National Personal Protective Technology Laboratory

PAPR Benchmark Testing

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December 13, 2005

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PAPR Benchmark Testing

1. **High Flow Particulate Tests**
2. **Service Life Tests**
3. **Air Flow Measurements**
4. **Alarms**

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PAPR Benchmark Tests

High Flow Particulate Testers

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High Flow Particulate Tests

- Two High Flow Particulate Testers located in bldg 104; modified ATI Model TDA 100P and TSI 3120.
- High flow testers are custom built to test at flows of 100 – 500 Lpm following the P100 specification written in 42 CFR Part 84.
- Both testers have been powered up and preliminary studies started. DOP has been generated for gravimetric tests.

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High Flow Particulate Tests

Set Up Experiences

- High flow testers need large vacuum pumps to run. High noise level in the laboratory.
- In a new location vacuum pumps will be in separate location.
- Discharge of DOP into air handling units
- High flow during gravimetric testing causes filter medium to tear. Solution is thick paper or multiple sheets.

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High Flow Particulate Tester

- TSI 3120 High Flow Tester with external vacuum pump
- Same frame as TSI 8130
- Gravimetric test shows at 100 Lpm testing, 200 mg of DOP deposited on filter approximately 12- 14 minutes
- TSI 8130 takes approximately 23 – 30 minutes for 85 Lpm

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High Flow Particulate Tester

- ATI TDA 100P$_{mod}$ High Flow Tester with external vacuum pump
- Gravimetric test shows at 100 Lpm testing, 200 mg of DOP deposited on filter approximately 27 – 30 minutes
- TSI 8130 takes approximately 23 – 30 minutes for 85 Lpm

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High Flow Particulate Tests

Next Steps for Validation

1. Run particle sizer on testers to verify particle size distribution count median diameter of 0.185 ± 0.020 micrometers with a geometric standard deviation not exceeding 1.6.
2. Verification of consistent gravimetric tests at various flows (100,115, 170 Lpm)
3. Correlation studies between high flow testers and TSI 8130s (100 to 110 Lpm)
4. Sufficient filter elements run at various flows that gives consistent penetration results.
5. Purchase additional tester from each manufacture for consistent penetration results

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High Flow Particulate Tests

Questions?

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Service Life Tests

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Service Life Benchmark Tests

Experiences at High Flow Service Life Testing

- Higher flows cause increased pressure in system
- Pressure needs to be as close to atmosphere as possible
- Pressure will affect the humidity values
- Pressure can be reduced by using 1 ¼ " piping
- Single canister is easier for laboratory testing
- Dual and Single Miller Nelson Controllers have been used for establishing flows

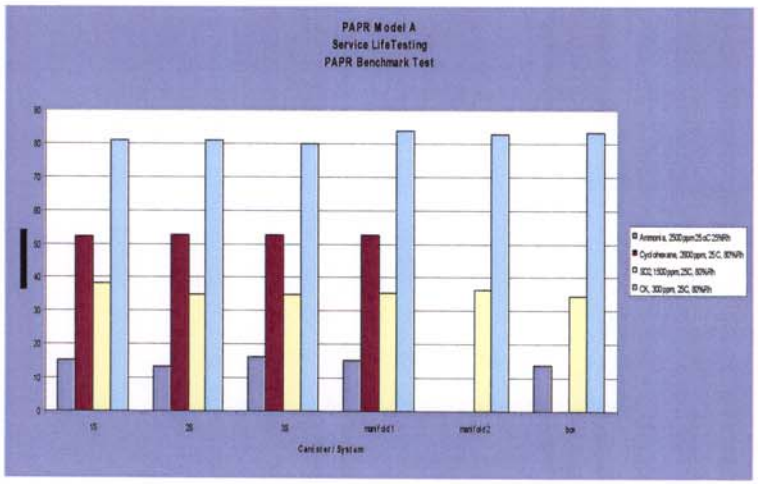
Service Life Benchmark Testing

- Benchmark data was collected using tight fitting PAPR units that have NIOSH approval and can be purchased on the market
- Both constant flow units and demand responsive units were used
- All units have 2 or 3 canisters each and were a "first responder" type of canister.

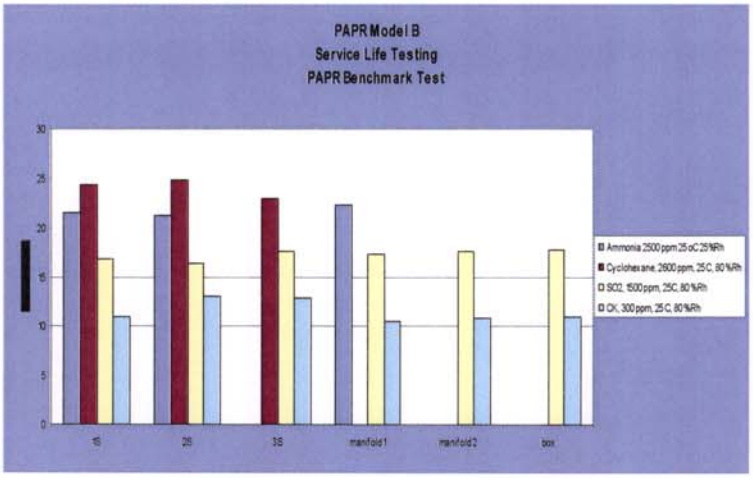
Service Life Benchmark Testing

- For "Constant Flow" units the performance air flow was measured using current NIOSH test procedures.
- For "Demand Responsive" units the airflow used was 300 Lpm
- Manifold with canisters were evaluated at the previously discussed airflows
- Single canisters were evaluated at the airflow divided by the number of canisters on the unit
- The test chamber with 2 or more canisters were used in addition or in place of the units manifold

Service Life Benchmark Testing



Service Life Benchmark Testing



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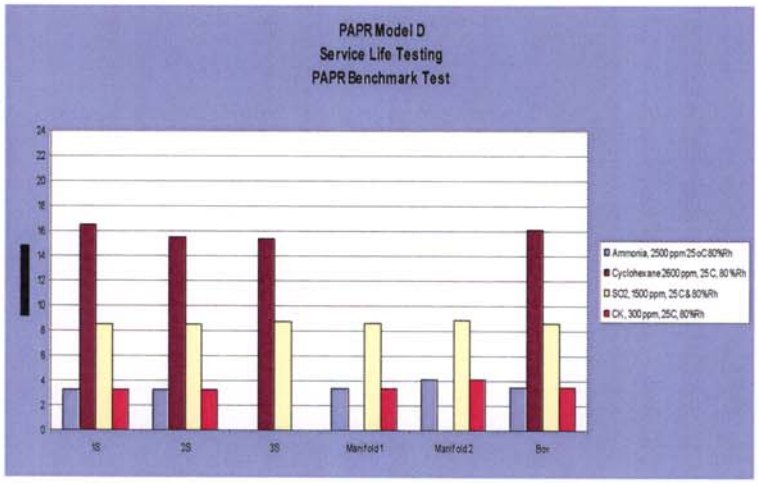
Service Life Benchmark Testing



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Service Life Benchmark Tests

Experiences at High Flow Service Life Testing

Phosphine: Bed depth is a concern. At 300 ppm phosphine, canister testing at 300 Lpm (2 canisters) shows instantaneous breakthrough.

Flow adjusted to 120 Lpm with 300 ppm phosphine, breakthrough falls to less than 0.3 ppm

Service Life Benchmark Tests

Experiences at High Flow Service Life Testing

Phosgene: Canister testing shows service life greater than 30 minutes for testing at 300, 150, 71, 56 Lpm. This was performed with both single and multiple canisters.

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Service Life Benchmark Tests

Questions?

