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Industrial Health and Safety Program

Integrated Sampling System for Measuring Workplace Protection Factors for Gases and Vapors

W. A. Groves, PhD, CIH, Penn State University
S. J. Reynolds, PhD, CIH, Colorado State University

Introduction – Respirator Use

- NIOSH/BLS Respirator Survey (2001)
  - Respirators used by ~3.3 million employees in 281,000 businesses
  - 264,000 establishments using non-powered air purifying respirators (APRs)
  - 107,000 use APRs for "Other dust"
  - 111,000 use APRs for "Paint vapors"

Introduction – APFs

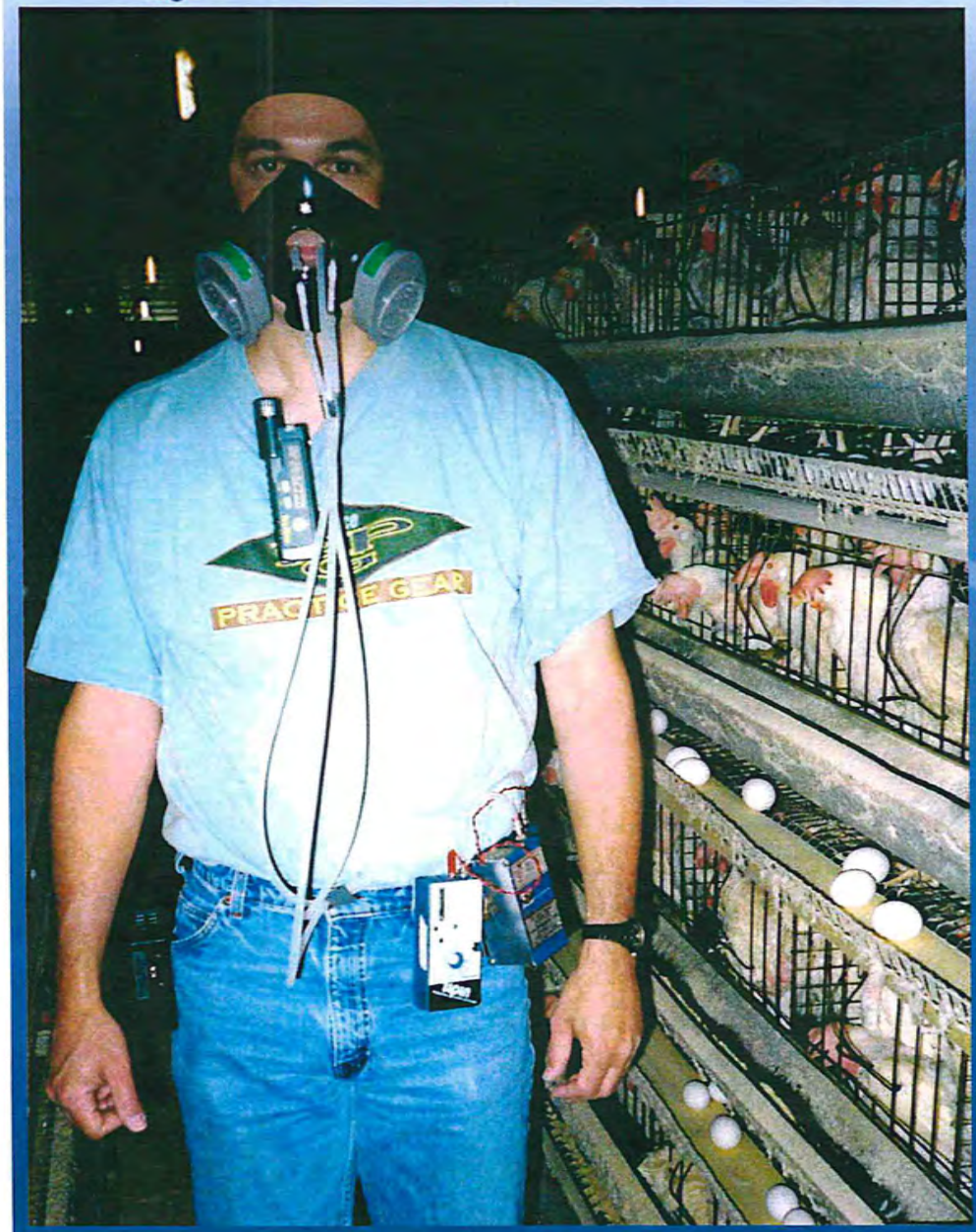
- Assigned Protection Factor (APF) section of OSHA standard reserved
  - Limited WPF data available
  - OSHA planned to promulgate APF provisions in the future
  - NIOSH and ANSI guidelines

