Air Purification Technology Overview

Presented by
Christopher J. Karwacki

Co-Authors: Michael Parham, Greg Peterson, Alex Balboa, Cheri Borruso, John Mahle

Chemical Biological Radiological Filtration Team
Research & Technology Directorate
Edgewood Chemical Biological Center
**ECBC Mission**

- Develop a Center of Excellence in respiratory protection through technology development, design, test, and evaluation of advanced air purification technologies
- Develop test standards for technology selection, integration and certification
- Support the Warfighter/DHS in development programs incorporating air purification technologies

**Single Pass Filtration w/ Optimized Adsorbents**

- **Zeolites**
- **Nanotubes**
- **Fibers**

**Advanced Filter Systems**

**Catalytic Oxidation (CatOx)**
- Catalytic Reactor
- Heater
- Heat Exchanger
- Contaminated Air
- Clean Air
- Less Toxic By-Products

**Regenerative Filtration (Regen)**
- PRODUCT AIR
- REDUCE PRESSURE, COOL, AND SPLIT
- PURGE AIR
- BED #1
- SWITCHING VALVE #2
- PURGE DUMP
- HIGH-PRESSURE FEED STREAM
- BED #2
- SWITCHING VALVE #1
ECBC PARTNERSHIPS & CUSTOMERS

ACE
DARPA
DHS
EPA
JECP
JPEO – CBD
JSTO – DTRA
OSHA/NIOSH
NSWC
NIST
PM-IP
PM-COLPRO
PM EFP
PM FCS
PM Guardian
TSWG

Air Purification Technology Development

- Concept Exploration
- AP Technology Development
- Material/System Modeling
- Application Requirements
- AP Selection and Integration
- Standards for Qualification and Certification

Reaching Out to The Community

- CRADAs
- MOU
- Proposals
- Publications
- Conference Presentations
- Patents
Advertisements Requirements

- Microporosity for physical adsorption
- Pore distribution that can support reactants
- Basic sites for removal of acid gases
- Acid sites for removal of base-forming and basic gases
- Access to reactive sites when adsorbed water is present
SINGLE PASS FILTRATION
DESIGN-LIMITING CHEMICALS

1 Strongly Physically Adsorbed

33 TIC’s

1 Marginally Physically Adsorbed

Inadequately Physically Adsorbed

30 Chemical Reaction Required

1 No Clear Reaction Mechanism

14 Acidic/Acid-forming

5 Basic/Base-forming

4 Cyanides/Cyanates

2 Aldehydes/Ketones

2 Nitrogen Oxides

2 Epoxides

1 Hydride

Select Performance-Limiting Chemicals
OBJECTIVE: Develop adsorbents to improve filtration of representative TICs

BF-38 Impregnated Zeolite
Target Chemicals: Ammonia
Ethylene Oxide

KRM Zeolite
Target Chemicals: Fuming Nitric Acid
Nitrogen Dioxide

Inlet: 2.0 cm ASZM-TEDA
Outlet: BF-38-3S
\[^{1}{\text{EO}}\] = 1,000 mg/m\(^3\)
9.6 cm/s Velocity
12 x 30 Mesh
Pre-Humidified, 80% RH

Filter:
KRM-623 (inlet)
2.0 cm ASZM-T (outlet)
\[^{1}{\text{NO}}_2\] = 375 mg/m\(^3\)
9.6 cm/s Velocity
12 x 30 Mesh
Pre-humidified, 80% RH

[Graphs showing concentration over time for BF-38 and KRM Zeolite]
Novel COLPRO Filter Designs

Filter Composition

<table>
<thead>
<tr>
<th>Material</th>
<th>Layer/Position</th>
<th>Bed Depth</th>
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</thead>
<tbody>
<tr>
<td>KRM-623</td>
<td>Inlet</td>
<td>1.5 cm</td>
</tr>
<tr>
<td>ASZM-TEDA</td>
<td>Middle</td>
<td>5.2 cm</td>
</tr>
<tr>
<td>BF-38-3S</td>
<td>Exit</td>
<td>4.3 cm</td>
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<table>
<thead>
<tr>
<th>Chemical</th>
<th>Estimated Performance (mg-min/m³)</th>
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<tbody>
<tr>
<td>DMMP</td>
<td>215,000</td>
</tr>
<tr>
<td>Hydrogen Cyanide (AC)</td>
<td>45,000</td>
</tr>
<tr>
<td>Cyanogen Chloride (CK)</td>
<td>62,000</td>
</tr>
<tr>
<td>Phosgene (CG)</td>
<td>226,000</td>
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<tr>
<td>Sulfur Dioxide</td>
<td>76,000</td>
</tr>
<tr>
<td>Ammonia</td>
<td>48,000</td>
</tr>
<tr>
<td>Ethylene Oxide</td>
<td>112,000</td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td>15,500</td>
</tr>
</tbody>
</table>
CATALYTIC OXIDATION
BROAD THREAT PROTECTION

