CO Protection for Escape Respirators

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Outline

• Background
• Objectives
• Research Methods
• Results
• Conclusion
Background
Respiratory Protection

- For long term use (~30 min.), SCBAs are used (bottled air with hose and full face mask – cost $2,000 – 3,000)
- Bottled air escape respirators (short term ~5 min.) use bottled air with a hood and airtight neck piece (cost ~$600)
- Air purifying escape respirator for Chemical, Biological, Radiological and Nuclear (CBRN) hazard protection for ~15 minutes (cost ~$250)
Carbon Monoxide

- First Responders and Respirators
  - Police & paramedics (firefighters have access to SCBA)
  - Most common incidents are fire related (1.7 million fires in the U.S. in 2000, resulting in ~4,200 deaths)

- Civilian Escape from Fires
  - Fires produce hazardous compounds, including CO

Typical contaminant levels in fire smoke

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Typical Conc (ppm)</th>
<th>Max Conc (ppm)</th>
<th>IDLH (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrolein</td>
<td>1.9</td>
<td>98</td>
<td>5</td>
</tr>
<tr>
<td>Benzene</td>
<td>4.7-56</td>
<td>250</td>
<td>3000</td>
</tr>
<tr>
<td>CO</td>
<td>246-1450</td>
<td>27000</td>
<td>1200</td>
</tr>
<tr>
<td>HCl</td>
<td>0.8-1.3</td>
<td>280</td>
<td>100</td>
</tr>
<tr>
<td>HCN</td>
<td>0.14-5.0</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>NO₂</td>
<td>0.04-0.7</td>
<td>9.5</td>
<td>50</td>
</tr>
<tr>
<td>SO₂</td>
<td>2.3</td>
<td>42</td>
<td>100</td>
</tr>
<tr>
<td>Particulates (mg/m³)</td>
<td>232</td>
<td>15000</td>
<td>n.a.</td>
</tr>
</tbody>
</table>
Escape Hoods

• Certified Escape Hoods for CBRN use are currently available
• Hood covers the head and neck and is made of laminate material
• Easy to put on, provides ~15 minutes of escape time
• Air flows through a canister (typically a carbon material)
• Exhaled air flows out of a separate valve
• Effective against CBRN
  – No hoods on the market that protect from CO
• New NIOSH certification requires CO protection
• NIOSH currently accepting applications for testing
NIOSH Design Criteria

• Requirements
  – 15 minutes of protection from 3,600 ppm of CO
  – Peak CO slip during 15 minutes should be no higher than 500 ppm
  – Testing to be done at 0°C with 64 slpm of air
Objective
Objectives

- Develop a catalytic solution that can be added to existing escape respirators
- Catalyst oxidizes CO to CO$_2$ (lower toxicity)
- Catalyst needs to work under NIOSH specified conditions
- Test catalyst under a CDC SBIR Phase I extramural grant
Research Methods
Catalysts for Low Temperature CO Oxidation

- Catalysts can oxidize CO in air at high temperature (>150°C)
  - Not at 0°C
  - Some need dry air

Test conditions:
- CO = 58 ppm
- H₂O = 1%
- CO₂ = 0.7%
- Balance Air
- GHSV = 60,000 h⁻¹
- T = 25°C

![Graph showing conversion over time for different catalysts](image)
Experimental Apparatus

- Testing in TDA’s labs using NIOSH protocol
  - 3600 ppm CO in air
  - 32°F (0°C)
  - 64 slpm (adjusted at TDA to give same space velocity in our smaller test bed)
  - Tested at GHSV of 30,000 to 120,000 hr⁻¹
Results
• 3600 ppm CO in air; 75% RH at 0°C (32°F)
Testing – Canister

- 64 slpm of 0°C air with 3,600 ppm CO
- Test for CO content in the outlet

**Test Conditions**
- temp. 0 °C
- 64 slpm
- 3600 ppm CO
- 75% R.H.
Conclusion
Summary

- TDA’s catalyst passes NIOSH test at small scale and in prototype scale canister
- In follow up effort,
  - Catalyst manufacture needs to be scaled up
  - Cost of catalyst (and canister) needs to be optimized/minimized
  - Prototypes need to be robustly tested
Impact

- Successful incorporation of CO catalyst into respirator will allow certification by NIOSH
- Respirator will protect civilians and first responders alike from harmful effects of CO
- Development may also have a significant impact on firefighter application
Acknowledgment

- NIH (NIOSH) for funding the SBIR project for proof of concept work