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PAPR Benchmark Tests

Air flow Measurements

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Air Flow Measurements

Aspects of Air Flow Measurements

- PAPR Air Flow Measurement Procedure
- Breathing Machine Comparison
- Reproducibility of PAPR Models

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Review of PAPR Air Flow Measurement Technique Discussed at the July '05 Public Meeting

Objective

- Derive a new flow measurement method that will allow both constant flow and demand response flow PAPRs to be evaluated utilizing the same test method and equipment

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Review of PAPR Air Flow Measurement Technique Discussed at the July '05 Public Meeting

Method

- **A flow curve was developed for each PAPR tested using the following method**
  - Mount the facepiece on a head form and leak test
  - Install a pressure tap at the PAPR manifold outlet
  - Plug the pressure tap in the head form
  - Connect the head form breathing tube to a flowmenter and vacuum blower
  - PAPR switched "Off"

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Review of PAPR Air Flow Measurement Technique Discussed at the July '05 Public Meeting

Method

- Incrementally increase the vacuum flow through the PAPR and record the corresponding manifold pressures
- Collect points from zero flow to 500 Lpm in increments of 50 Lpm
- Create a pressure vs. flow graph (polynomial fit)

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Review of PAPR Air Flow Measurement Technique Discussed at the July '05 Public Meeting

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PAPR Air Flow Measurement

- **Correlate PAPR Flow to Pressure Drop Across Canisters**
  - Tap canister(s) and manifold to pressure transducer
  - Connect PAPR hose directly to flow measurement, flow control, and vacuum blower assembly
  - Record pressure drop vs. air flow data over typical range of PAPR operation (PAPR blower off)
  - Correlate using second order polynomial fit

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PAPR Air Flow Measurement

- **Generate PAPR Flow Profile Using Breathing Machine**
  - Mount mask on headform coupled with breathing machine
  - At specified breathing rate start PAPR operation and record pressure drop profile across canister(s)
  - Use pressure drop vs. flow correlation to convert to flow profile

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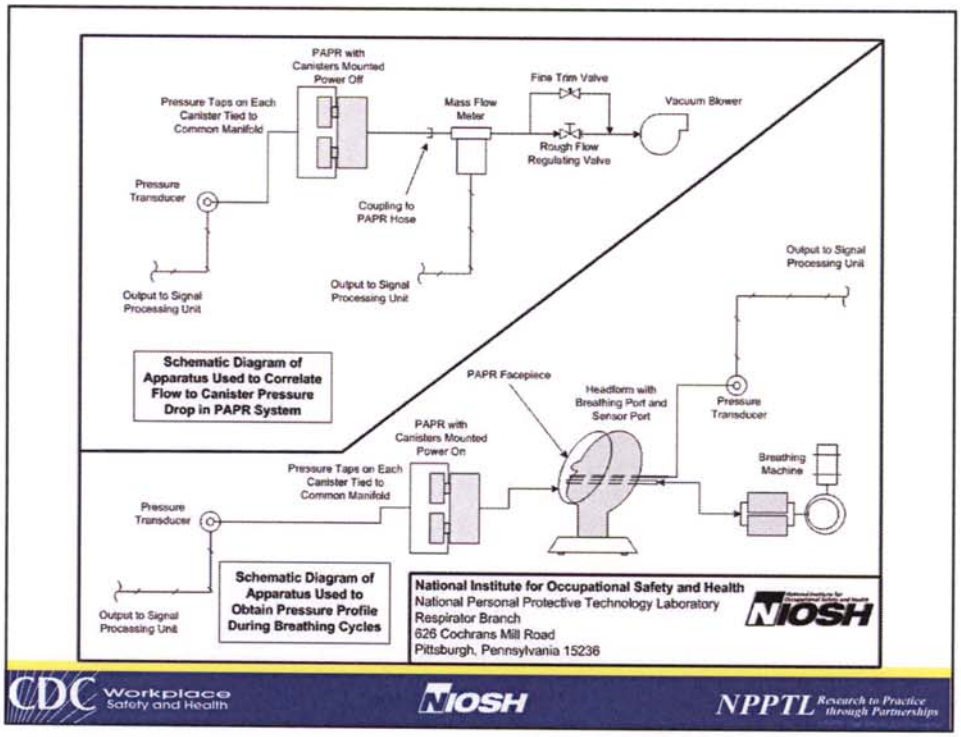

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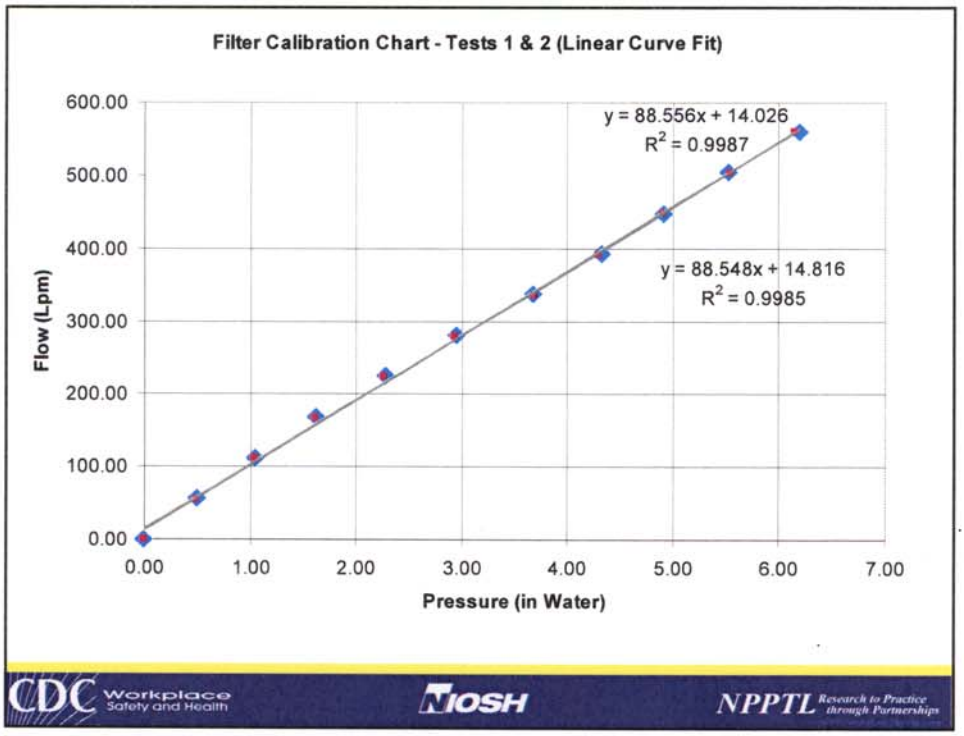
Filter Calibration Chart - Tests 1 & 2 (Linear Curve Fit)
y = 88.556x + 14.026
R2 = 0.9987
y = 88.548x + 14.816
R2 = 0.9985
Flow (Lpm)
Pressure (in Water)
600.00
500.00
400.00
300.00
200.00
100.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
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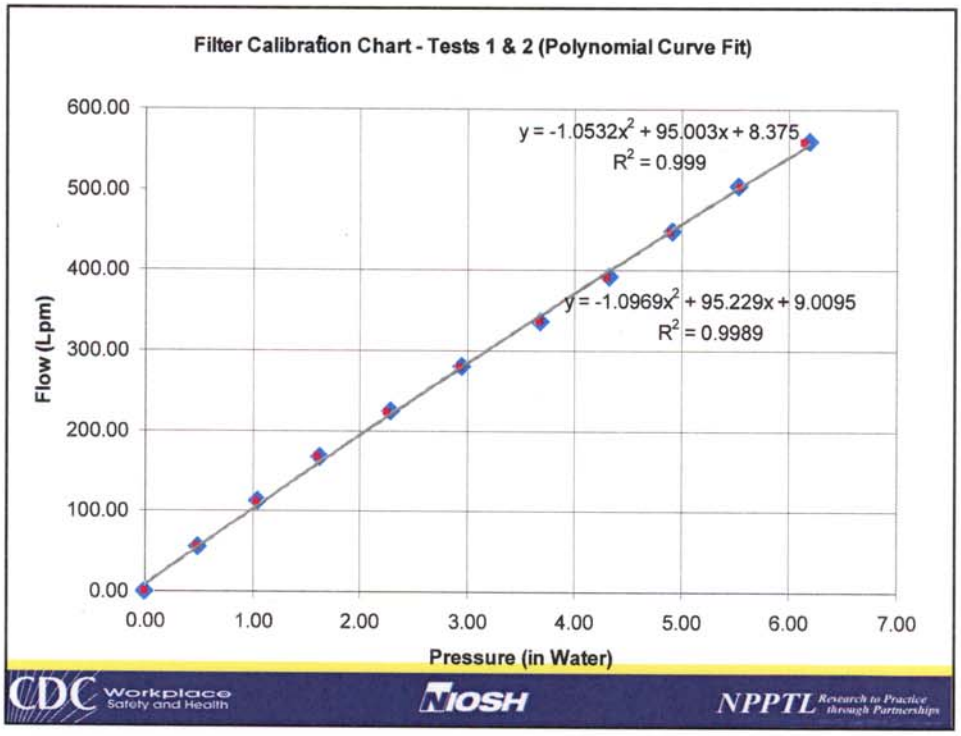
Filter Calibration Chart - Tests 1 & 2 (Polynomial Curve Fit)
y = -1.0532x2 + 95.003x + 8.375
R2 = 0.999
y = -1.0969x2 + 95.229x + 9.0095
R2 = 0.9989
Flow (Lpm)
Pressure (in Water)
600.00
500.00
400.00
300.00
200.00
100.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
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Breathing Machines