- Catalytic Oxidation converts chemical vapor threats into carbon dioxide, water, and less toxic acid by-products.

- The catalyst monolith reactor is an established industrial technology.

- Combined with a post treatment system to remove acid gases, CatOx offers:
  - Broad threat protection
  - Low maintenance
  - Destruction of chemical threats

- Drawbacks of technology
  - Catalyst operates at a high temperature (200-400°C)
  - Uses a recuperative heat exchanger which heats up incoming contaminated air with clean hot air.

- Design Drivers
  - Activity: What temperature is required for the desired level of chemical destruction?
  - Selectivity: What level of undesired by-products are generated at the operating temperature? What is the post treatment strategy?
  - Durability: How much loading of P, As, Se, B, Br can occur before activity decreases?
CATALYTIC OXIDATION PROGRESS AT ECBC

• Partners
  – Honeywell
  – Guild Associates

• Commercial Catalyst Screening

• Lab scale catalyst reactor studies

• 50 SCFM Demonstrator Test and Evaluation

• System Application Studies
**CATALYTIC OXIDATION SYSTEM OPTIMIZATION**

- **Catalyst**
  - Operating temperature drives energy utilization and determines burden on post treatment system.

- **Post Treatment System**
  - High temperature reactive adsorbent.
  - Ambient temperature water scrubbing.
  - In both cases NOx is design limiting.
  - All other compounds are more easily removed.

- **Heater or waste heat utilization**
  - Aggressive start up time requirements will drive up the peak power demand and lead to infeasible heater or waste heat exchanger designs.
  - Start up time requirements of 30 minutes are more reasonable.

- **Recuperative heat exchanger design**
  - Operating temperature of catalyst will drive material selection.
  - Utilization of waste engine heat or catalyst material improvements is a lower risk power reduction strategy.
• **Regenerative Filtration cleans air by adsorption**
  – Adsorbent beds are regenerated by counter-current by pressurized or thermal purge.

• **Regenerative Filtration is an established industrial technology**

• **Regenerative Filtration offers:**
  – Broad threat protection
  – Low maintenance

• **Drawbacks of technology**
  – Higher energy consumption may limit its use to suitable waste heat sources
  – Mitigation of contaminant purge

• **Design Drivers**
  – Chemical Requirement: What chemicals need to be removed and dosage
  – Bed Size/Cycling/Energy: Energy available for optimum pressurization
Maturation

- **Adsorbents** – Adsorption Equilibria has been measured for a wide range of chemicals

- **Bed Design** – Sorbent type, layering, bed velocity

- **Process Optimization** – Cycling, temperature and purge characterized to minimize energy

- **Modeling** – Process models matured and validated to for a wide range of chemical requirements and operating conditions
• System Testing and Validation
  – Industry test stands 50 – 200 CFM

• Integration in Relevant Applications
  – Abrams Tank, Shelter, EFV, FCS

• Standard Test Method Development
  – Technical Readiness Evaluation
  – JSTO Test & Evaluation
• Single AP technology will likely not be suitable for all emerging requirements and applications

• Protection and application requirements must be assessed against the capabilities of a particular AP technology
  
  – Energy per CFM
  – Size and Weight per CFM
  – Reduced Chemical threat
  – Critical Asset
CONCLUSIONS

• Major advances in key AP technologies (single-pass filtration, regenerative filtration, catalytic oxidation) show promise in meeting current and emerging protection requirements

  – Technology must provide **BREATHABLE AIR**
    • TIC, CWA, NTA

  – Technology must integrate effectively into application
    • Energy Requirements
    • Weight and Space Claim
Acknowledgements

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