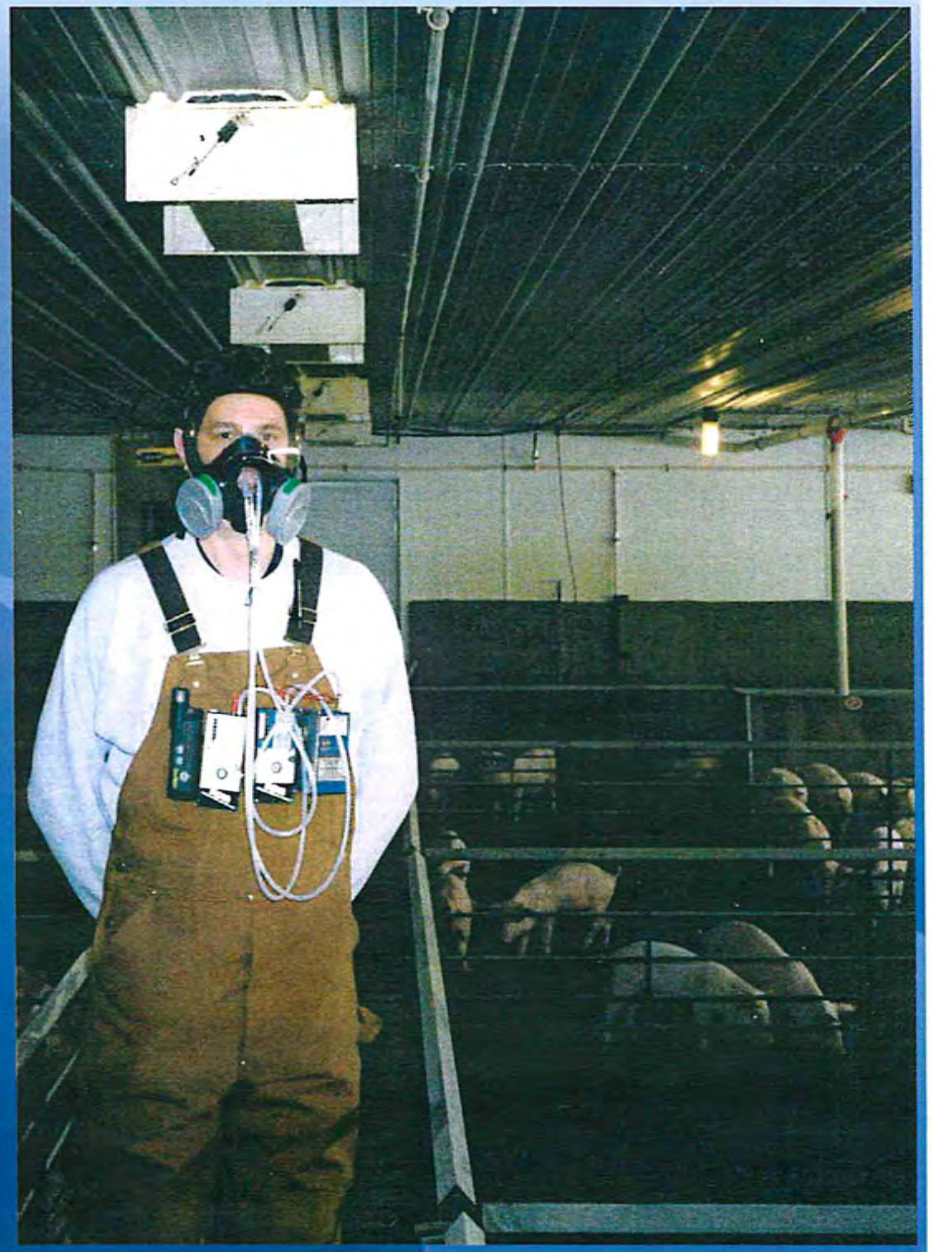
Introduction - WPFs

- Why so little data on WPFs ?
  - Tedious sampling
  - Analytical challenges
    - Temperature, humidity, sensitivity
    - Continuous vs. intermittent sampling
      - How to address lung retention
  - Limited resources - not a priority

Previous Work

- Prototype sampling system developed at University of Iowa to measure WPFs
  - Ammonia in livestock production facilities
  - Intermittent sampling with sorbent tubes for sample collection
- Consisted of two pumps, pressure transducer, and switching circuitry





