Literature Review of Workplace Breathing Rates & Filter Efficiency Testing under Moderate to High Flow Rates

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Workplace Breathing Rates

- **Objectives**
  - Quantify ventilatory parameters based on workplace activities
  - Review literature and analyze compiled data to quantify impacts of respirators on ventilation

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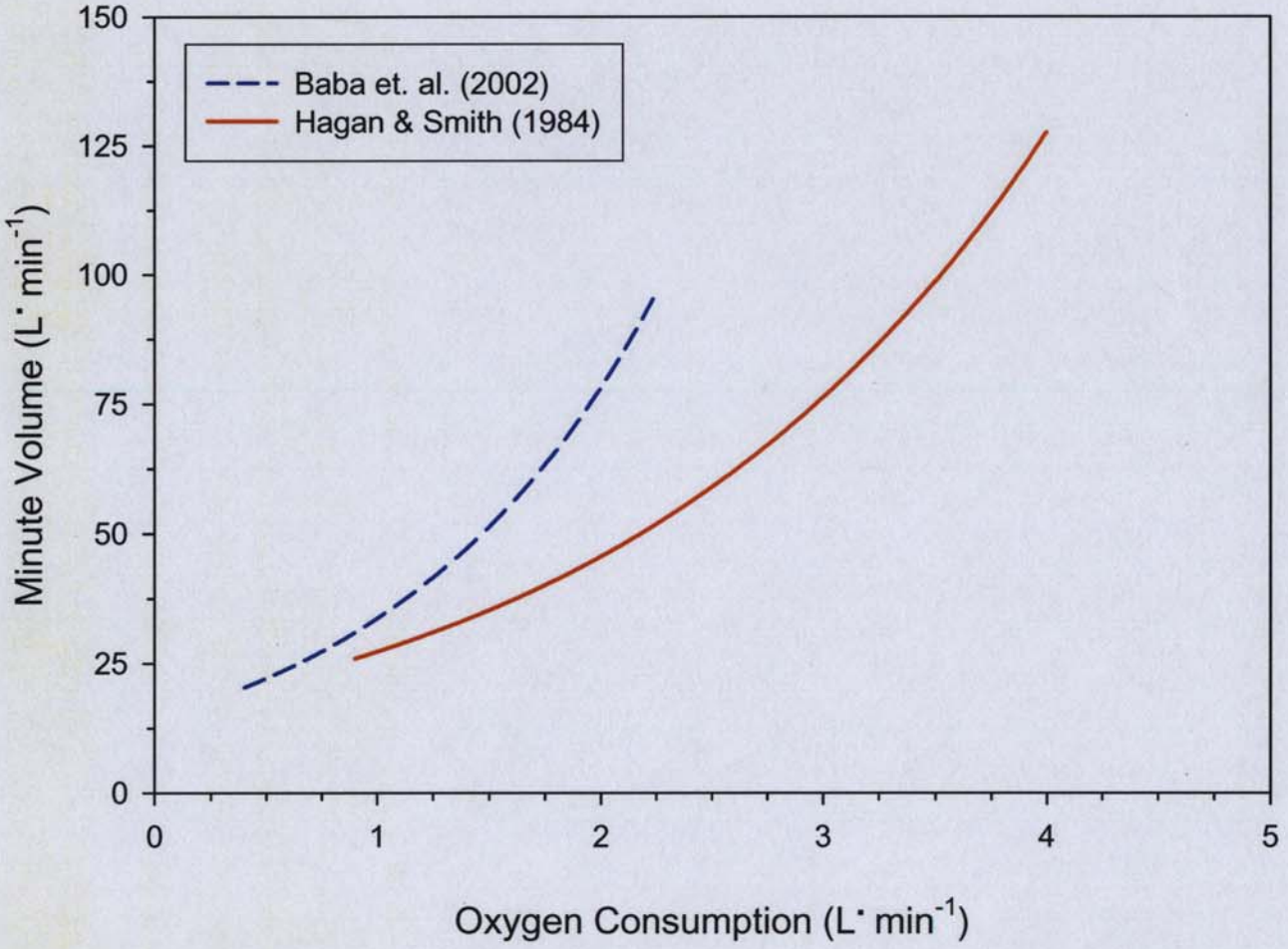
Workplace Breathing Rates

- **Literature review and analysis**
  - Literature review published Sep 04 (ECBC-TR-0316)
  - Limited empirical data to meet objectives

- **Adopted approach for estimating minute volumes from energy expenditure literature**
  - Exponential functions utilized to estimate minute volume (V_E) from energy expenditure literature when V_E not reported
  - Range of V_E based on oxygen consumption (V_{O_2})