- **Performance Comparison Between Fixed and Variable Tidal Volume Breathing Machines**
  - Traditionally fixed volume machines have been used for testing
  - Potential benefits of variable volume breathing machines
    - Single machine for multiple tidal volume applications
    - Accurate and repeatable stroke frequency control
    - Ability to simulate human breathing patterns

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Breathing Machines

- **Performance Comparison Between Fixed and Variable Tidal Volume Breathing Machines**

Fixed

- **40 Lpm: 26 rpm X 1.57 Liters**
- **86 Lpm: 21 rpm X 4.1 Liters**
- **103 Lpm: 25 rpm X 4.1 Liters**

Variable

- **40 Lpm: 24 rpm X 1.67 Liters**
- **86 Lpm: 25 rpm X 3.43 Liters**
- **103 Lpm: 30 rpm X 3.43 Liters**

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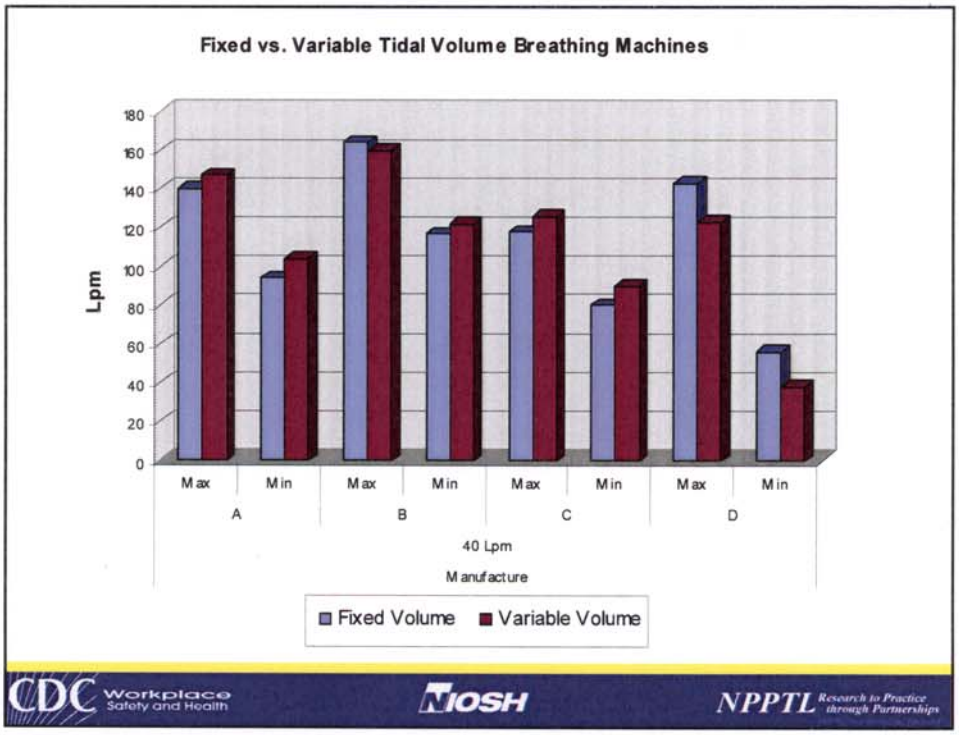
Fixed vs. Variable Tidal Volume Breathing Machines
Lpm
180
160
140
120
100
80
60
40
20
0
Max
Min
Max
Min
Max
Min
Max
Min
A
B
C
D
40 Lpm
Manufacture
Fixed Volume
Variable Volume
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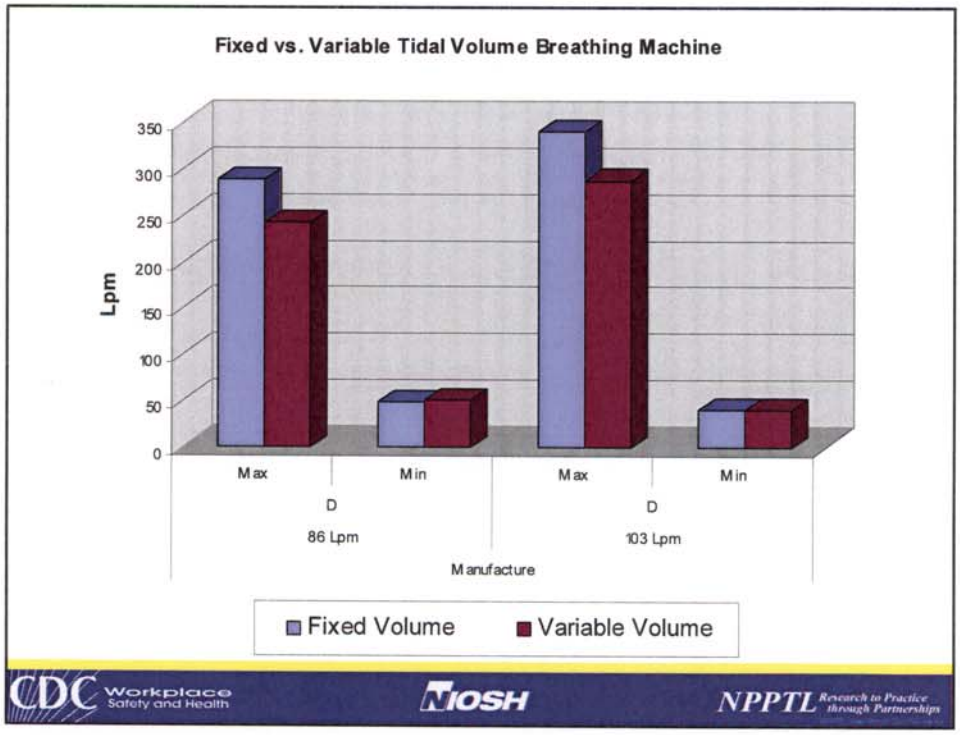
Fixed vs. Variable Tidal Volume Breathing Machine
Lpm
350
300
250
200
150
100
50
0
Max
Min
Max
Min
D
86 Lpm
D
103 Lpm
Manufacture
Fixed Volume
Variable Volume
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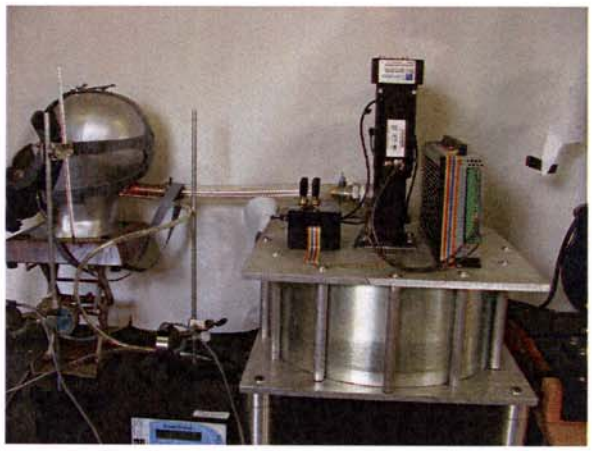
Variable Tidal Volume Breathing Machine