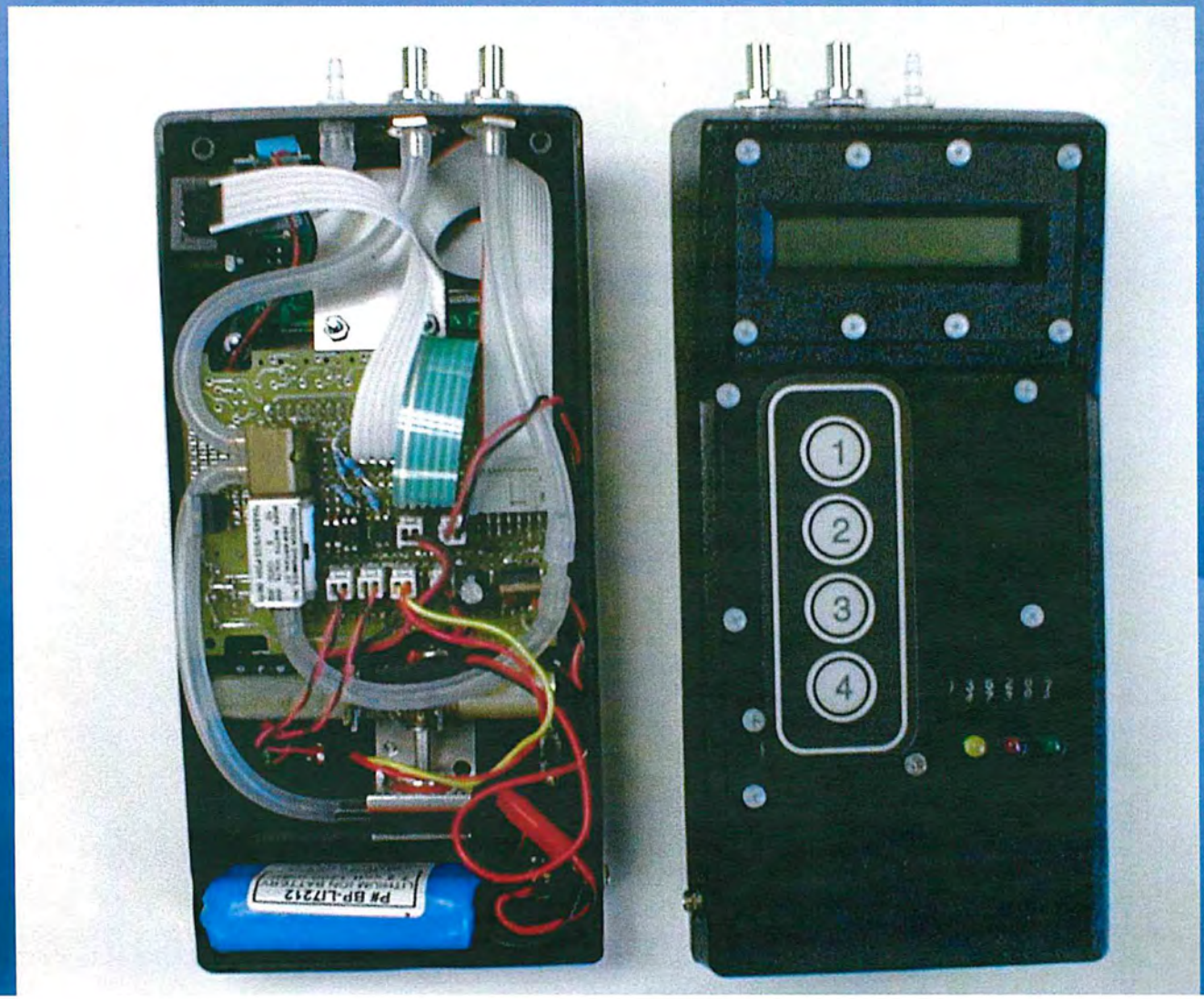
Previous Work

- Prototype system functioned well
  - Reliable sampling during inhalation
- System was awkward to use in the field due to separate components
  - Two pumps, three hoses, and pressure transducer enclosure

Specific Aims for Current Project

- Integrate main components of personal sampling system into single enclosure measuring 5”x5”x2.5” and weighing < 2.5 lbs
  - Low flow pump with stroke counter
  - Pressure and heart rate transducers
  - Data logger, conditioning circuitry