- **Predictions of peak flow rates**
  - Based on linear relationship ($R^2 = 0.82$, $p < 0.001$) between V_E and PIF for individual subject data and prediction intervals
  - Range of PIF based on V_E

Estimation of Minute Volume



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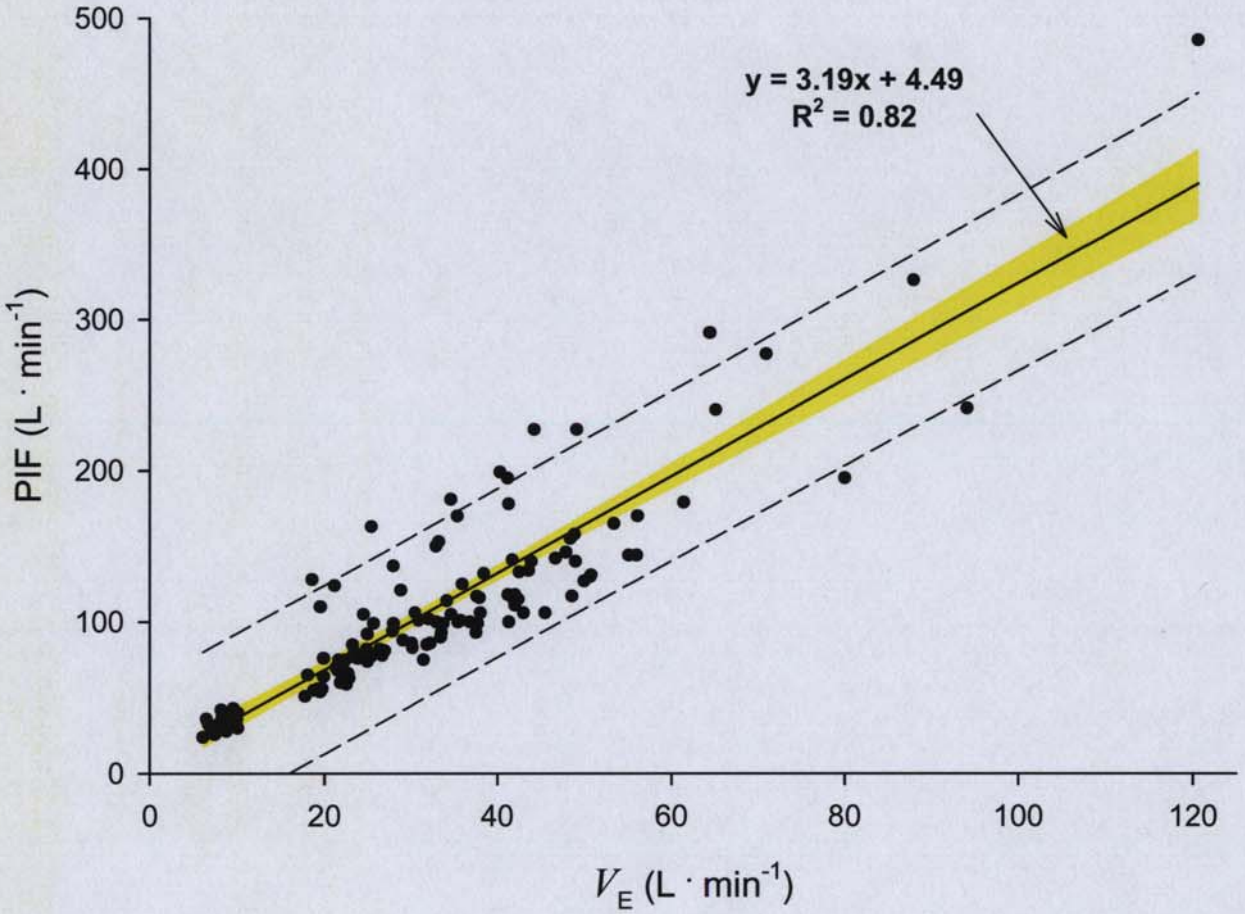
Estimation of PIF Rates



