National Personal Protective Technology Laboratory

CBRN Benchmark Testing (Breathing Rates, Battery Indicators, Low Flow Indicators, Particulate Tests, Crisis Provision)

Holiday Inn Select, Pittsburgh South
Pittsburgh, PA

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CBRN Respirator Standards

The findings and conclusions in this presentation have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

National Personal Protective Technology Laboratory

Breathing Requirements of CBRN Powered Air-Purifying Respirators with Benchmark Results

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July 20, 2005

Breathing Performance

- This is an evaluation of the respirator system performance based on a specific breathing rate and time.
- The performance that we are looking for is “positive pressure” in the breathing zone.
- The specific breathing rate and time is chosen by the applicant.
- Breathing rates “Moderate” or “High”
- Times are in 30 minute intervals

Breathing Performance

Breathing Rates

- **Moderate**: 40 Lpm Minute Volume, 24 respirations per minute. Using Silverman cam (622 kg•m/min)
- **High**: 86 Lpm Minute Volume, 30 respirations per minute. Sinusoidal wave form. Plus last 10 minutes at 103 Lpm, 37 respirations per minute.
- **Positive Pressure:** Measured in the breathing zone. Pressure must be greater than 0.0 and less than 3.5 inches of water column pressure

Breathing Performance Benchmark Data

- 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.
- Pass / Fail could not be identified except if a unit was less than positive pressure in the breathing zone during any part of the test

Breathing Performance Tests
Benchmark Data

Model \ Flow	40 Lpm	86 Lpm	103 Lpm
A	Pass	Fail	Fail
B	Pass	Fail	Fail
C	Pass	Fail	Fail
D	Pass	Pass	Pass

Breathing Performance at 40Lpm Benchmark Data

Time / Model	Start High/Low (in H_2O)	Midpoint High/Low (in H_2O)	End High/Low (in H_2O)	Total Time (hr:min)
A	1.0/0.0	0.9/0.0	0.8/-0.1	8:00
B	1.4/0.2	1.4/0.2	1.1/0.1	5:20
C	1.2/0.0	1.1/0.0	1.0/-0.1	8:00
D	1.4/0.1	1.4/0.1	1.3/0.1	6:00

Average values over one minute

Breathing Performance at 86Lpm Benchmark Data

Time / Model	Start High/Low (in H_2O)	Midpoint High/Low (in H_2O)	End High/Low (in H_2O)	Total Time (hr:min)
A	1.7/-3.5	1.7/-3.5	1.6/-3.6	2:00
B	1.8/-1.5	1.8/-1.4	1.8/-1.4	2:00
C	2.1/-3.5	1.9/-3.8	1.9/-3.9	2:00
D	2.2/0.4	2.2/0.4	2.2/0.4	2:20

Average values over one minute

Breathing Performance at 103Lpm Benchmark Data

Time / Model	Start High/Low (in H_2O)	Midpoint High/Low (in H_2O)	End High/Low (in H_2O)	Total Time (hr:min)
A	1.9/-4.8	1.8/-4.9	1.8/-5.0	2:00
B	2.1/-2.9	2.0/-3.0	2.0/-3.0	2:00
C	2.3/-5.2	2.2/-5.2	2.1/-5.2	2:00
D	2.4/0.4	2.6/0.2	2.5/0.2	2:02

Average values over one minute

Breathing Performance

Summary

- **Unit will be certified as “Moderate” or “High” breathing performance**
- **Moderate - 40 Lpm**
- **High - 86 Lpm (with 10 minute at 103 Lpm)**
- **Positive pressure in the facepiece**

Breathing Performance

Remaining Issues

- **What will be considered a less than zero pressure?**
- **Collection and evaluation of the data**

Breathing Performance

QUESTIONS?