Prototype Instrument

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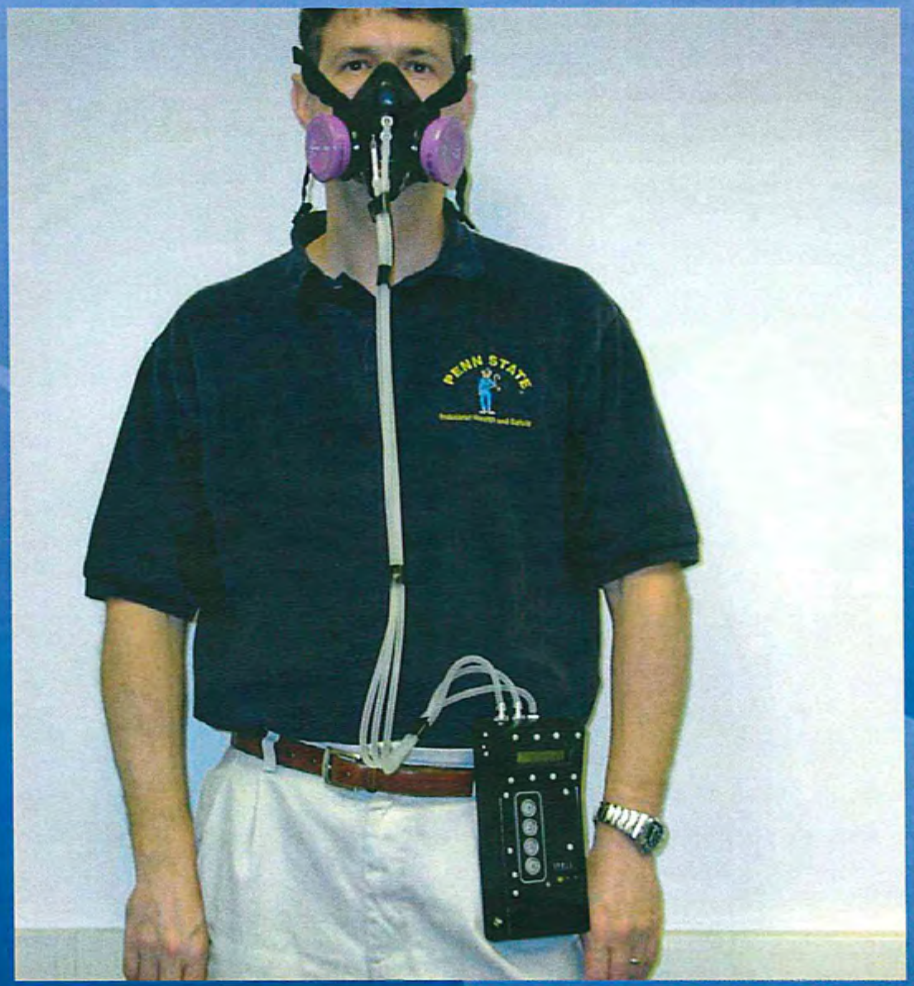
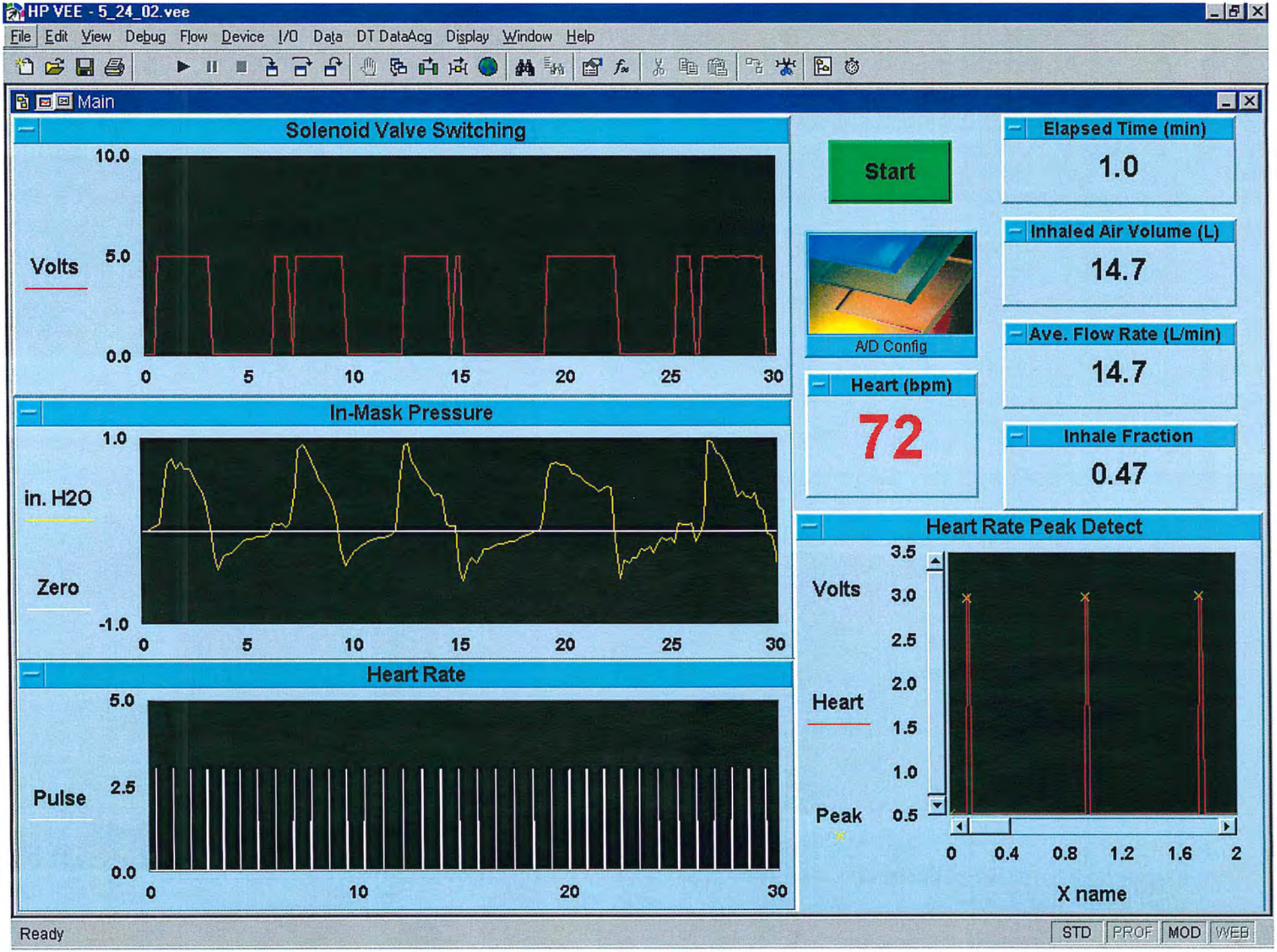
WPF Sampling System

- Data-logging and display of heart rate, pressure, volume
- Slightly larger than typical sampling pump




HP VEE - 5_24_02.vee
File Edit View Debug Flow Device I/O Data DT DataAcq Display Window Help
Main
Solenoid Valve Switching
Volts
10.0
5.0
0.0
0 5 10 15 20 25 30
In-Mask Pressure
in. H2O
Zero
1.0
-1.0
0 5 10 15 20 25 30
Heart Rate
Pulse
5.0
2.5
0.0
0 10 20 30
Start
A/D Config
Heart (bpm)
72
Elapsed Time (min)
1.0
Inhaled Air Volume (L)
14.7
Ave. Flow Rate (L/min)
14.7
Inhale Fraction
0.47
Heart Rate Peak Detect
Volts
Heart
Peak
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0 0.4 0.8 1.2 1.6 2
X name
Ready
STD PROF MOD WEB