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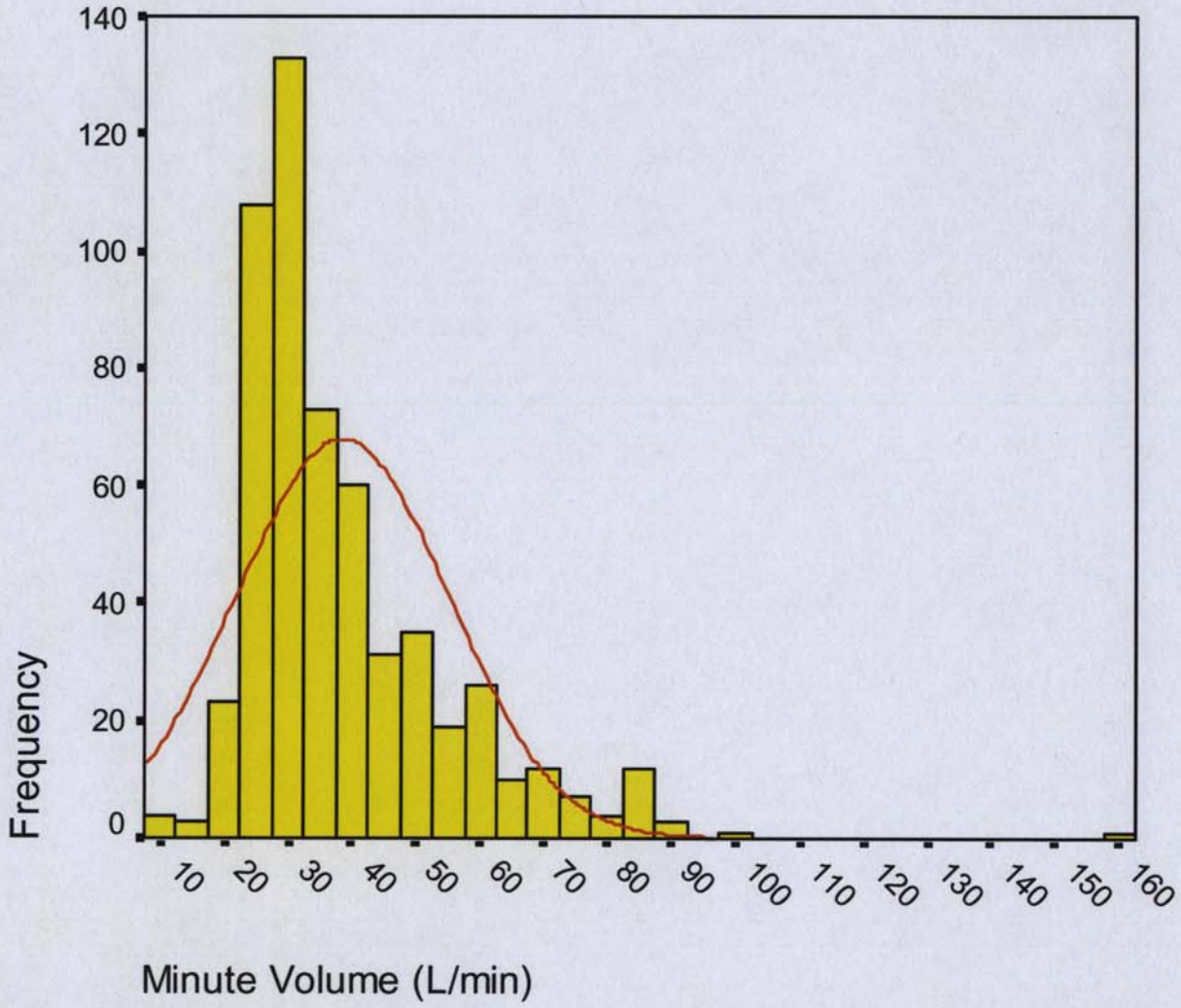
V_E Distribution for Work Tasks



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Workplace Breathing Rates

- **Minute volume distribution**
  - Mean = 38.5 $\pm$ 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 $L \cdot min^{-1}$

- **PIF ranges**
  - 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 $L \cdot min^{-1}$*
  - Peak V_E in range (~102 $L \cdot min^{-1}$): 273 to 389 $L \cdot min^{-1}$

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Peak Human Performance

- **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 ~ 300 $L \cdot min^{-1}$
  - Peak in-house value ~ 485 $L \cdot min^{-1}$ during hard work
  - Extremes of 500+ $L \cdot min^{-1}$ reported

Summary of Workplace V_E

- **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 $L \cdot min^{-1}$
- **Higher V_E and peak flows will occur!**
  - Literature suggests such instances are not the norm

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Analysis of Respirator Data

- **Objectives**
  - Validate/update current knowledge on ventilation during respirator wear
  - Identify data gaps for further research

- **Status**
  - Gathered human ventilation data from 4 sources
  - Database variables defined and populated
  - Analysis of data initiated October 2004
  - Anticipate completion January 2004; report to follow