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Low Battery Indicator, Low Pressure Indicator with Benchmark Results

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July 20, 2005

Low Battery Indicator

- This is an evaluation of the respirator system to alert the user there is at least 15 minutes of battery life sufficient to keep positive pressure in the facepiece
- The indicator will be evaluated while breathing at the at the “moderate” or “high” breathing rate as requested by the applicant

Low Battery Indicator

- No other battery indicator is required for the PAPR or the charger
- The indicator can be audible, visual, vibratory (or any combination), and must be readily detectable by the user
- The performance will be evaluated at room temperature 25 ± 2.5 °C and the lowest specified operational temperature (± 2.5 °C)

Low Pressure Indicator

- This is an evaluation of the respirator system to alert the user when there is insufficient airflow maintain positive pressure in the facepiece
- The indicator will be evaluated while breathing at the at the “moderate” or “high” breathing rate as requested by the applicant

Low Pressure Indicator

- The indicator can be audible, visual, vibratory (or any combination), and must be readily detectable by the user
- The performance will be evaluated at room temperature 25 ± 2.5 °C and the lowest specified operational temperature (± 2.5 °C)

Low Battery Indicator
Low Pressure Indicator
Benchmark Data

Model \ Indicator	Battery	Pressure	Flow
A	NA	NA	NA
B	Visible Indicator ≈ 20 min	Visible / audible flow indicator, unrelated to pressure	
C	NA	NA	NA
D	Visible / audible indicator ≈ 10 min	Visible / audible low pressure indicator	

Low Battery Indicator
Low Pressure Indicator
Benchmark Data

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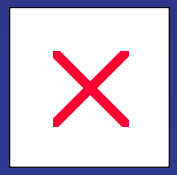

Low Battery Indicator
Low Pressure Indicator
Benchmark Data

QUESTIONS?

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Service Life Testing with Benchmark Results

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Service Life Testing

TRA	Challenge Concentration (ppm)	Breakthrough Concentration (ppm)
Cyclohexane	2600	10
Sulfur dioxide	1500	5
Hydrogen sulfide	1500	5
Cyanogen Chloride	300	2
Phosgene	250	1.25
Hydrogen Cyanide	940	4.7*
Ammonia	2500	12.5
Phosphine	300	0.3
Nitrogen dioxide	500	1 ppm NO_2 or 25 ppm NO
Formaldehyde	500	1

Service Life Testing

- **Manufacturer will apply for**
  - Moderate breathing rate performance
  - High breathing rate performance
- **Manufacturer specifies filter capacity**
  - Cap 1 through 6
- **System Service Life Test has been dropped from this concept**
- **Service life testing will be performed on individual canisters**

Service Life Testing

Airflow

- Constant flow PAPR
  - Canister shall be tested at a continuous airflow rate of the measured airflow divided by the number of canisters on the unit
- Demand Responsive PAPR
  - Using the equation: Minute Volume Flow $_{rms}$ = PIF / $\sqrt{2}$
  - Moderate: Peak Inspiratory Flow (PIF) of 126 Lpm therefore tested at 89 Lpm
  - High: Peak Inspiratory Flow (PIF) of 270 Lpm therefore tested at 191 Lpm

Service Life Testing

- Three tests at 25% RH, 25ºC at capacity requested, calculated flow
- Three tests at 80% RH, 25ºC at capacity requested, calculated flow
- Three tests at 50% RH, 25ºC at Crisis Provision, 263 Lpm divided by number of canisters

Crisis Provision (Panic Demand)

Constant Flow Testing

- The "constant flow" method was selected for the crisis provision testing
  - Consistency with common laboratory testing technology
  - The value of 263 Lpm is derived from an average maximum inhalation peak flow

Crisis Provision (Panic Demand)

Where does 263 Lpm come from?

- **Studies show that average maximum instantaneous peak airflows are approximately 370 Lpm.**
- **Assuming a sinusoidal wave and converting the peak flow to a constant flow the root mean square equation**

Minute volume $Flow_{rms}$ = PIF / $\sqrt{2}$

Service Life Testing

Example 1: Constant flow, Moderate breathing rate, 150 Lpm measured air flow using 2 canisters, Capacity 1

- Three canisters tested at 25% RH, 25ºC, 75 Lpm, 15 minutes
- Three canisters tested at 80% RH, 25ºC, 75 Lpm, 15 minutes
- Three canisters tested at 50% RH, 25ºC, 132 Lpm, 5 minutes

Service Life Testing

Example 2: Constant flow, High breathing rate, 285 Lpm measured air flow using 3 canisters, Capacity 1

- Three canisters tested at 25% RH, 25ºC, 95 Lpm, 15 minutes
- Three canisters tested at 80% RH, 25ºC, 95 Lpm, 15 minutes
- No Crisis Provision needed due to airflow exceeding the 263 Lpm

