Enhanced Protection Positive Pressure Respirator (EP3R)

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Introduction

- Negative pressure respirator

- Three potential leak paths
  - Canister
  - Outlet valve
  - Face seal

- Distribution of protection factors seen from laboratory & field testing

- Improve protection
  - Prevent inward leakage
  - Reduced dependency on seal conformity
  - User real time feed back on fit
Powered Air Purifying Respirators

• Provide positive pressure
  – >150 l·min⁻¹ continuous flow
  – Overcome shortcomings in fit
  – Offer very high levels of protection

• Comprise
  – Bulky
  – Sizable power source
  – Multiple canisters
  – Demand can exceed blower supply
Dual Cavity (DC) Concept

- Dstl concept
- Isolates breathing within an inner sealing oro-nasal mask (nose cup)
- Employs a small self-contained blower and separate filter canister to create a positive pressure within the eye space
DTRA Funded Effort

- Retro-fit negative pressure respirator with dual cavity components
- No external blower units
- Provides a step change increase in the level of protection

Chin cup and air guide replaced by oro-nasal mask

Fan (0.35 W) 10 l·min⁻¹

Dual Cavity Control

NORMAL BREATHING

NO

BOHSS SPEAKING DEEP BREATHING BREACH SEAL

Log 'In mask particle count' /particles.cm⁻³

Time /s

Dual Cavity
Control
EP3R Concept TSWG

• Extension of the Dual Cavity Respirator
• Single, ergonomic dual flow canister
Programme Outline

• Phase 1
  – Canister design concepts
  – Prototype canister development & testing

• Phase 2
  – Real-time fit indicator
  – Integration of components into respirator
  – Final EP3R prototype assessment against a commercial PAPR system
Canister Concept

- Two beds completely separate
- Maximises performance of Bed A
Canister Requirements

- NIOSH (42 CFR Part 84, Full-face respirator)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NIOSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canister diameter</td>
<td>≤ 12.54 cm</td>
</tr>
<tr>
<td>Weight</td>
<td>≤ 500 g</td>
</tr>
<tr>
<td>Pressure drop (85 l·min⁻¹)</td>
<td>&lt; 490 Pa</td>
</tr>
<tr>
<td>Particulate Efficiency (P100)</td>
<td>99.97%</td>
</tr>
<tr>
<td>Cyclohexane (2600 ppm, 64 l·min⁻¹, 25% RH)</td>
<td>≥ 15 min</td>
</tr>
<tr>
<td>Cyclohexane (2600 ppm, 64 l·min⁻¹, 80% RH)</td>
<td>≥ 15 min</td>
</tr>
<tr>
<td>Service Life (2600 ppm, 100 l·min⁻¹, 50% RH)</td>
<td>≥ 5 min</td>
</tr>
</tbody>
</table>

Bed A only (Bed B assessed at 20 l·min⁻¹)
Prototype Construction

- 9 dual flow prototype canisters
  - Nylon
  - ULPA grade particulate filter (99.999%)
  - ASZMT carbon (12 x 30)
- Canister diameter 12 cm (NIOSH ≤ 12.54)
- Carbon weight
  - Bed A 153 g ± 1 g
  - Bed B 47 g ± 1 g
- Passed bromobutane test
- Total canister weight 515 g (NIOSH ≤ 500 g)
# Canister Test Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NIOSH</th>
<th>EP3R Prototype</th>
</tr>
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<tbody>
<tr>
<td>Canister diameter / cm</td>
<td>≤ 12.54</td>
<td>12 ✔</td>
</tr>
<tr>
<td>Weight / g</td>
<td>≤ 500</td>
<td>515 ✗</td>
</tr>
<tr>
<td>Pressure drop / mmH₂O (at 85 l·min⁻¹)</td>
<td>&lt; 50</td>
<td>342 ✔</td>
</tr>
<tr>
<td>Particulate Efficiency % (at 85 l·min⁻¹)</td>
<td>99.97</td>
<td>&gt; 99.999 ✔</td>
</tr>
<tr>
<td>Cyclohexane (64 l·min⁻¹, 25% RH) / min</td>
<td>≥ 15</td>
<td>27 ✔</td>
</tr>
<tr>
<td>Cyclohexane (64 l·min⁻¹, 80% RH) / min</td>
<td>≥ 15</td>
<td>23 ✔</td>
</tr>
<tr>
<td>Service Life (100 l·min⁻¹, 50% RH) / min</td>
<td>≥ 5</td>
<td>14.5 ✔</td>
</tr>
</tbody>
</table>

Bed A  | Bed B (20 l·min⁻¹)
---     | ---
342 ✔  | 301
> 99.999 ✔ | > 99.999
27 ✔  | 17
23 ✔  | 12
14.5 ✔ | N/A
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Real-Time Fit Indicator (RTFI)

- Pressure sensors
- \( \Delta P = P_{\text{eye space}} - P_{\text{external}} = +ve \)
- Micronel D301Q blower
- Dual colour LED
- Feedback loop
  - Increase the power supply to blower if \( \Delta P \) falls below a threshold level
Internal Assembly Unit

- Blower, electronics, battery
EP3R Prototype
RTFI Assessment

Green LED indicates in-mask pressure > 20 Pa
Protection Factor (PF) Assessment

- EP3R, APR and PAPR
- Single volunteer (6 repeats)
- Salt challenge (approx. $3 \times 10^6$ p/cc)
- RBES (real-time PF)
- Exercises
  - Normal Breathing (NB)
  - Deep Breathing (DB)
  - Head Side to Side (HSS)
  - Head Up and Down (HUD)
  - Bending over moving Head Side to Side (BOHSS)
  - Breach seal (combined with a deep breath after 10 s, 30 s and 50 s)
Mean PF Results

![Graph showing mean protection factor results for different exercises and equipment types. The x-axis represents various exercises (No Blower, Normal Breathing, Deep Breathing, Head to Side, Head Up and Down, Bend Over, Head to Side), and the y-axis represents the mean protection factor (PF). The graph compares EP3R oro-nasal, EP3R eye space, APR, and PAPR.]
Breach Seal

- Breach seal (combined with a deep breath (DB) after 10 s, 30 s and 50 s)
- In-mask particle count
Breach Seal Results

![Graph showing Breach Seal Results](image)

- EP3R oro-nasal
- EP3R eye space
- PAPR

Exercise:
- Breach Seal
- DB1
- DB2
- DB3

Mean In-Mask Count / Particles cm⁻³
Conclusions

• EP3R concept has been developed
• EP3R prototype offered a step change increase in protection compared to a conventional APR device, without the associated drawbacks of positive pressure systems
• For the Breach Seal exercise the EP3R provided increased levels of protection compared with pressurised, PAPR
• UK industry is now working with Dstl and Ploughshare Ltd to explore the commercialisation of the EP3R concept
Acknowledgements

• TSWG
• Emcel Filters
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• Circuit Master Design