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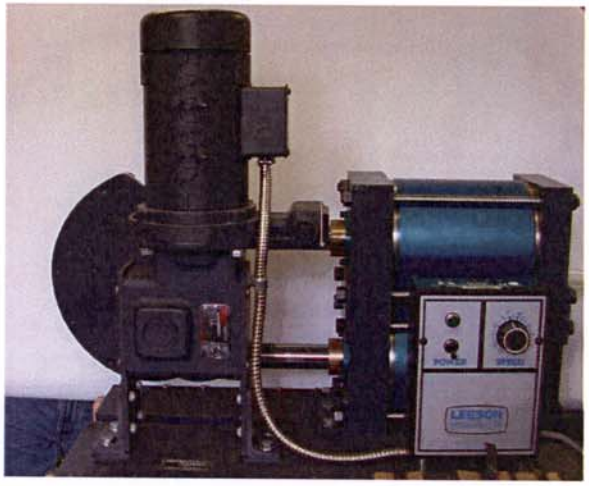
Fixed Tidal Volume Breathing Machine



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Reproducibility of PAPR Models

- **Determine unit to unit consistency within product lines**
- **Products from four manufacturers evaluated**
  - Three examples of each unit tested
  - Pressure profiles from all four manufacturers generated at 40 Lpm breathing rate
  - Data also generated at 86 and 103 Lpm for single higher capacity model

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Reproducibility of PAPR Models

- **Comparison Procedure**
  - Equivalent data snapshots for each test
  - Converted pressure profile to flow profile using previously determined correlation
  - Superimposed flow profiles from each manufacturer

