National Personal Protective Technology Laboratory

# Powered Air-Purifying Respirator (PAPR) Work Rate Evolution

Policy and Standards Development Branch

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# Stages of PAPR Work Rate Evolution

- **Current Approval Method**
  - Constant flow requirement
- **Work Rates Proposed in December 21, 2007 Draft of PAPR Standard**
  - Positive pressure at maximum manufacturer specified work rate
- **Additional Work Rates Now Under Consideration**
  - Breath Assisted and Positive Pressure PAPR classifications
  - Approval requirement to be determined for Breath Assisted class

# Current PAPR Airflow Requirements

- **Minimum constant airflow required for approval**
  - Respiratory inlet covering mounted on headform in sealed chamber with blower outside
  - Vacuum blower removes air from chamber to maintain zero pressure differential between chamber and atmosphere
  - Vacuum blower flow monitored with dry test meter

# Current PAPR Airflow Requirements

**Currently Approved Minimum Flow Rates**

| | |
|---|---|
| **Tight-fitting PAPR** | **115 Lpm** |
| **Loose-fitting PAPR** | **170 Lpm** |

- **In most cases, these flows are capable of maintaining positive pressure in the breathing zone of the PAPR respiratory inlet covering at a work rate corresponding to 40 Lpm breathing rate**

# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

- **Original objectives of multiple work rate approvals**
  - Improved protection
    - Sufficient airflow
    - Positive pressure
  - Flexibility
    - Comfort
    - Cost savings

# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

**Proposed NIOSH Work Rates (Sinusoidal Waveform) Expressed as Respiration Rates**

| Work Rate | Minute Volume | Tidal Volume and Respirations | Peak Flow |
|---|---|---|---|
| Low | 25 liters | 1.30 liters @ 19.2 per minute | 78.54 Lpm |
| Moderate | 40 liters | 1.67 liters @ 24 per minute | 125.66 Lpm |
| High | 57 liters | 1.95 liters @ 29.1 per minute | 179.07 Lpm |

# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

- **Projected test protocol**
  - Manufacturer specifies highest work rate from table for intended use of PAPR
  - PAPR must maintain positive pressure in breathing zone of respiratory inlet covering while properly mounted on a breathing machine operating at the specified work rate

# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

- **Additional criteria for fully evaluating PAPR performance at specified work rate**
  - Appropriate airflow for particulate and gas/vapor challenge testing
    - Minimum constant airflow required to maintain positive pressure in the breathing zone of the respiratory inlet covering
    - Required flows experimentally determined for moderate and high work rates for tight-fitting PAPR and for all three work rates for loose-fitting PAPR

# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

**PAPR Bench Test Constant Airflow Requirements Based on Positive Pressure Tests With Single Speed Units**

| Respirator Type | Flow Associated with Each Work Rate | | |
|---|---|---|---|
| | Low Work Rate | Moderate Work Rate | High Work Rate |
| Tight-fitting | Not Applicable | 115 Lpm | 170 Lpm |
| Loose-fitting | 115 Lpm | 170 Lpm | 235 Lpm |

