AMT

Hollow Fiber Membrane Based Technology to Remove VOCs from N₂ or Air Streams
Key Features/Benefits of VOC-$R^3$ System

**Removal – Recovery - Reuse**

- 98 %+ removal & solvent recovery potential
- Effective both for batch & continuous processes
- Suitable for steady/unsteady flow processes
- Compact devices
- Point of use
- Moderate capital cost
- Low operational cost
- No fire explosion risk
AMT VOC-R$^3$ Technology

New Technology is protected by U.S. /European Patents

VOC/N2 from Process

Membrane Module

Purified N2 or Air

VOC Gases

Vacuum Pump

Liquid VOC

Condenser
VOC – R³ System Description

- Microporous hydrophobic polypropylene hollow fibers with an ultra-thin plasma polymerized silicone skin
- Thousands of hollow fibers are bundled in a cartridge, which are part of the VOC – R³ separation module
- VOC-containing gas mixture is passed through the bore of the fibers. By applying a vacuum to the shell-side of the hollow-fiber cartridge the VOCs are separated from the feed stream. Molecules such as oxygen and nitrogen are much slower permeators and are rejected by the membrane film and vented to the air.
- The permeate is condensed to recover and to reuse the VOCs; the non-condensed are returned to the feed.
VOC – $R^3$ Separation Module

15 cm Diameter: 4 cartridges
10,000 Fibers/Cartridge – 90 LPM

Vacuum – VOC Outlet

20 cm = 12 cartridges (270 LPM)  30 cm = 28 cartridges (630 LPM)
Membrane Technology Comparison

AMT Hollow Fibers vs. Flat Films

AMT Key Advantages:

- Multiple higher surface area allows compact cartridge designs.

- Lower pressure difference requirements eliminate the need for a compressor (operational and capital cost savings, compact design, safer).
VOC Removal Performance
Paint Box Exhaust Stream - NASA

- VOC reduction >97%
  (fixed air flow rate and membrane surface area)
- Consistent high VOC reduction performance despite inlet VOC concentration changes

![Graph showing VOC concentration and removal percentage]
RESULTS

- Methanol reduction > 98%
- Reduction level depending on gas flow rate and membrane surface area/# of modules

Methanol vapor removal at different feed gas flow rates.
Membrane area in each module: ~4 m²

- 2 modules; methanol concentration in feed gas: 13.0 ± 1.2%
- 3 modules; methanol concentration in feed gas: 14.0 ± 4.0%
<table>
<thead>
<tr>
<th>Technology</th>
<th>Capital Costs</th>
<th>Operation Costs</th>
<th>Safety</th>
<th>Recovery</th>
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<tbody>
<tr>
<td>Membrane Separation</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>Incineration</td>
<td>Moderate To High</td>
<td>High</td>
<td>Low</td>
<td>No</td>
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<tr>
<td>Adsorption</td>
<td>Moderate To High</td>
<td>High</td>
<td>Low</td>
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<tr>
<td>Cryogenic Condensation</td>
<td>Moderate To High</td>
<td>Moderate</td>
<td>Moderate to Low</td>
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</table>
# Investment, Annual Costs, Net Present Costs – Flat Film Membrane Systems

<table>
<thead>
<tr>
<th>Waste Gas Flow Rate</th>
<th>Composition (Vol %)</th>
<th>Investment ($1,000)</th>
<th>Annual Costs ($1,000)</th>
<th>N P S ($1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 scfm</td>
<td>43% CFC – 114</td>
<td>370</td>
<td>110</td>
<td>545</td>
</tr>
<tr>
<td>34 scfm</td>
<td>10% CFC - 114</td>
<td>410</td>
<td>125</td>
<td>620</td>
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<tr>
<td>284 scfm</td>
<td>10% CFC - 114</td>
<td>1,180</td>
<td>395</td>
<td>1,950</td>
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<tr>
<td>28.5 scfm</td>
<td>18% methanol</td>
<td>320</td>
<td>92</td>
<td>470</td>
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<tr>
<td>24.5 scfm</td>
<td>0.6% xylene</td>
<td>350</td>
<td>103</td>
<td>500</td>
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<tr>
<td>25 scfm</td>
<td>0.1% acetone</td>
<td>370</td>
<td>110</td>
<td>545</td>
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</tbody>
</table>
AMT voc – R³ Membrane System

30 scfm gas flow rate – pharmaceutical plant*

- Estimated investment cost

TOTAL = $114,000

*WITH VACUUM AND CONDENSORS IN PLACE
AMT voc – $R^3$ Membrane System

30 scfm gas flow rate – fine chemical plant*

- Estimated investment cost
  - TOTAL = $174,000

- MTR Flat Membrane Technology: $320,000
- Thermal Oxidizer: $50,000

* NO VACUUM AND CONDENSORS IN PLACE
AMT voc – R³ Membrane System

30 scfm gas flow rate – fine chemical plant*

- Estimated annual operating cost
  TOTAL = $30,000

- MTR Flat Membrane Technology: $92,000
- Thermal Oxidizer: $170,000
# AMT VOC – R³ Membrane System

30 scfm gas flow rate – fine chemical plant*

Estimated investment and 1 year operating cost

<table>
<thead>
<tr>
<th></th>
<th>VOC – R³</th>
<th>MTR</th>
<th>Thermal Oxidizer</th>
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<tbody>
<tr>
<td>Investment</td>
<td>$174,000</td>
<td>$320,000</td>
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<tr>
<td>1. Year Operating Cost</td>
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<td>$ 92,000</td>
<td>$170,000</td>
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<tr>
<td>TOTAL</td>
<td>$204,000</td>
<td>$412,000</td>
<td>$220,000</td>
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