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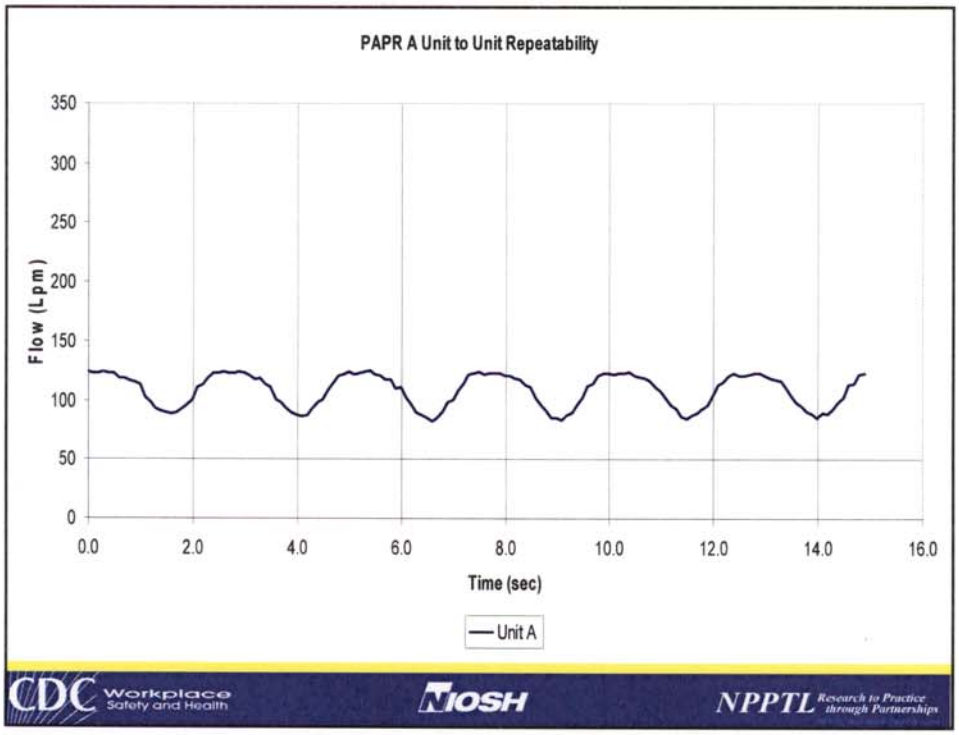
PAPR A Unit to Unit Repeatability
350
300
250
200
150
100
50
0
Flow (Lpm)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Time (sec)
Unit A
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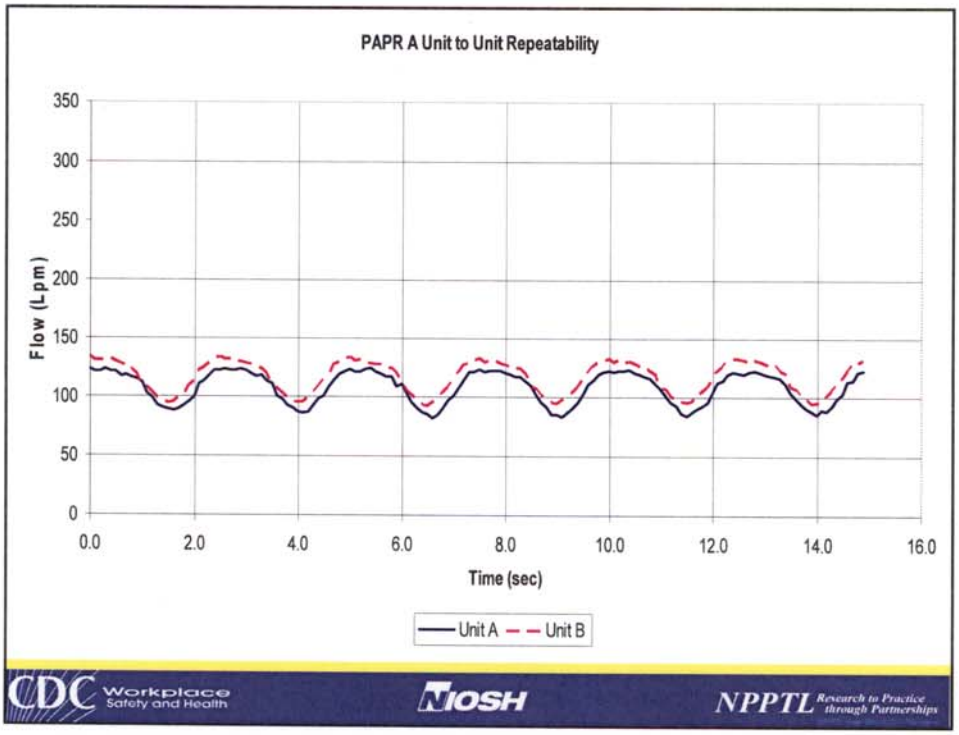
PAPR A Unit to Unit Repeatability
350
300
250
200
150
100
50
0
Flow (Lpm)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Time (sec)
Unit A
Unit B
CDC Workplace Safety and Health
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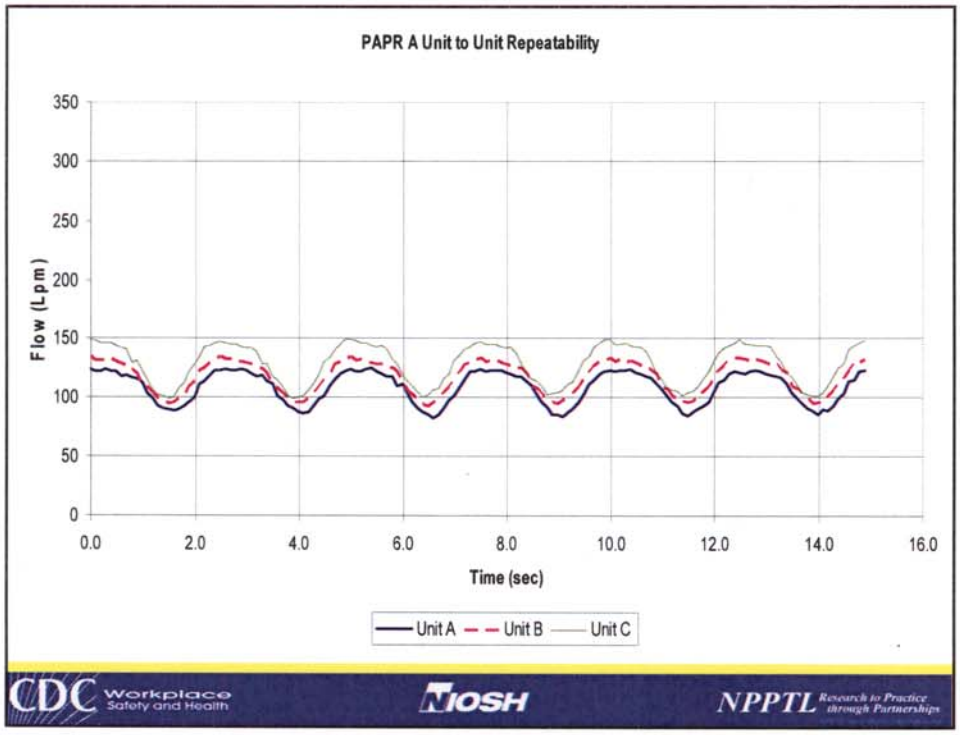
PAPR A Unit to Unit Repeatability
Flow (Lpm)
350
300
250
200
150
100
50
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Time (sec)
Unit A
Unit B
Unit C
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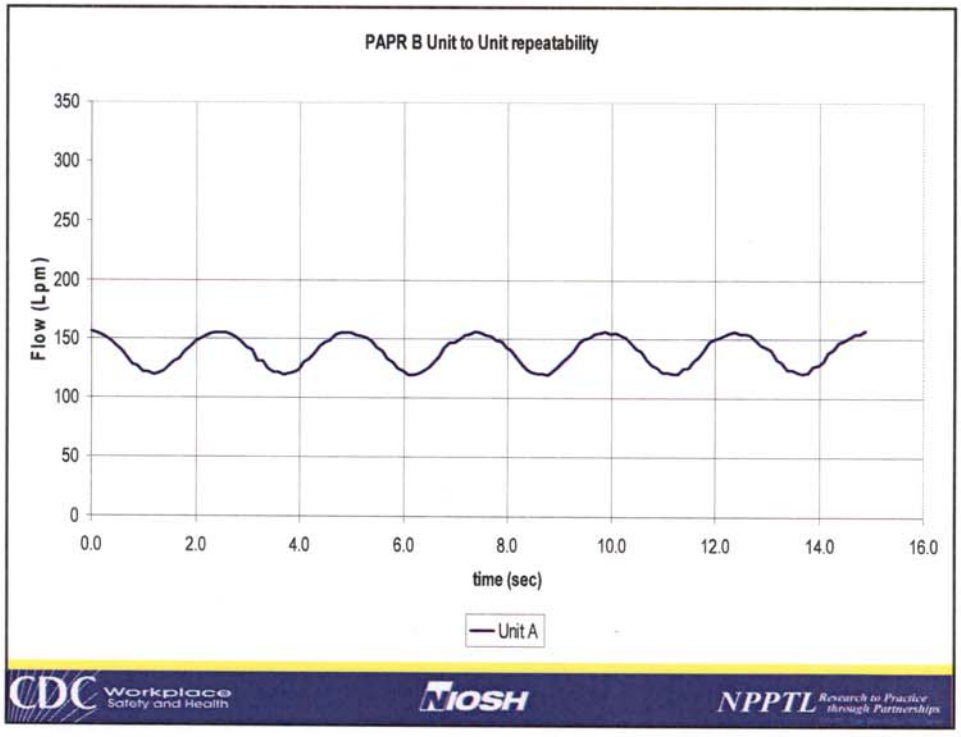
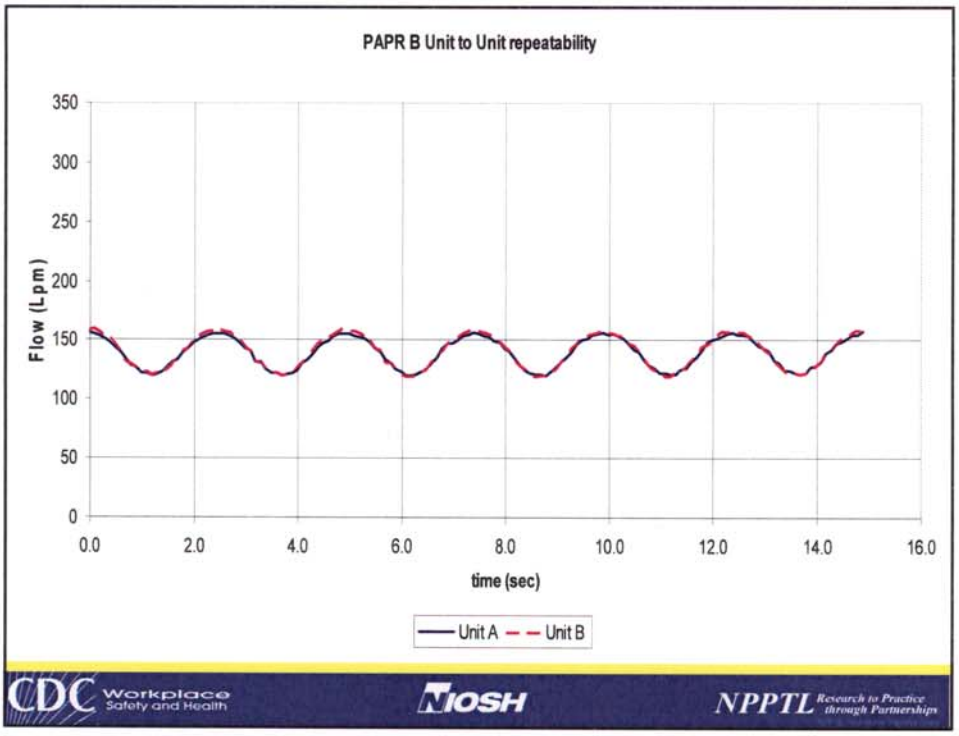

PAPR B Unit to Unit repeatability
Flow (Lpm)
350
300
250
200
150
100
50
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
time (sec)
Unit A
CDC Workplace Safety and Health
NIOSH
NPPTL Research to Practice through Partnerships