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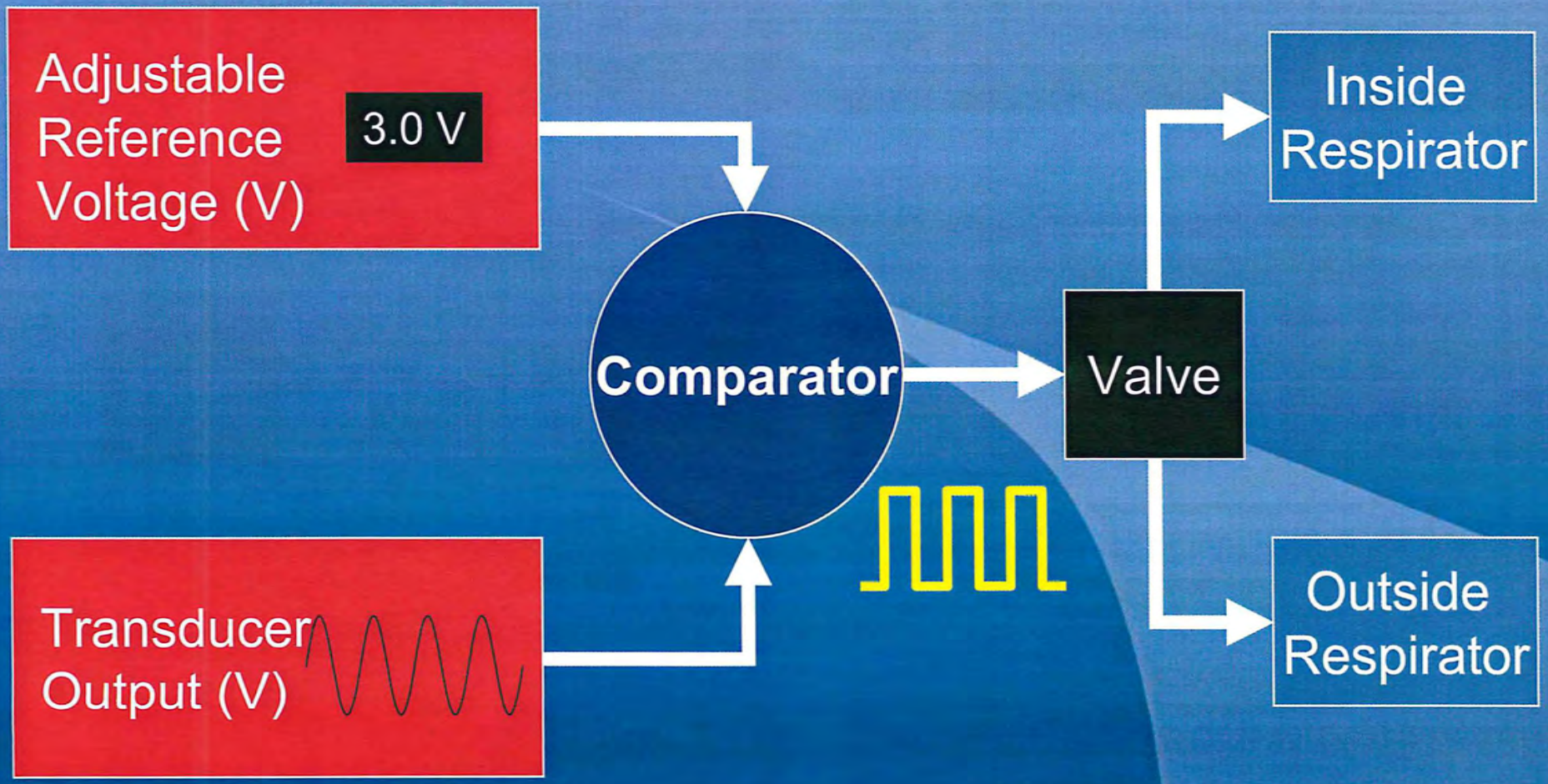
Intermittent Sampling



Intermittent Sampling

- Sample collected only during inspiration
- Mitigates temperature and humidity effects
- Reduces bias due to lung retention
- Allows use of single pump

Specific Aims for Current Project

- Evaluate whether the sampling system affects respirator performance
- Explore use of pressure transducer output for estimating respiration rates and cumulative air volumes
- Conduct laboratory evaluation of system performance

Comparison of Pre- and Post-Modification Fit Factors

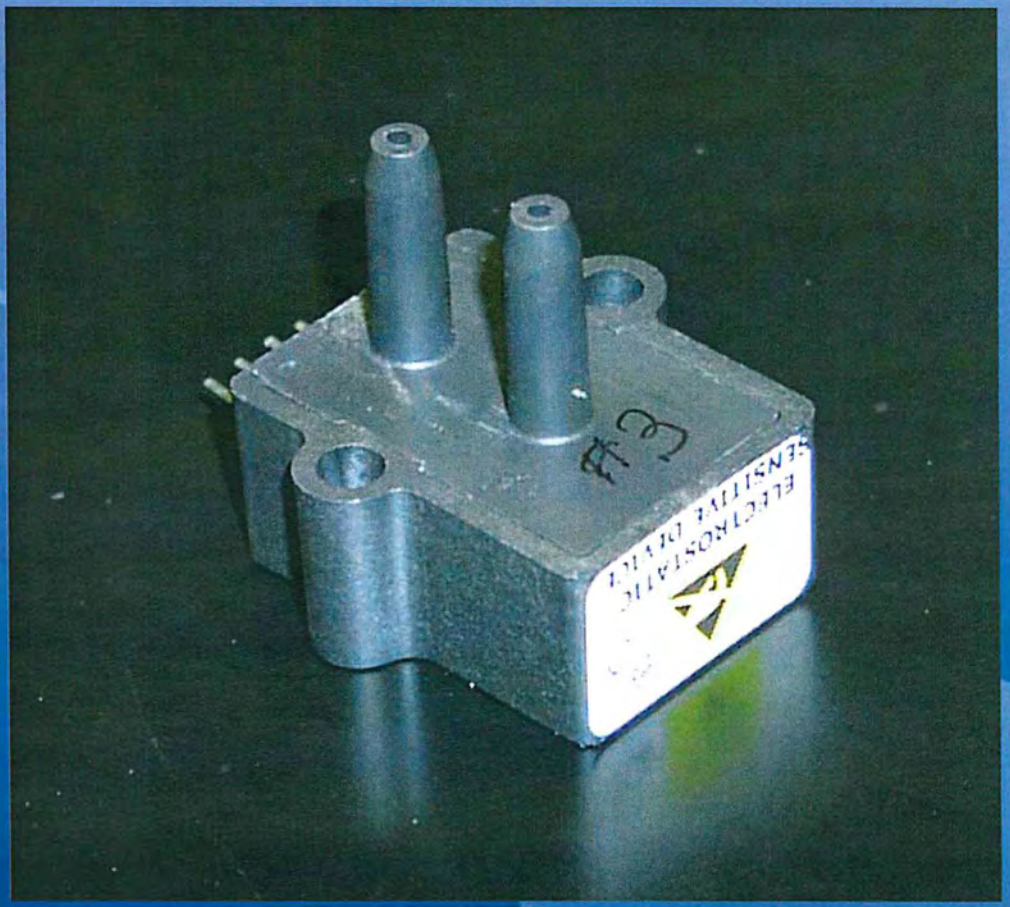
- 299 quantitative fit-tests completed for two different types of respirators (half-mask, full-face) from two manufacturers (North, MSA)
- t-test used to compare mean pre- and post-modification fit factors