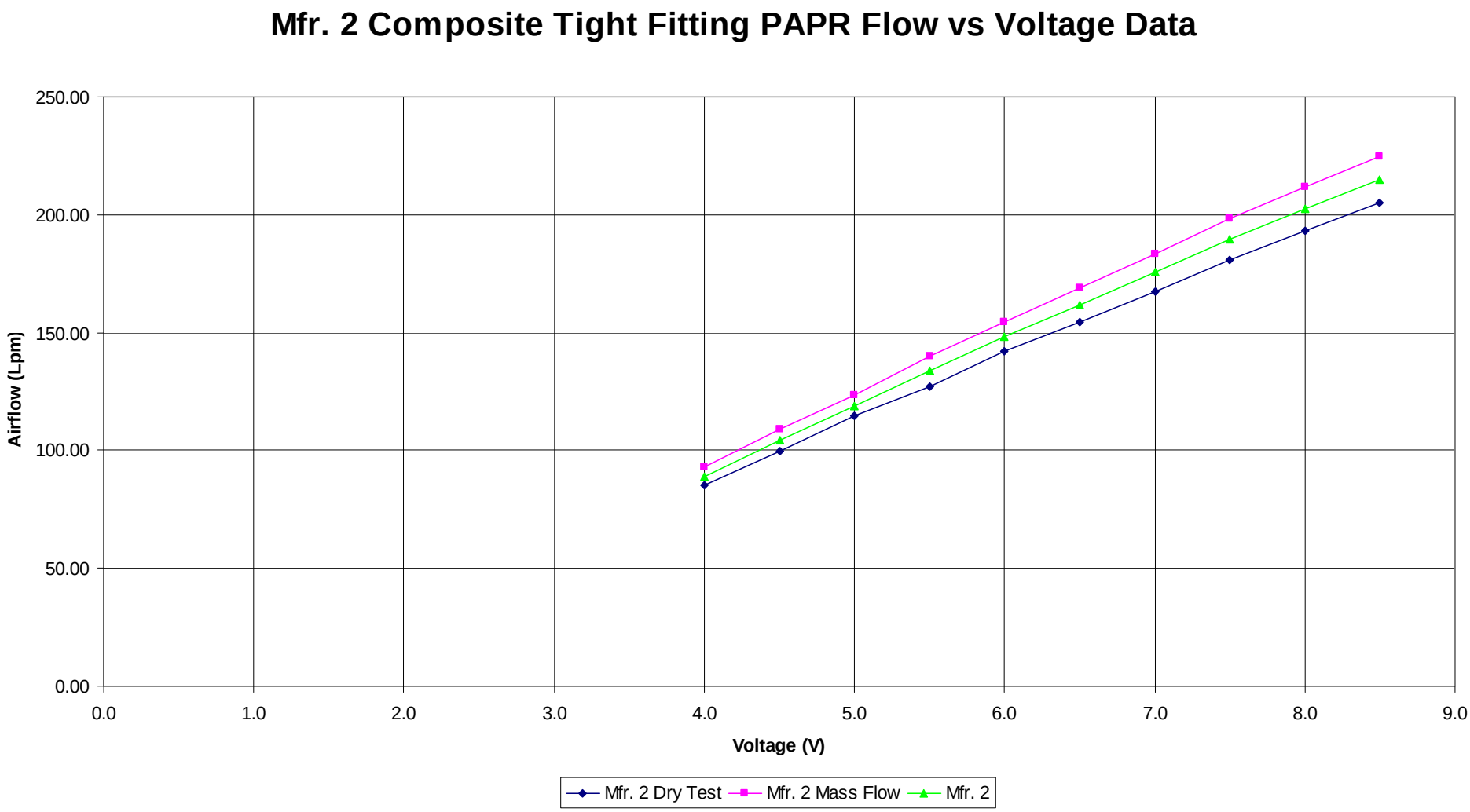
# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

- **Experimental determination of constant airflows required to maintain positive pressure in breathing zones of PAPR respiratory inlet coverings**
  - PAPRs designed to operate at desired constant flow rates not commercially available
    - Flow rates of several samples of two blower models equipped with both tight and loose-fitting respiratory inlet coverings controlled by varying input voltage through external power supply in lieu of manufacturer battery packs

# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

- **Calibration of airflow versus voltage**
  - Vary voltage and record airflow for each PAPR sample
    - Measure airflow for each sample using both a dry test meter and a mass flow meter
  - Plot data and correlate using second order polynomial fit
    - Voltages required to obtain desired test flows can now be predicted
    - Flow at voltage required to maintain positive pressure can be calculated