PAPR B Unit to Unit repeatability
Flow (Lpm)
350
300
250
200
150
100
50
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
time (sec)
Unit A
Unit B
CDC Workplace Safety and Health
NIOSH
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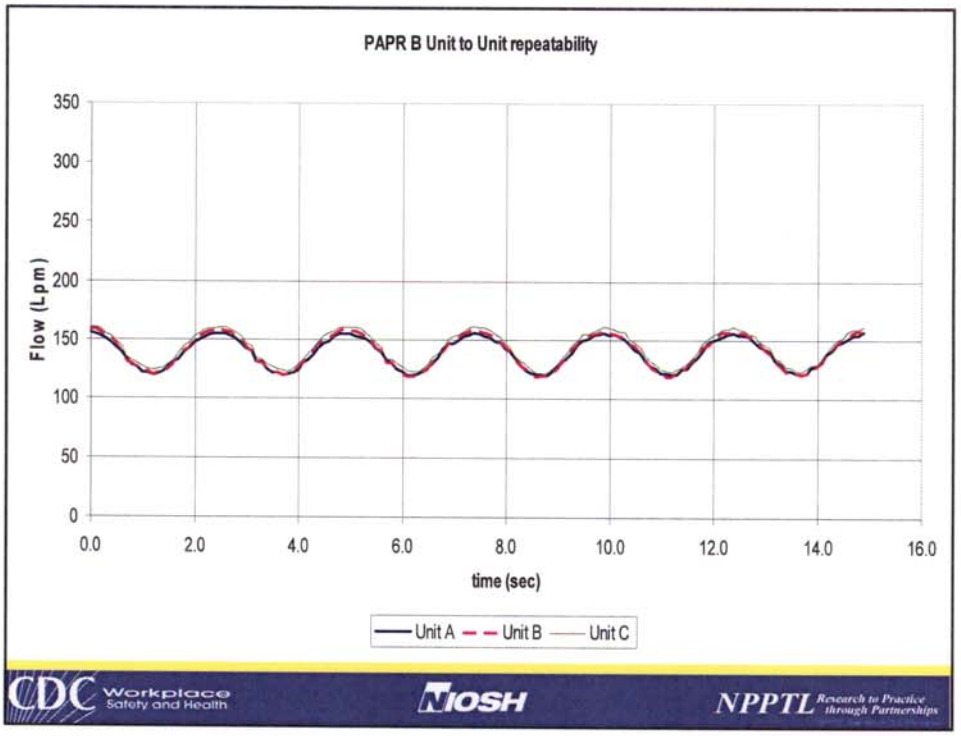
PAPR B Unit to Unit repeatability
Flow (Lpm)
350
300
250
200
150
100
50
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
time (sec)
Unit A
Unit B
Unit C
CDC Workplace Safety and Health
NIOSH
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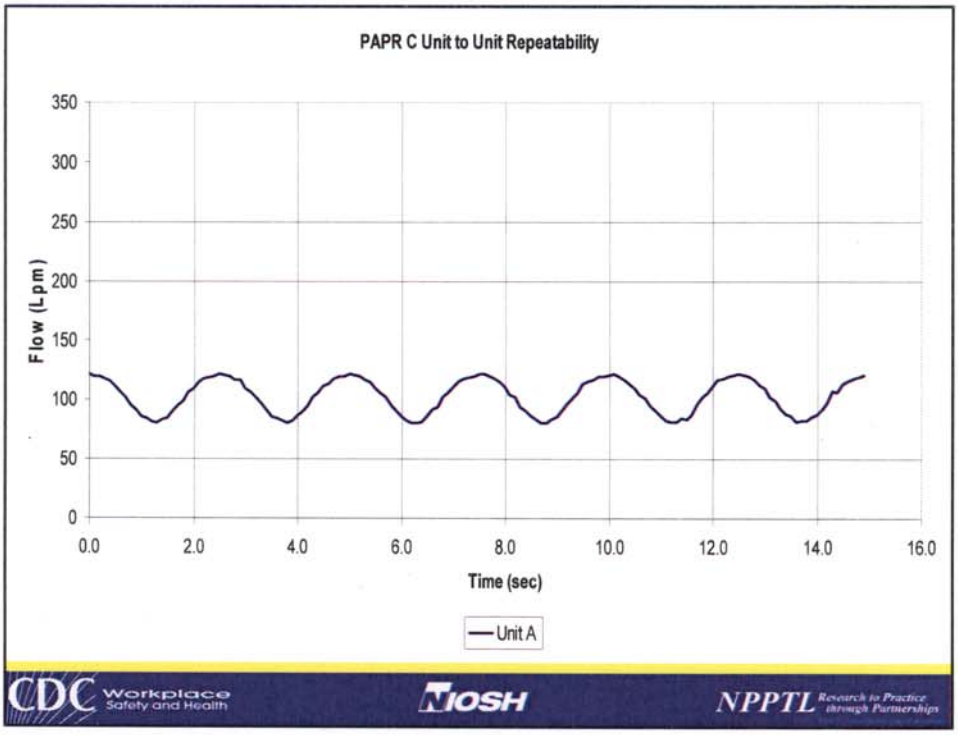
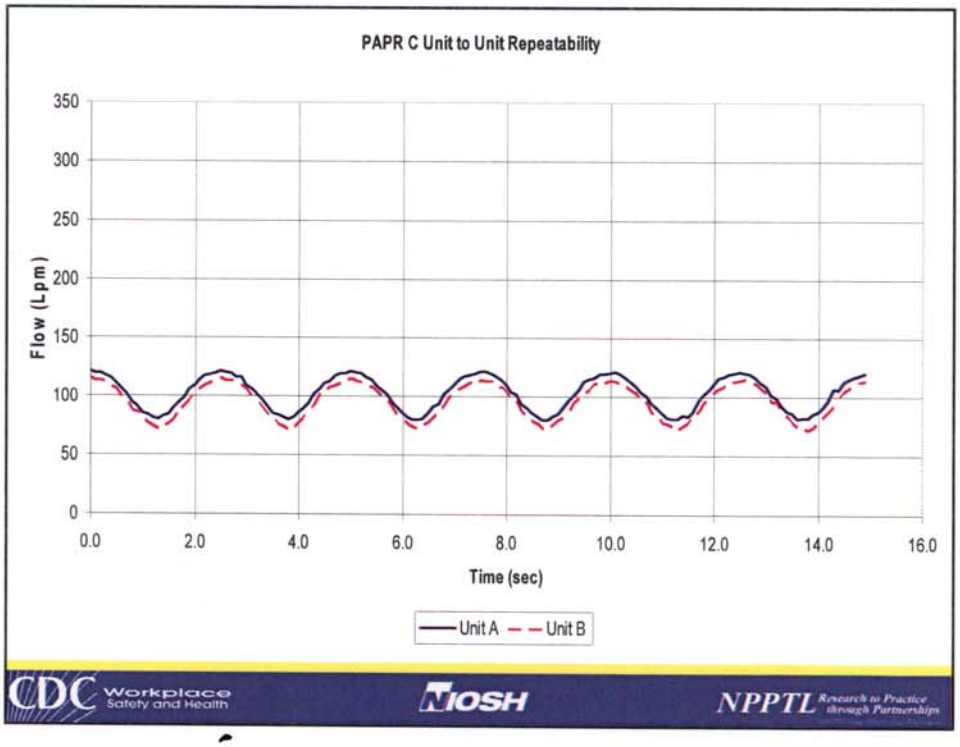

PAPR C Unit to Unit Repeatability
Flow (Lpm)
350
300
250
200
150
100
50
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Time (sec)
Unit A
CDC Workplace Safety and Health
NIOSH
NPPTL Research to Practice through Partnerships