Table 1. Comparison of Pre- and Post-Modification Fit Factors

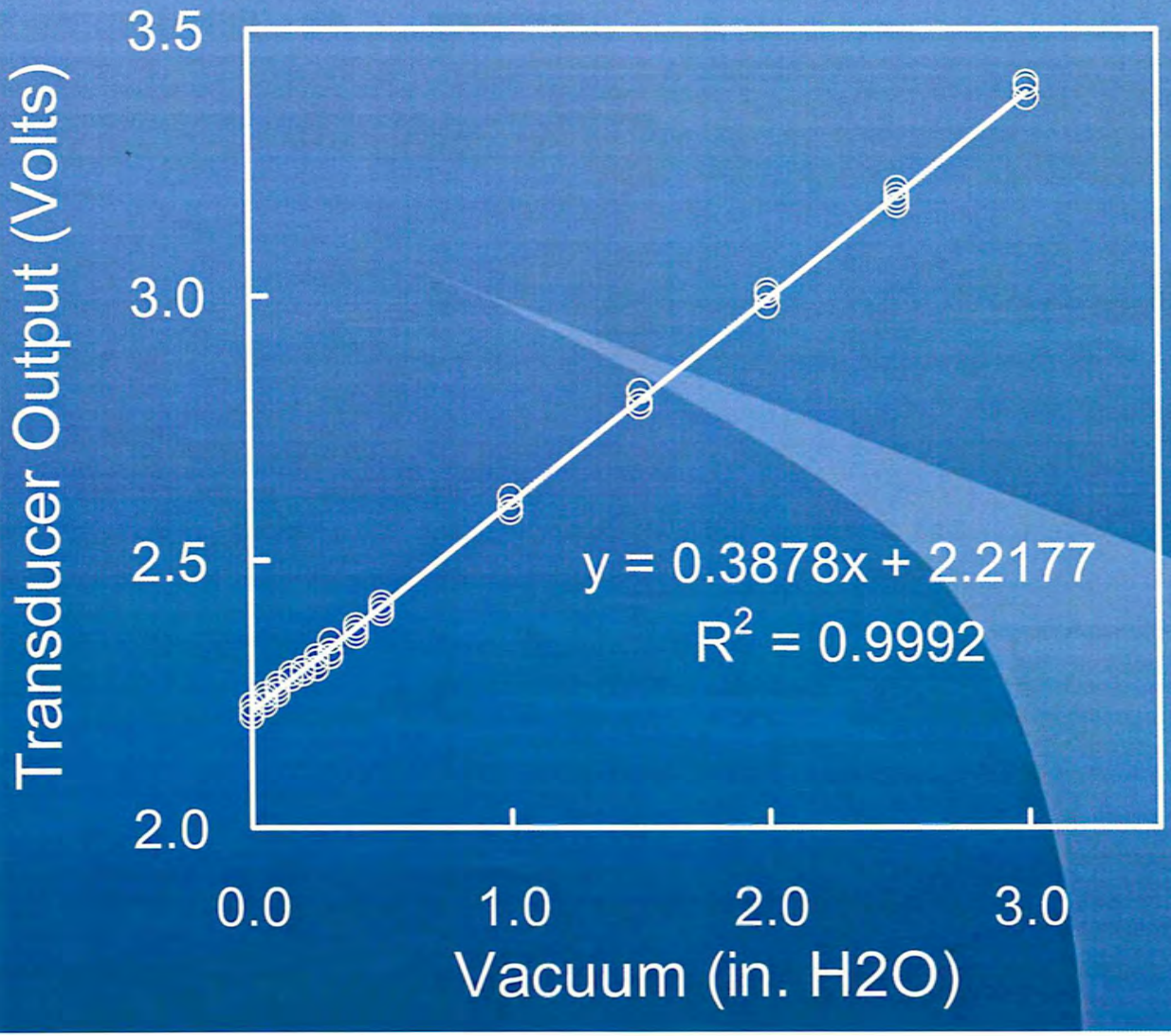
Respirator	Descriptive Statistics			Statistical Test
	n	*mean*	*CV%*	*t (p-value)*
North (7600,7700)				
Pre full-face	32	27,928	33	-0.455 (0.651)
Post full-face	32	29,019	35	
Pre half-mask	33	7,532	26	1.306 (0.196)
Post half-mask	30	6,890	28	
MSA (Advantage)				
Pre full-face	28	16,829	26	-0.013 (0.990)
Post full-face	28	16,844	25	
Pre half-mask	58	7,229	59	0.134*
Post half-mask	58	8,480	51	