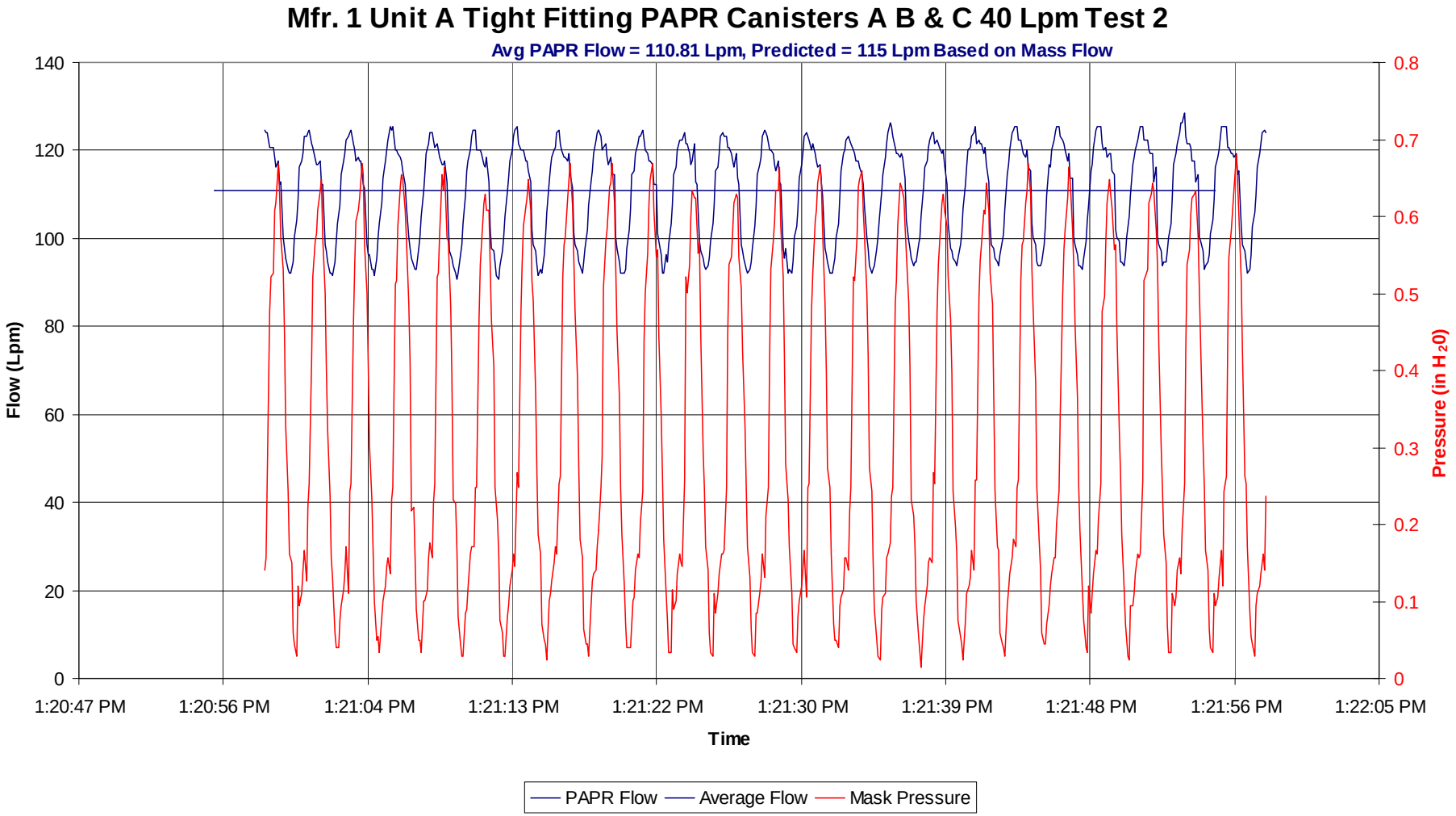
# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)



# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

- **Positive pressure breathing machine test**
  - Mount PAPR respiratory inlet covering on torso coupled to a variable frequency and tidal volume breathing machine
  - Monitor and record breathing zone pressure and canister pressure drop
  - Plot pressure profile, flow profile calculated from canister $\Delta P$ and average PAPR flow

# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)



# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

- **Conclusions from positive pressure PAPR breathing machine tests**
  - Flow versus voltage correlations were similar regardless of whether dry test meter or mass flow meter used to determine flow
  - Excellent repeatability between different samples of same model
  - Excellent agreement of predicted flow with average of flow calculated from canister pressure drop

# Work Rates Proposed in PAPR Standard Concept Paper (December 21, 2007)

- **Conclusions from positive pressure PAPR breathing machine tests (cont.)**
  - Flow required to maintain positive pressure at both work rates for tight-fitting PAPR similar for both models tested
  - Flow required to maintain positive pressure at all three work rates for loose-fitting PAPR similar for both models tested

# Work Rates Under Consideration for Inclusion in PAPR Standard

- **Two PAPR classes**
  - Breath assisted
  - Positive pressure
- **Additional work rates (expressed as respiration rates)**
  - Sedentary (11Lpm)
  - Extremely high (78 Lpm, 99 Lpm or both)
  - Based on International Technical Specification ISO/TS 16976-1:2007, Classes 1, 7 and 8 for the ISO standard man (body surface of 1.8$m^2$)

# Work Rates Under Consideration for Inclusion in PAPR Standard

- **Characterization of proposed work rates**
  - Sedentary rate
    - Sinusoidal ventilation profile
    - Undefined tidal volume and frequency
  - Extremely high work rate(s)
    - Undefined ventilation profile
    - Undefined tidal volume and frequency

# Work Rates Under Consideration for Inclusion in PAPR Standard