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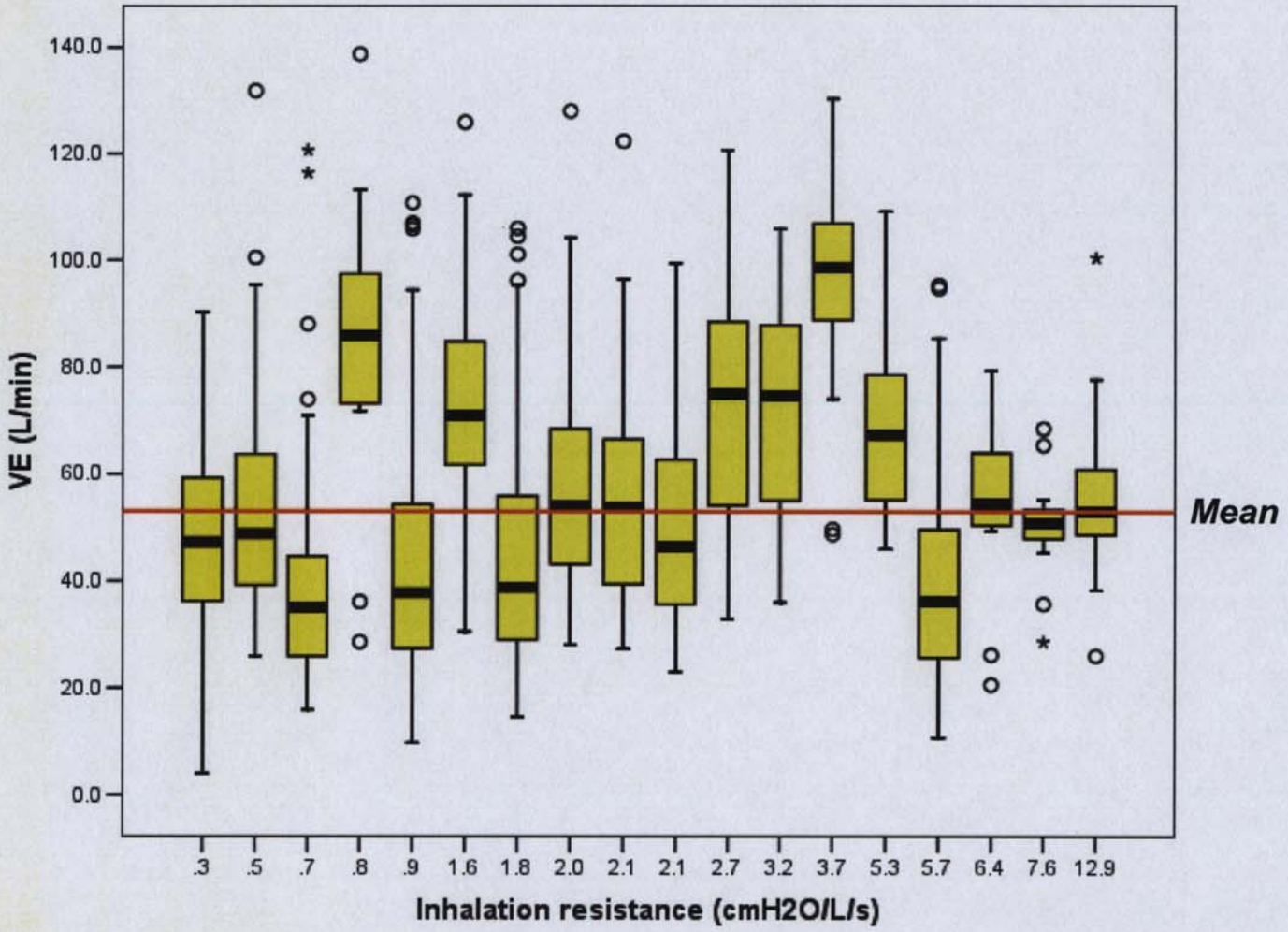
Preliminary Findings