Differential Pressure Transducer

- Conditioned, amplified output, 1 - 5V
- 5V power supply
- Low current consumption ~5 mA

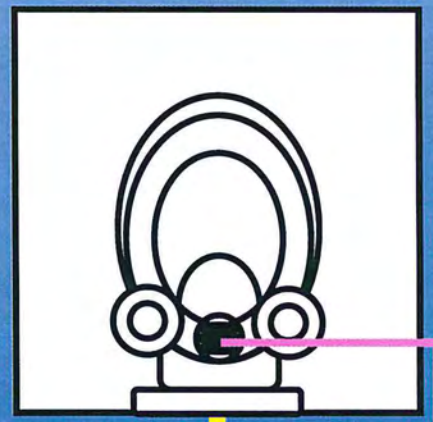


Pressure Transducer Calibration



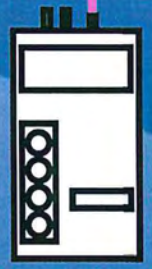
Flow Rate vs. In-Mask Pressure

Headform (PosiCheck[3])



Mass Flow Meter

Gast Pump (0.5 - 75L/min)



Sampling System

Flow Rate vs. In-Mask Pressure

- Measurement of flow rate through head-form mounted respirators as a function of differential pressure
- Three sets of two different types of respirator cartridge (AM/MA and OV)
- Three respirators each from two different manufactures for both half-mask and full face respirators

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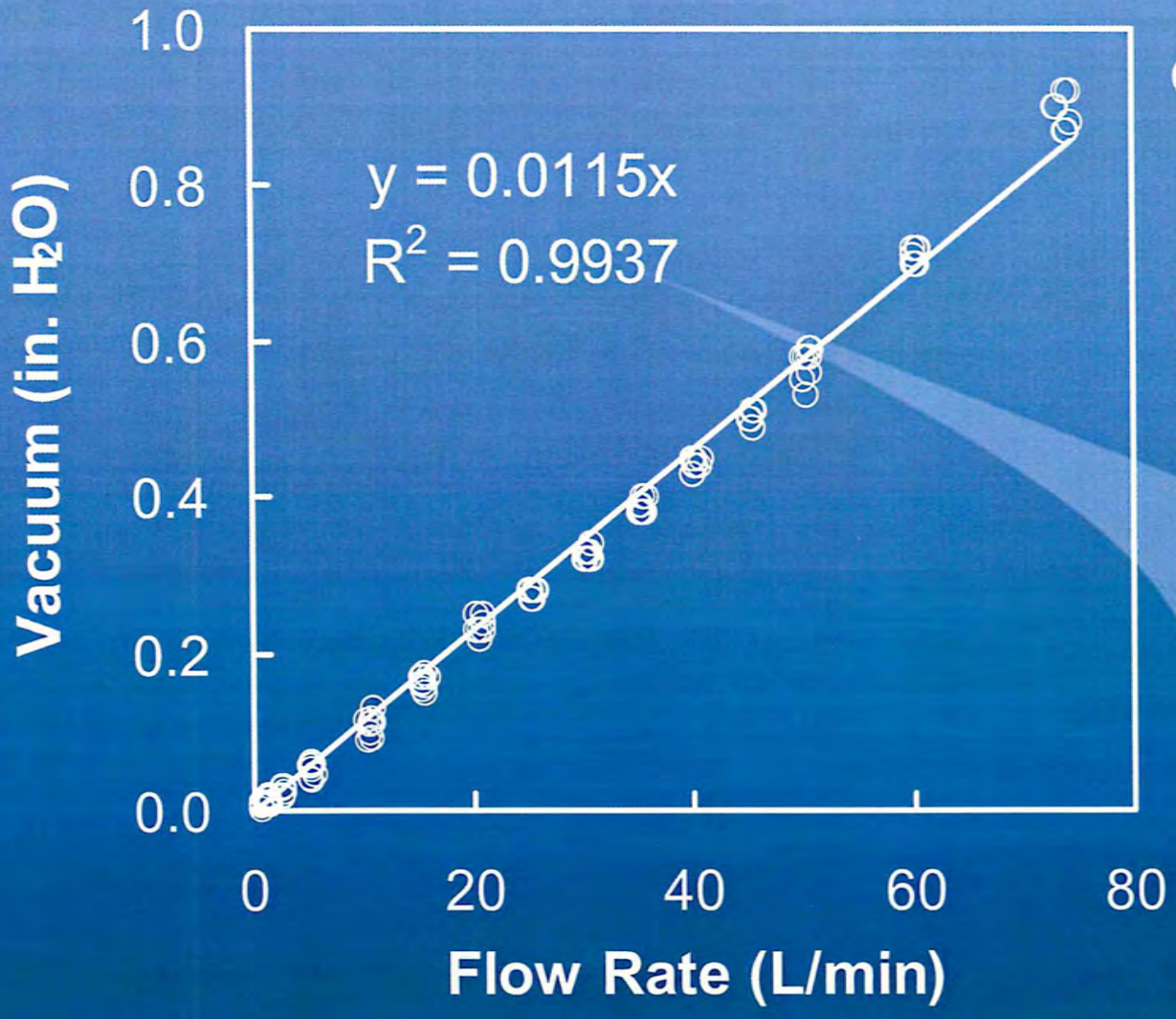
Flow Rate vs. In-Mask Pressure



Combined results for

- Three different North 7600 full-face respirators
- Three different sets of AM / MA cartridges

