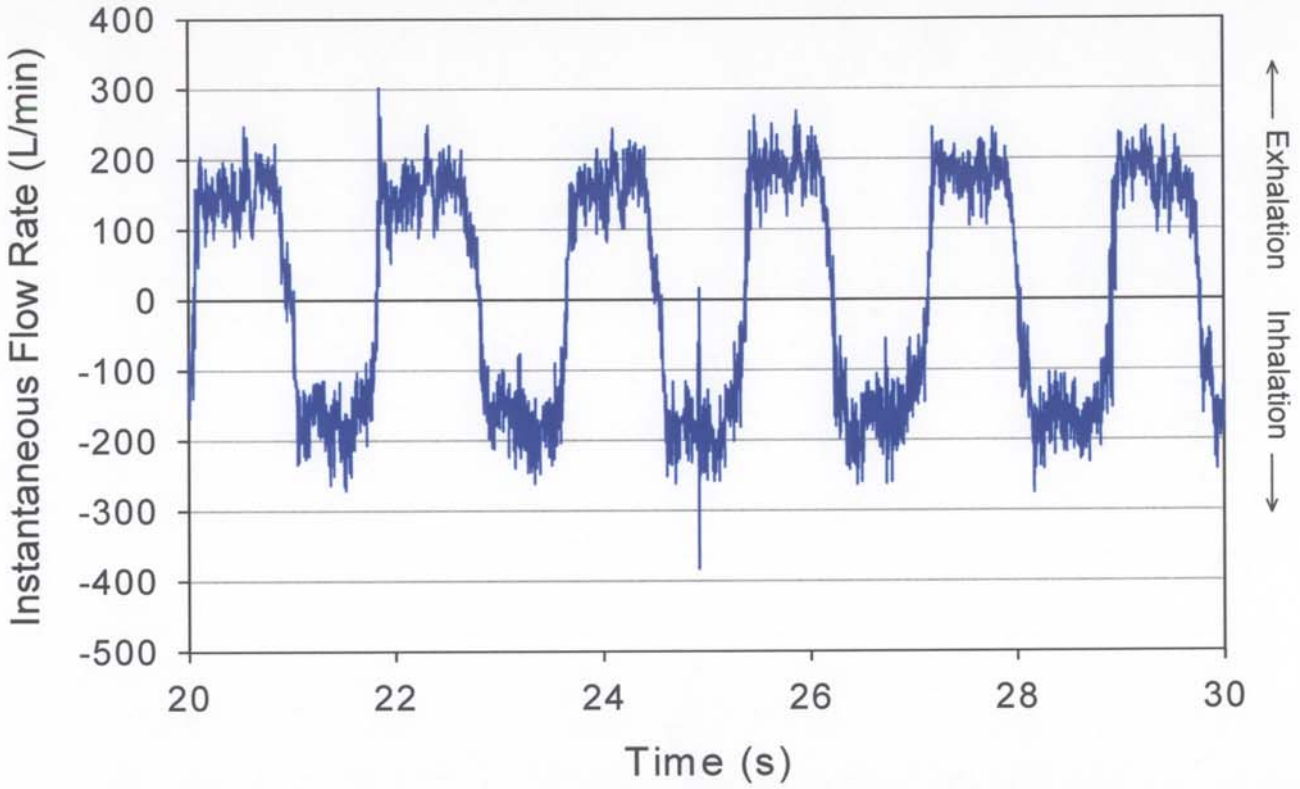
Data Compilation: Sample



TI	TE	f	VT	VI	VT/TI	TI/TTOT	PIFR	PEFR	PIFR/VE	PEFR/VE
(s)	(s)	(1/min)	(L)	(L/min)	(L/s)		(L/min)	(L/min)		
0.94	0.82	34.01	2.16	73.52	2.30	0.53	271.49	302.67	3.69	4.12
1.00	0.84	32.72	2.35	76.94	2.36	0.54	262.26	243.96	3.41	3.17
0.89	0.82	34.93	2.16	75.45	2.42	0.52	383.51	268.75	5.08	3.56
0.86	0.92	33.79	2.42	81.92	2.82	0.48	263.58	245.27	3.22	2.99
0.89	0.89	33.57	2.43	81.58	2.72	0.50	275.44	245.27	3.38	3.01

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Respirator Wear Testing

- **Recommendations based on:**
  - Literature review
    - Investigate the relationship between ventilation and oxygen usage on a population of respirator users
    - Measure workplace ventilation rates during respirator wear
  - Compiled data
    - To be determined

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Project Milestones

- **Completed**
  - Literature review report — Mar 04
  - Provided flow rates for NIOSH sponsored high flow filter testing — Mar 04
- **In progress**
  - Publish literature review report — May 04
  - Complete compiled data analysis — Jun 04
  - Provide final flow rate recommendations — Aug 04

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