Service Life Testing

Example 3: Demand responsive, High breathing rate, 2 canisters, Capacity 1

- Three canisters tested at 25% RH, 25ºC, 96 Lpm, 15 minutes
- Three canisters tested at 80% RH, 25ºC, 96 Lpm, 15 minutes
- Three canisters tested at 50% RH, 25ºC, 132 Lpm, 5 minutes

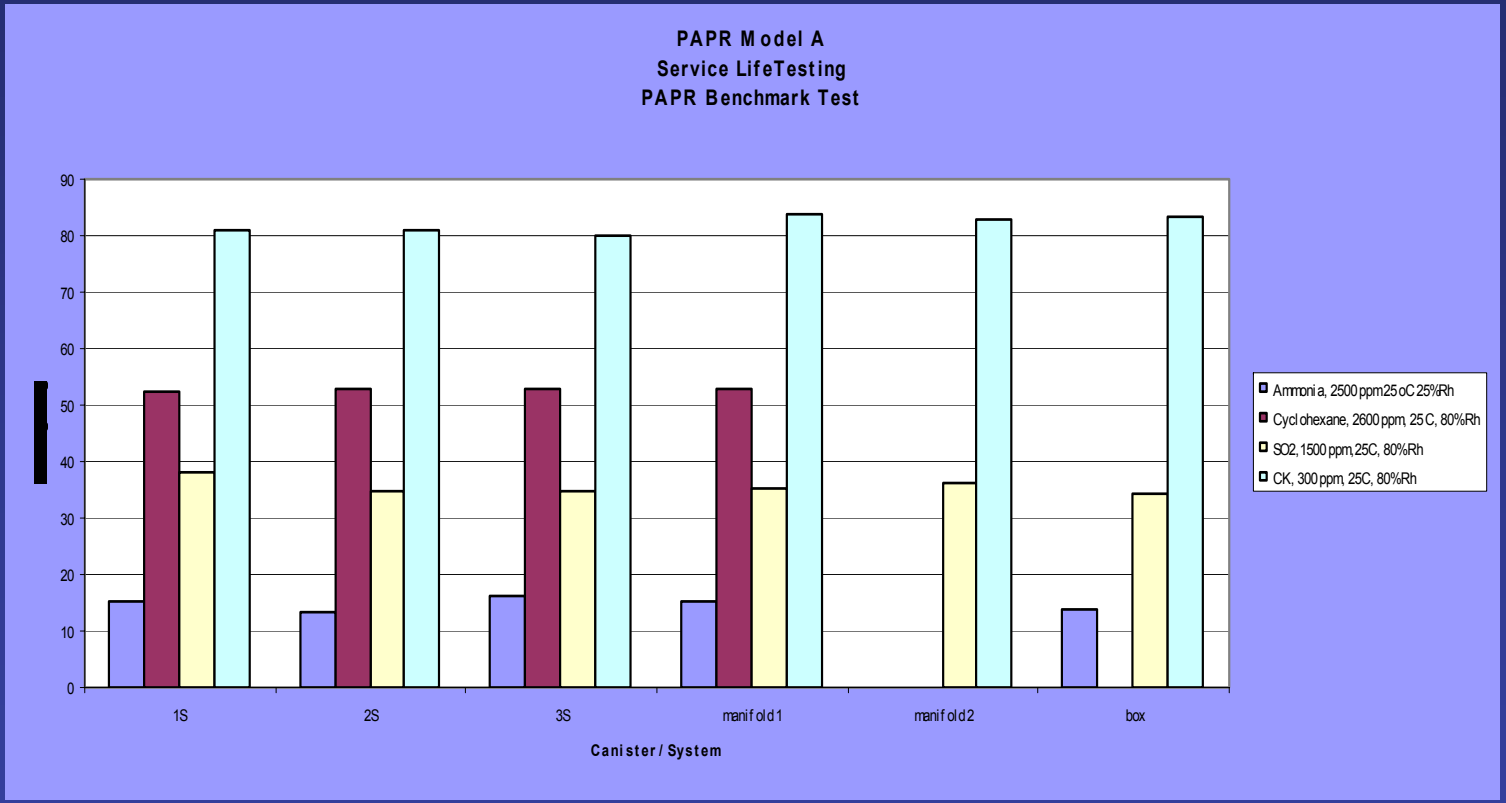
Service Life Benchmark Testing

- **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.**