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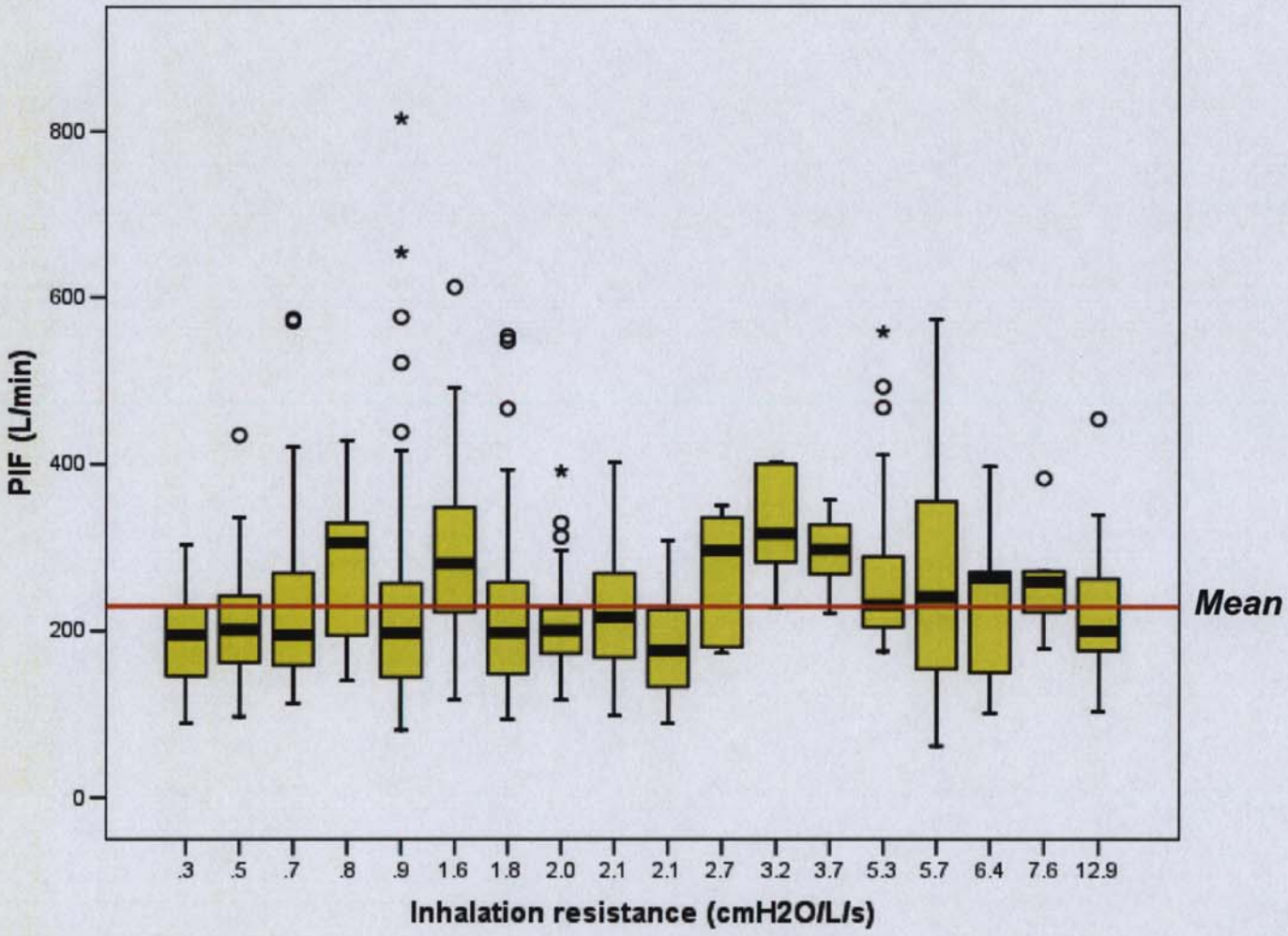
Preliminary Findings



