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)
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
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
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
Distribution of ventilation rates measured or estimated from occupational activity literature fitted with a normal distribution.
Literature Review: Results

Occupational activities:

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

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

Human performance literature:

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

- **Peak flow rates**
  - Maximum exercise values as high as ~ 300 L·min$^{-1}$
  - Peak in-house value ~ 485 L·min$^{-1}$ during hard work
  - Speech values not substantially different
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
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 95\textsuperscript{th} percentile $V_E$ (73 L·min\textsuperscript{-1})

  - Greater range of human ventilation:
    • Adopt values based on $V_E$ max of 114 L·min\textsuperscript{-1}

  - Other factors involved:
    • Cyclic flows vs. constant flows?
    • Contaminant exposure levels?
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
Data Compilation: Sample

![Graph showing instantaneous flow rate over time]

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<th>f (1/min)</th>
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<th>VI (L/min)</th>
<th>VT/TI</th>
<th>TI/TTOT</th>
<th>PIFR (L/min)</th>
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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
Project Milestones

- Completed
  - Literature review report
  - Provided flow rates for NIOSH sponsored
  - High flow filter testing

- In progress
  - Publish literature review report
  - Complete compiled data analysis
  - Provide final flow rate recommendations