PAPR C Unit to Unit Repeatability
Flow (Lpm)
350
300
250
200
150
100
50
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0.0
2.0
4.0
6.0
8.0
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12.0
14.0
16.0
Time (sec)
Unit A
Unit B
CDC Workplace Safety and Health
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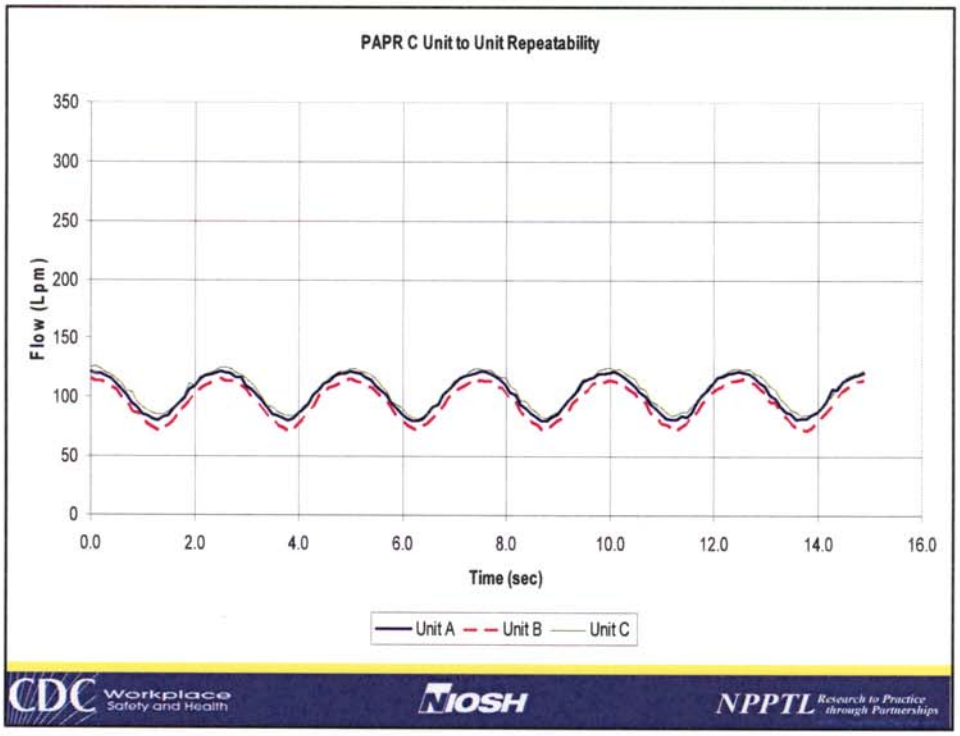
PAPR C Unit to Unit Repeatability
Flow (Lpm)
350
300
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50
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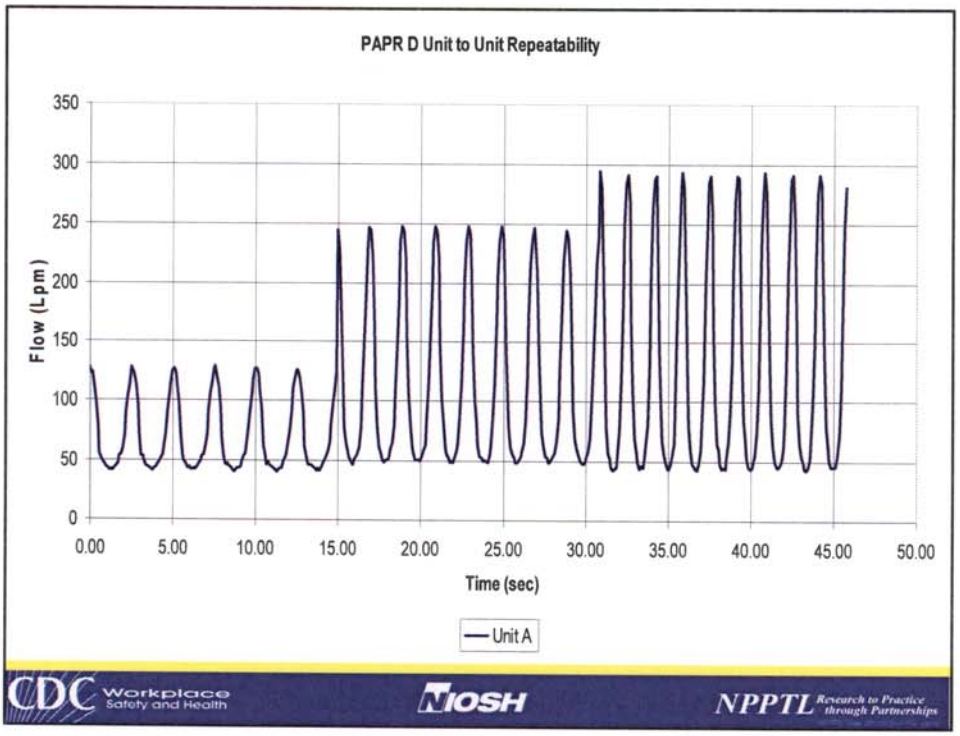
Time (sec)
Unit A
Unit B
Unit C
CDC Workplace Safety and Health
NIOSH
NPPTL Research to Practice through Partnerships


PAPR D Unit to Unit Repeatability
Flow (Lpm)
350
300
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
Time (sec)
Unit A
CDC Workplace Safety and Health
NIOSH
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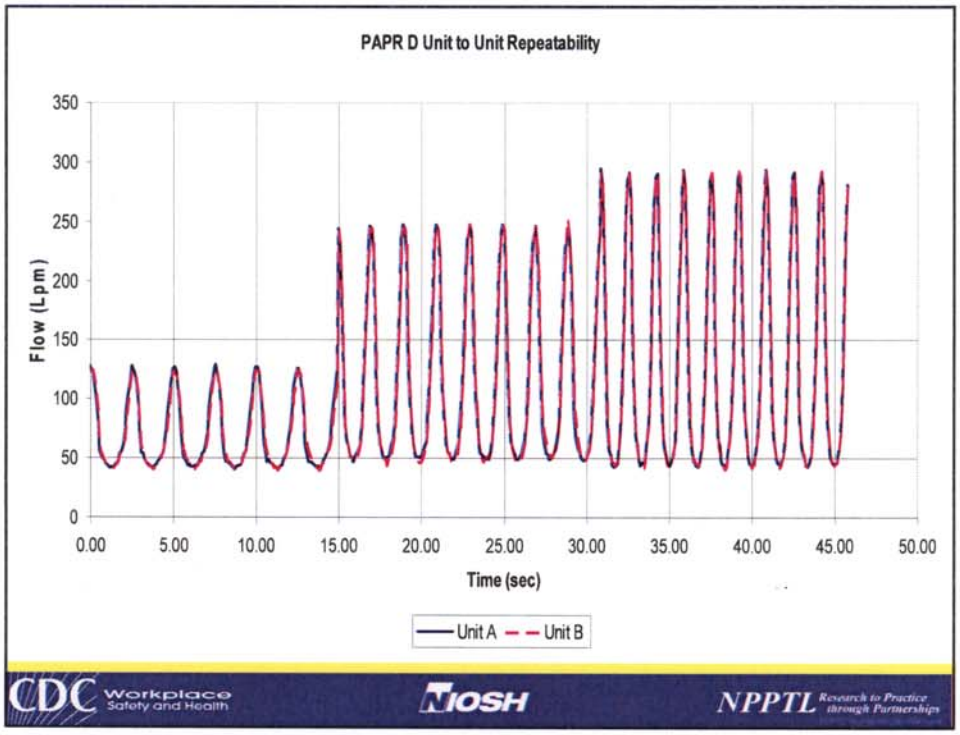
PAPR D Unit to Unit Repeatability
Flow (Lpm)
350
300
250
200
150
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50
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0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
Time (sec)
Unit A
Unit B
CDC Workplace Safety and Health
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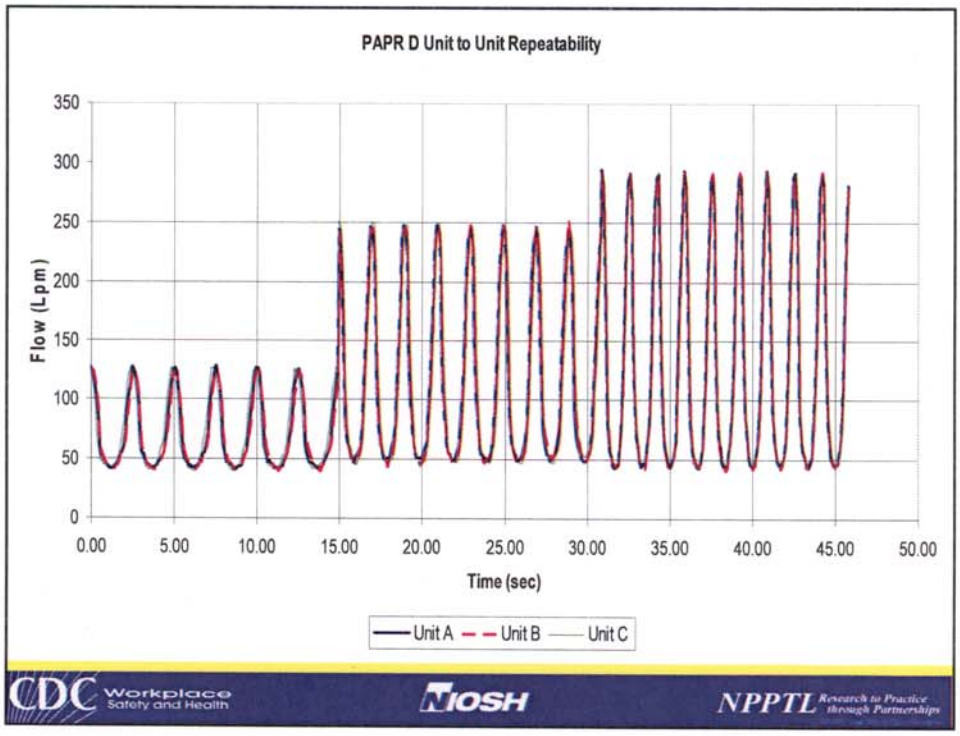
PAPR D Unit to Unit Repeatability
Flow (Lpm)
350
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250
200
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10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
Time (sec)
Unit A
Unit B
Unit C
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NIOSH-1 4/03