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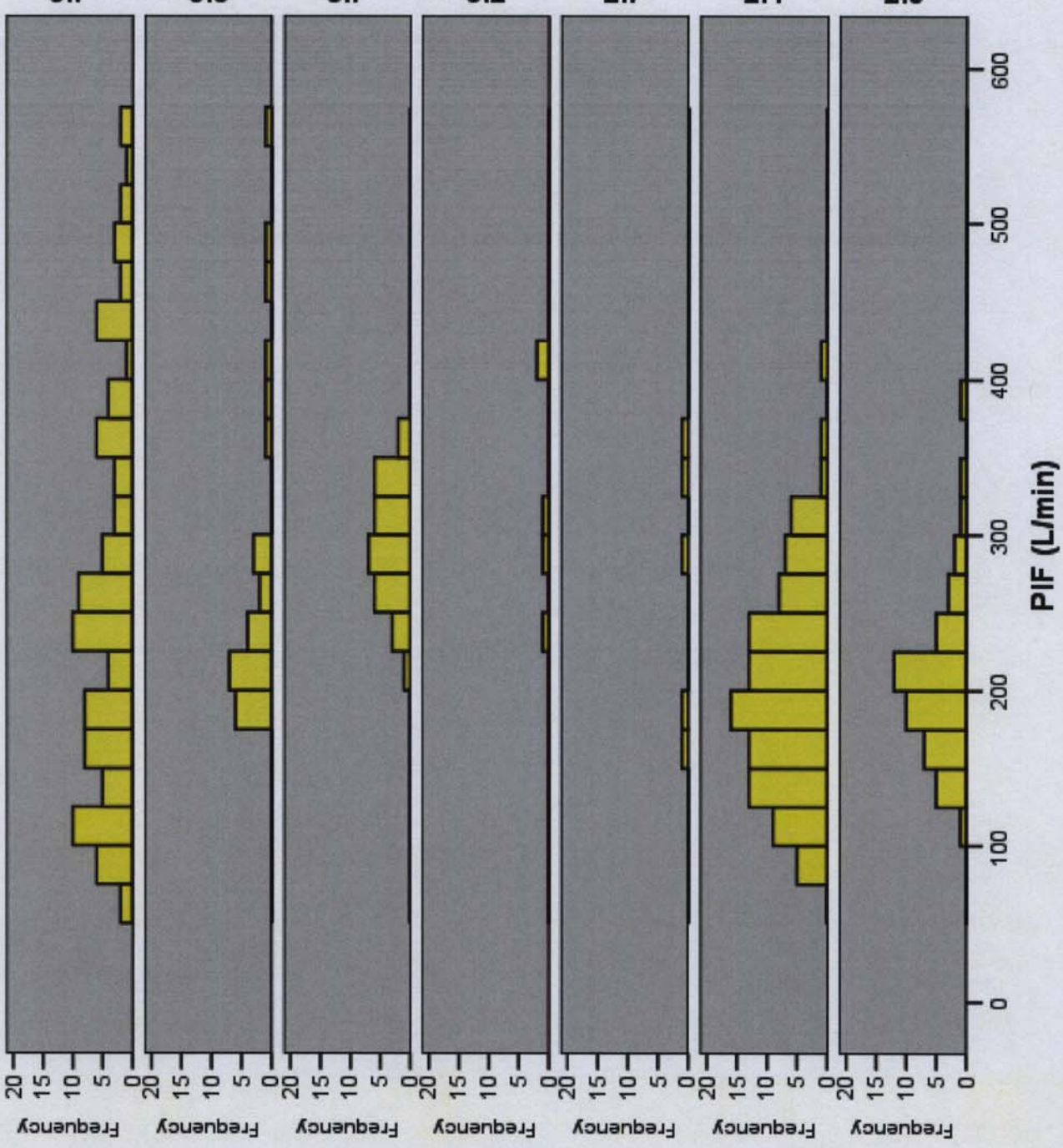
Inhalation resistance (cmH2O/L/s)
5.7
5.3
3.7
3.2
2.7
2.1
2.0
Frequency
0
5
10
15
20
0
100
200
300
400
500
600
PIF (L/min)


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Filter Efficiency Testing

- **Objectives**
  - Assess effect of moderate to high flows on performance of NIOSH-approved particulate respirator filters
  - Compare efficiencies measured under constant and cyclic flow conditions
  - Compare efficiencies measured using inert and bioaerosol challenges

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Test Materials

- **Test filters**
  - Eight NIOSH-approved N95 and P100 respirator filters
    - Non-powered APR particulate filters
    - Cartridges: 2 N95 and 2 P100
    - Filtering facepieces: 2 N95 and 2 P100

- **Challenge Aerosols**
  - Inert particles: 0.02 to 3 μm
    - N95: NaCl, polystyrene latex spheres
    - P100: DOP, Emery 3004
  - Bioaerosols:
    - Bacterial: Bg spores
    - Viral: MS2 phage

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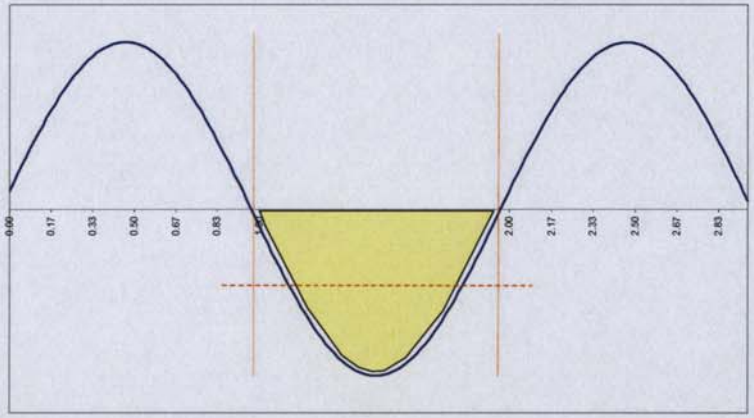
Test Parameters

Flow Condition	Minute Volume[a] (L/min)	Tidal Volume (L)	Breathing Rate (#/min)	PIF[b] (L/min)	MIF[c] (L/min)
Constant	85	N/A	N/A	85	85
Constant	270	N/A	N/A	270	270
Constant	360	N/A	N/A	360	360
Cyclic	40	1.6	25	130	80
Cyclic	85	2.3	37	270	170
Cyclic	115	2.7	42	360	230
Cyclic	135	3.1	44	430	270

(a) Minute volume halved when testing single cartridge from dual cartridge respirator