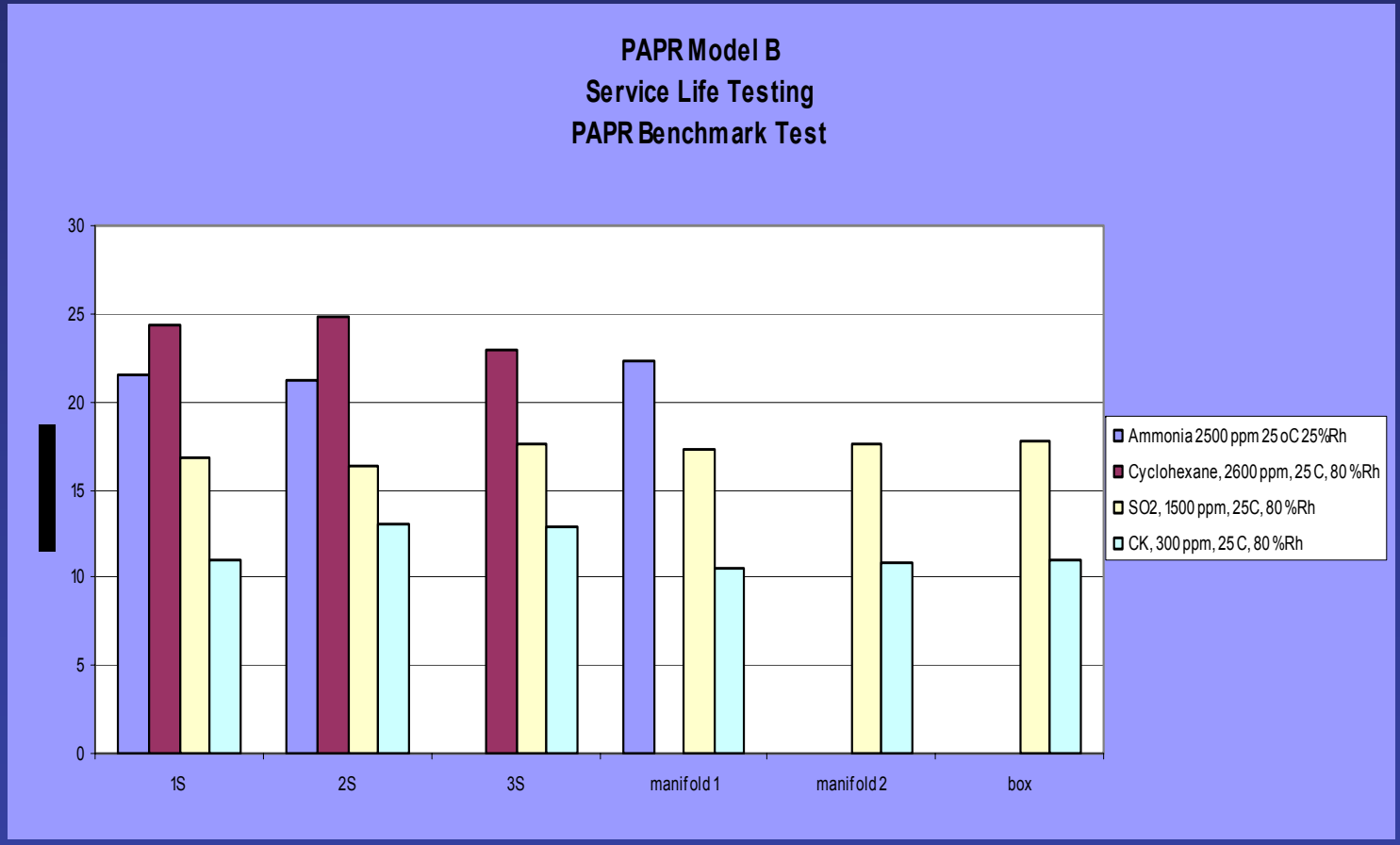
Service Life Benchmark Testing

- 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

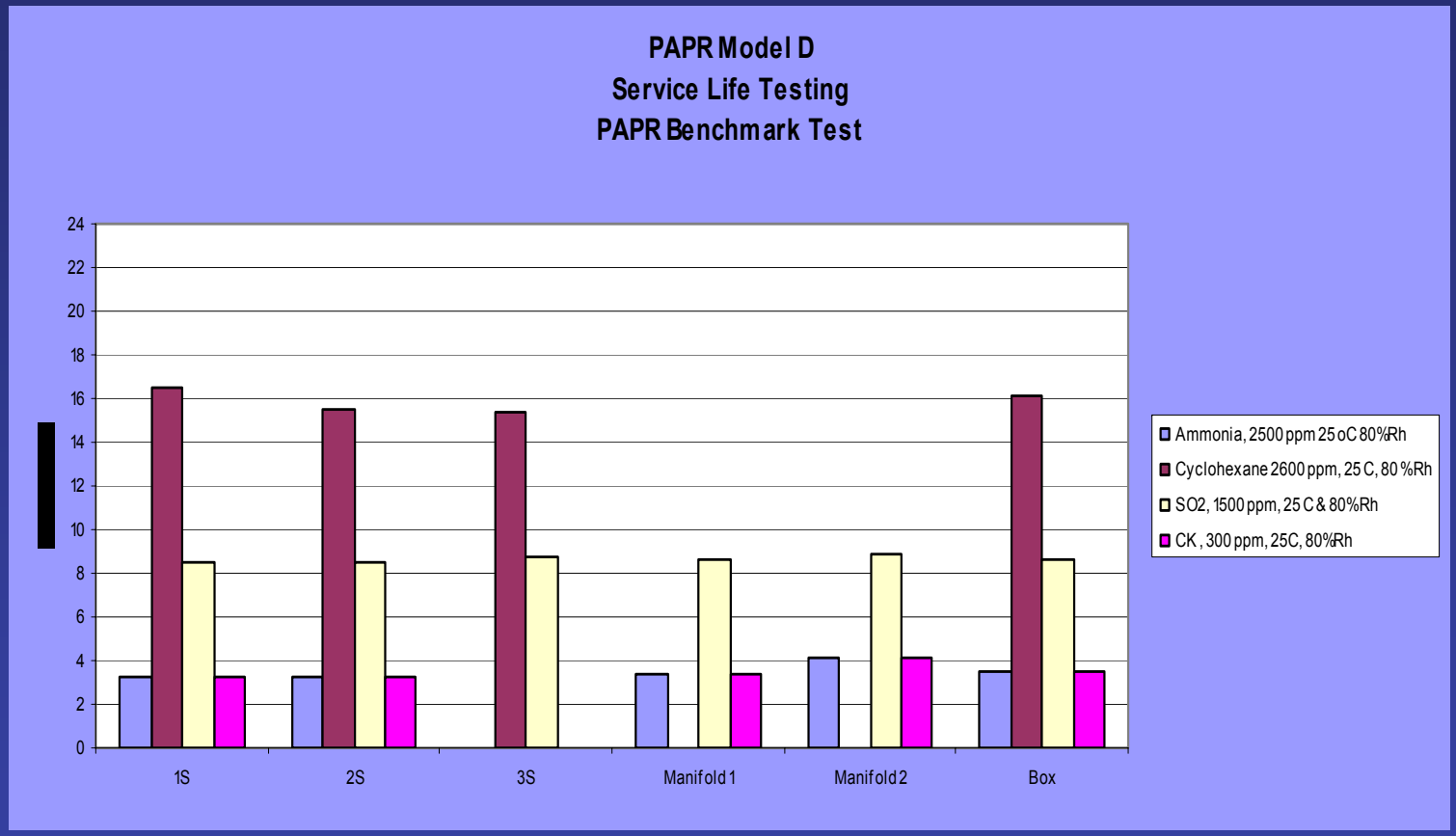
Service Life Benchmark Testing



Service Life Benchmark Testing



Service Life Benchmark Testing



Service Life Particulate Testing

- One high flow particulate tester has been delivered to NPPTL
- Second high flow particulate tester is expected for delivery this month
- Particulate tester is setup in the laboratory with proper compressed air and ventilation requirements
- Initial gravimetric testing for 200 mg challenge point to begin this week

Service Life Testing

Remaining Issues

- **High Flow Particulate Testers**
- **Formaldehyde Study**
- **Continue service life benchmark testing**
  - HCN; Phosgene; Phosphine

Service Life Testing

- **QUESTIONS?**