Air Flow Measurements

Questions?

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PAPR Benchmark Tests
Alarms

Sheraton Station Square
Pittsburgh, PA

Terry Thornton, Chemist

December 13, 2005

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Low Pressure Alarms

- Studies of a procedure to test Low pressure alarms
- An alarm is desired to alert the user that there is no longer sufficient pressure / flow in the facepiece to maintain positive pressure or maintain the protection
- Pressure is easier to measure in the facepiece than flow
- Technology will be for both the tight-fitting and loose-fitting

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Low Pressure Alarms

- Simple tests are to restrict the flow into the facepiece
- Room Temperature
- Cold Temperature

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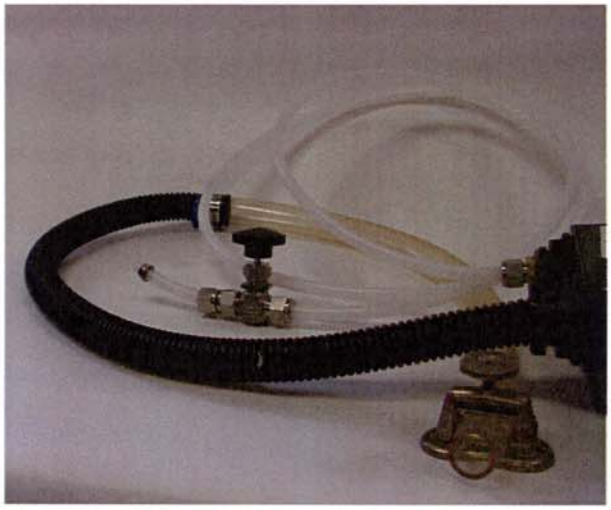
Low Pressure Alarm Facepiece Simulator



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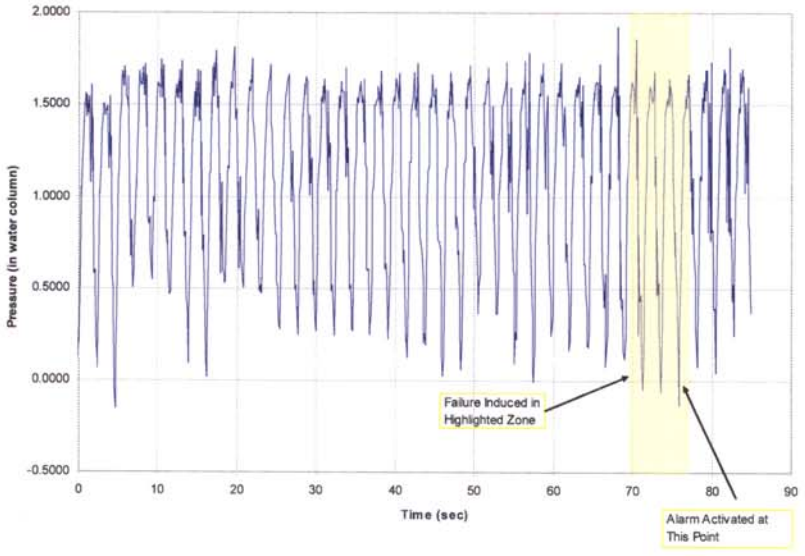
Low Pressure in Facepiece Failure



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Low Battery Alarms

- **Studies of a procedure to test Low Battery Alarms**
- **An alarm is desired to alert the user that there is sufficient battery life for a given amount of time**
- **What amount of time is sufficient?**
- **Under what conditions?**
  - Room temperature and low temperature?
  - Breathing rates?

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Low Battery Alarms

- **Evaluate alarm response to PAPR performance**
  - Audible, visual & vibratory
  - Facepiece pressure
  - No voltage measurement

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Low Battery Alarms

- **Monitored alarm performance of PAPR's B & D**
  - Evaluated at manufacturer's minimum recommended operating temperature
  - Batteries not cold soaked
  - Blower units cold soaked unless battery integrated
  - Insufficient data to draw conclusions on current technology vs. concept paper
  - Inconsistent battery life at cold temperatures

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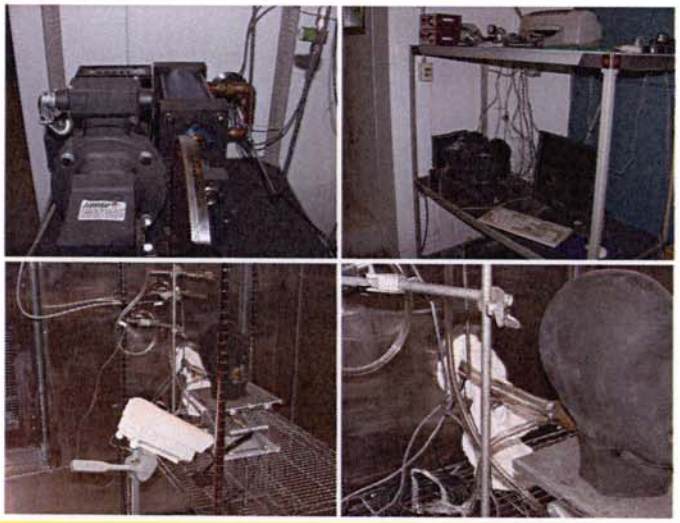
Environmental Testing



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Alarms

Questions?

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