(b) Peak Inspiratory Flow

(c) Mean Inspiratory Flow



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Test Parameters

- **Cyclic flow conditions based on Workplace V_E review and analysis**
  - 40 $L \cdot min^{-1}$: mean V_E = 38.5 $L \cdot min^{-1}$
  - 85 $L \cdot min^{-1}$: current test flow parameter
  - 115 $L \cdot min^{-1}$: average $V_{E\,max}$ = 114 $L \cdot min^{-1}$
  - 135 $L \cdot min^{-1}$: $V_{E\,max}$ + 1SD = 137 $L \cdot min^{-1}$

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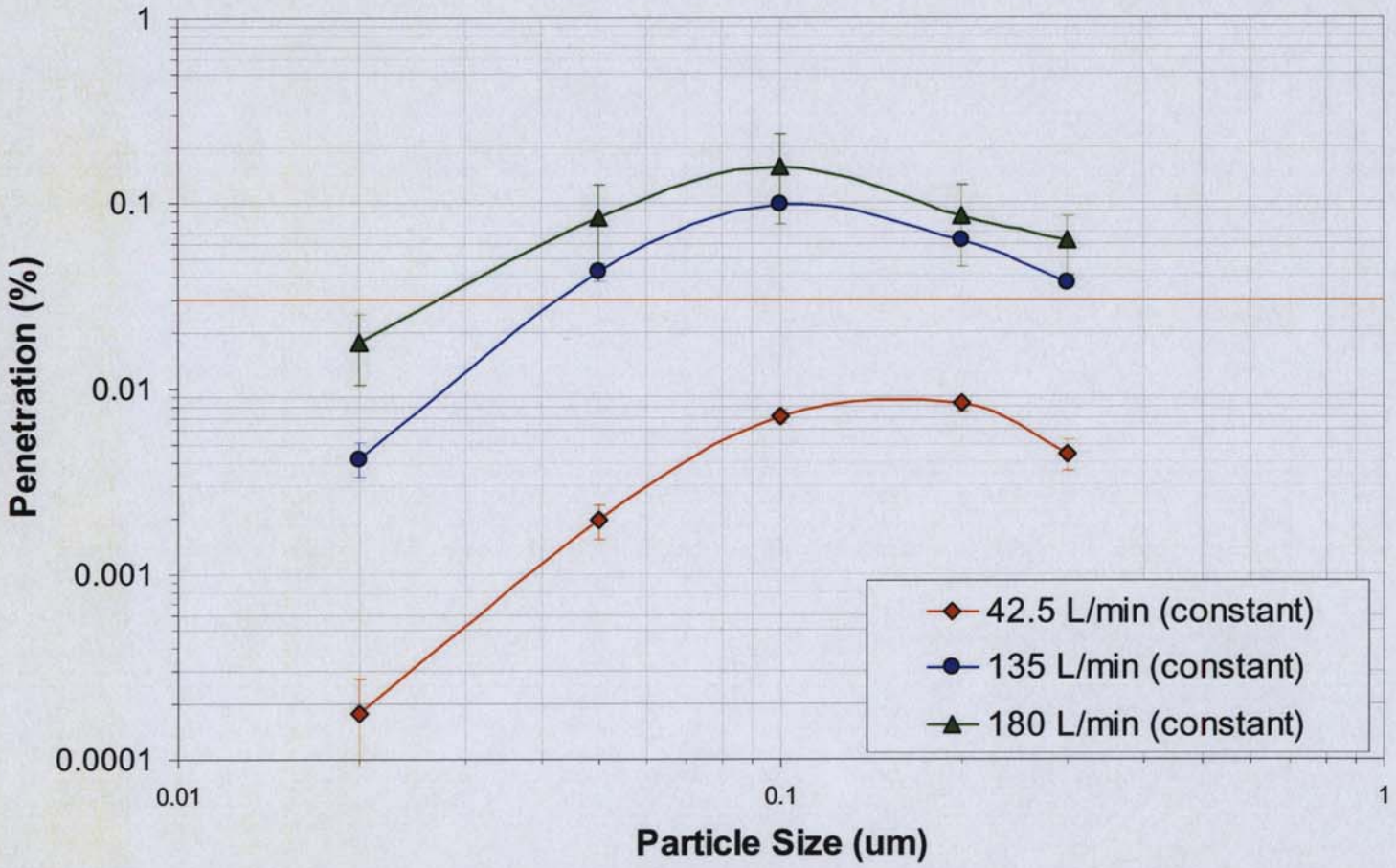
Preliminary Findings

- Effect of flow rate and particle size on measured penetration through a P100 cartridge