Flow Rate vs. In-Mask Pressure

- Results indicate that in-mask pressure can be used to estimate inhalation flow rates
- Integration of transducer output over time yields inhalation air volume
- Volume may be useful in characterizing work rate associated with WPF

Laboratory Evaluation of System Performance

- 50 ppb concentration of perchloroethylene
- Head-form mounted respirator connected to breathing machine
- Non-filtering cartridge
- Concentration in respirator measured using sampling system

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Breathing Machine / Test Chamber

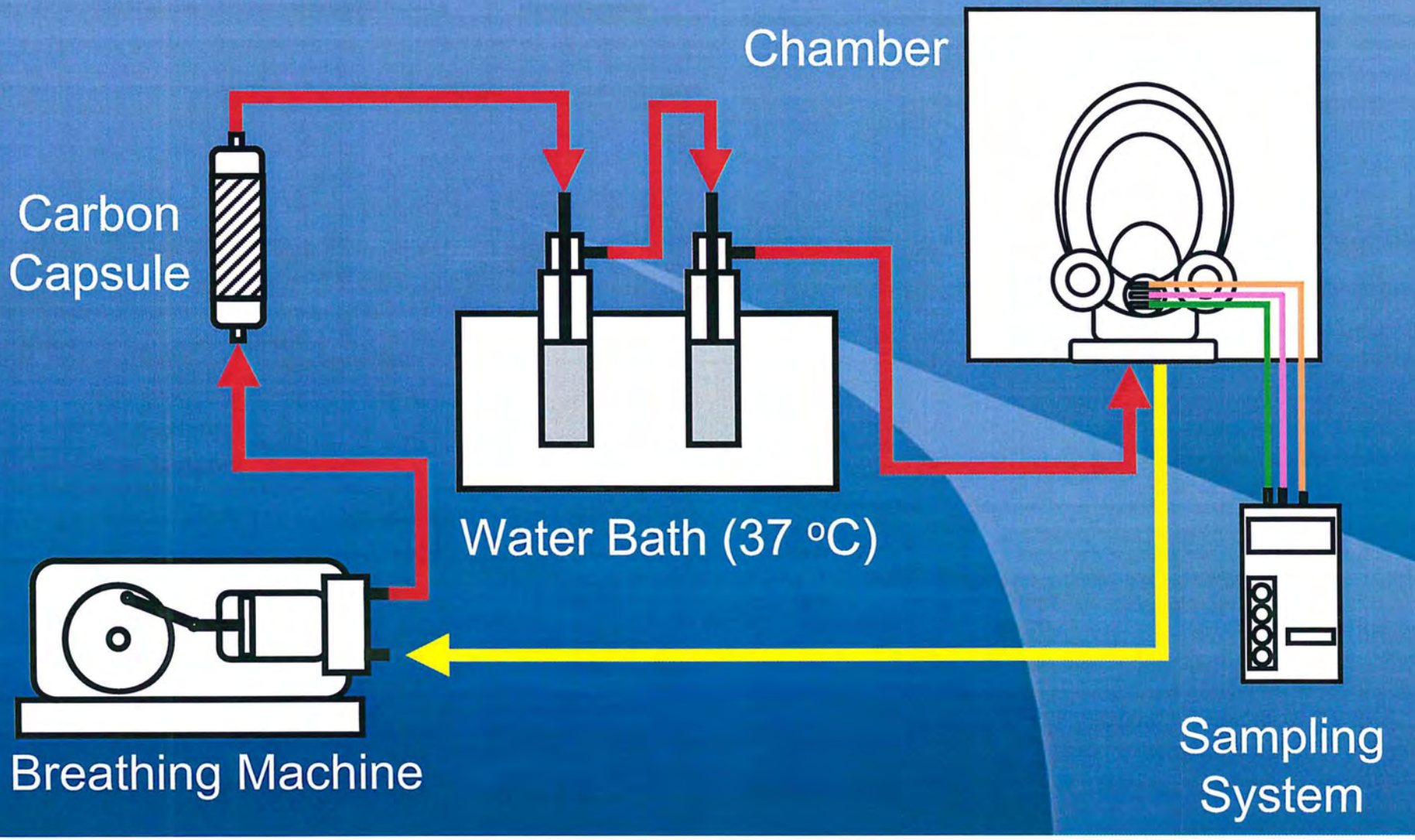


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Table 2. Results for Laboratory Evaluation of System Performance

Chamber, C_o (PPB)	**Respirator, C_R (PPB)**		**C_R / C_o**	
	Continuous	*Intermittent*	*Continuous*	*Intermittent*
50	25	40	0.50	0.80
51	24	42	0.47	0.82
48	22	37	0.46	0.77
48	23	37	0.48	0.77
45	24	35	0.53	0.78
		Ave =	**0.49**	**0.79**
		SD =	**0.03**	**0.02**

North 7600 full-face respirator; perchloroethylene

Laboratory Evaluation of System Performance

- Contaminant concentrations corresponding to WPFs of 500-25,000 successfully measured
- Marked difference in amount of water condensed in samples
- Apparent influence of respirator dead volume on concentration in respirator

Future Work

- Complete laboratory evaluation for remaining chemicals and respirators
- Examine differences between respirator concentrations measured using intermittent vs. continuous sampling
- Explore use of system for particulate
- Develop larger study of WPFs using sampling system

Conclusions

- An improved sampling system for measuring WPFs for gases and vapors has been developed
- The resulting integrated sampling system should be a valuable tool for evaluating respirator performance in the workplace

Acknowledgement

Support for this research was provided by the National Institute for Occupational Safety and Health (NIOSH) through a SERCA grant (5K01 OH00177)