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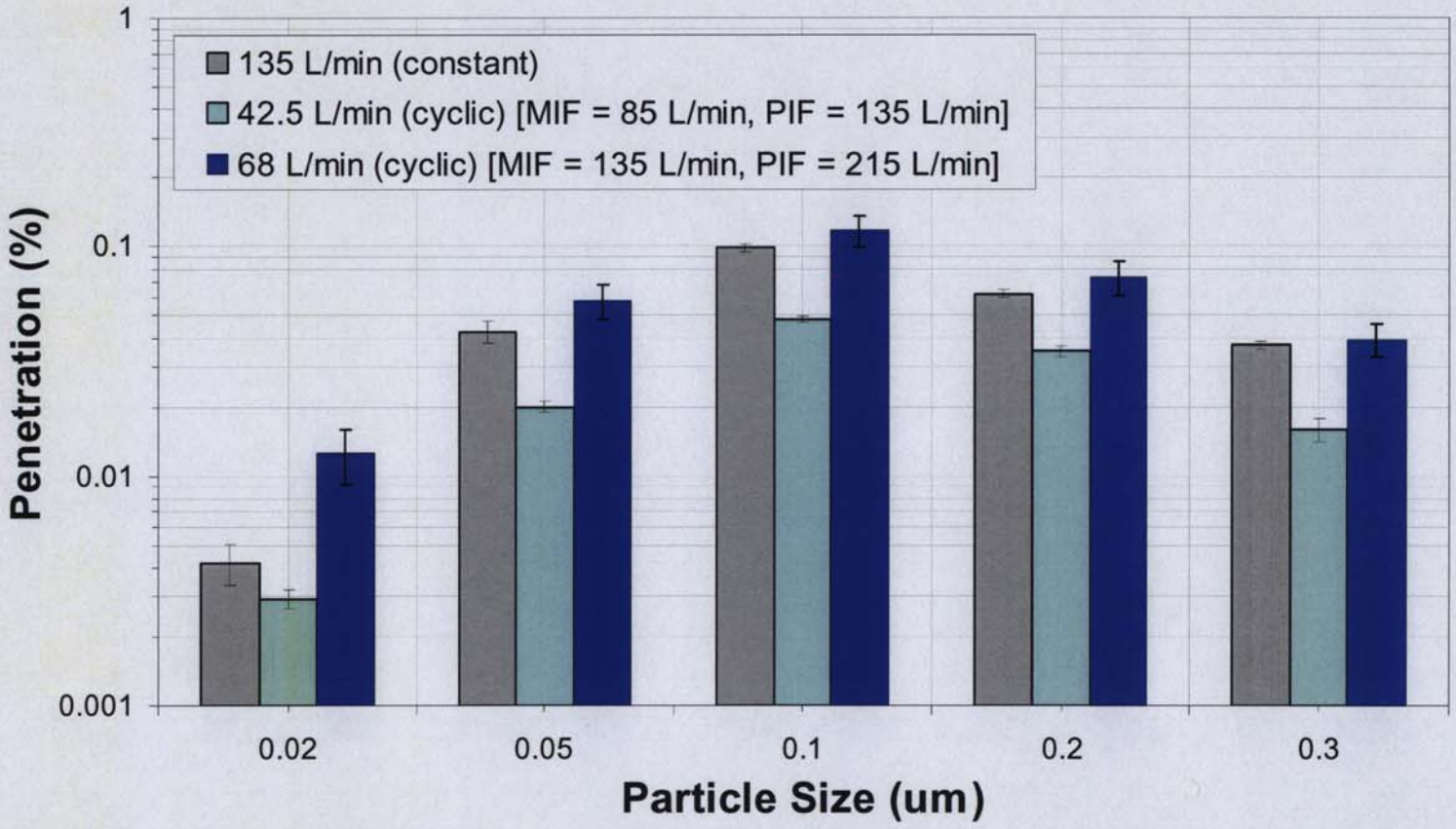
Preliminary Findings

- Comparison of penetrations measured under constant and cyclic flow conditions through a P100 cartridge



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Test Status

- **Inert submicron aerosol**
  - Testing complete
  - Initiated "large" particulate testing (0.7, 1.3, 3.0 μm)
  - Anticipate completion in February 2005

- **Bioaerosol testing**
  - Cartridge tests completed with Bg spore challenge
  - Initiated filtering facepiece Bg testing
  - MS2 phage testing will commence following Bg trials
  - Testing scheduled for completion in April 2005

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Future Directions

- **Workplace breathing & respirator ventilation data**
  - Update findings based on any new found information
  - Evaluate human breathing during occupational task performance
- **Filter testing**
  - Study combination filters/CBRN filters
  - Determine filtration efficiency based on waveshapes and/or breathing profiles
- **Other**
  - Human factors review of CC SCBA

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