Ascent Particle Filter Molecular Conductance Study

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This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

[Signature]
David E. Davis
SMC/EA
Ascent particle filters on enclosures containing space hardware, such as electronics boxes, regulate venting of these enclosures during launch and ascent. While allowing venting to occur, these filters prevent the transport of particles into and out of the enclosures. Particle filters are primarily characterized with respect to the flow of gas through the filter; the conductance of outgassed molecules is not quantified. This report documents a series of tests performed at The Aerospace Corporation's Space Materials Laboratory to measure the conductance of outgassed molecular contamination from a model contaminant across a typical particle filter as a function of outgassing arrival rate. The results herein show that a typical ascent particle filter significantly limits the conductance of molecular contamination.
Ascent Particle Filter Molecular Conductance Study

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Ascent Particle Filter Molecular Conductance Study

Introduction

- Particle filters on enclosures containing space hardware (electronics boxes, etc.) provide venting during launch and ascent

- Filters are typically sized in the 5 to 10 μm effective filtration range
  - Prevent the ingestion of particles into the assembly
  - Prevent the release of particles from the interior of the enclosure

- Filters are most often characterized with respect to the flow of gas through the filter
  - Conductance of outgassed molecules is not quantified

Question to Answer: To what extent does a typical ascent particle filter limit the conductance of molecular contamination?
Ascent Particle Filter Molecular Conductance Study

Experiment Design

- Molecular conductance through a filter can be thought of in two ways:
  - **Effective Aperture Size**: Size of the obstruction-free aperture that will pass molecules at the same rate as the filter
  - **Mass Throughput**: Percentage of mass per unit time that the filter can pass relative to an unobstructed target
- Molecular conductance is considered to be a function of:
  - Filter parameters (design, effective filtration size, material, etc.)
  - Macro dimensions of the filter (length, width, thickness)
  - Temperature of the filter
  - Rate of outgassing arrival
- **Objective**: Measure the molecular conductance* across a typical filter as a function of outgassing arrival rate for a model contaminant (Diocyl Phthalate)

* Molecular conductance measured for a Clausing beam profile, not for an omnidirectional pressure distribution. These experiments can be thought of as measuring the mass throughput attenuation of the ascent particle filter.
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Prototypical Ascent Filter

• Rigimesh 5 µm Filter from Pall Aeropower Corporation
  – *Wire Thickness: 0.0014 inches*
  – *Filter Thickness: 0.006 inches*

Macro photo of prototypical ascent filter.

SEM pictures of prototypical ascent filter. Magnification specified.

*Prototypical sintered stainless steel wire mesh filter*
Ascent Particle Filter Molecular Conductance Study

Chamber Configuration

The Carrier QCM, which is mounted on the Carrier, is identical to the Shroud QCM. For this study, it was located directly behind the Ascent Filter, with a gap of approximately 0.2 inches. Both QCMs were held at -75°C to collect all impinging flux, but not condense water.

Ascent particle filter mounted in chamber for testing
Ascent Particle Filter Molecular Conductance Study

Experiment Overview

- QCM Calibration
  - *Calibrate the unobstructed Carrier QCM to the Shroud QCM to understand mass accumulation rate differences*

- Install the filter approximately 0.2 in directly in front of the Carrier QCM

- 21°C Single Filter Tests
  - *Measure mass accumulation on the Carrier QCM & Shroud QCM with the single filter held at 21 °C (+2 °C, -1 °C) for each molecular flux of interest*

- 5°C Single Filter Tests
  - *Measure mass accumulation on the Carrier QCM & Shroud QCM with the single filter held at 5 °C (+2 °C, -1 °C) for each molecular flux of interest*

*Filter testing performed at two filter temperatures and multiple molecular flux levels*
## Ascent Particle Filter Molecular Conductance Study

### Single Filter Test Accumulation Rate Summary

<table>
<thead>
<tr>
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<th></th>
</tr>
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<tbody>
<tr>
<td><strong>Background†</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrier QCM</td>
<td>0.038 †</td>
<td>0.488</td>
<td>0.709</td>
<td>0.469</td>
<td>0.452</td>
<td>1.358</td>
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<tr>
<td>Shroud QCM</td>
<td>0.115 †</td>
<td>0.087</td>
<td>0.445</td>
<td>1.240</td>
<td>0.668</td>
<td>0.704</td>
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<td>1.060</td>
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<td>16.8% ‡</td>
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<td>Carrier QCM</td>
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</tr>
<tr>
<td>Shroud QCM</td>
<td>0.96% ‡</td>
<td>10.2% ‡</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>Effusion Cell 50°C</strong></td>
<td>10.70</td>
<td>0.370</td>
<td>0.434</td>
<td>0.114</td>
<td>0.291</td>
<td>3.1% ‡</td>
</tr>
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<td>Carrier QCM</td>
<td>10.91</td>
<td>9.512</td>
<td>9.874</td>
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</tr>
<tr>
<td>Shroud QCM</td>
<td>98.1% ‡</td>
<td>3.9% ‡</td>
<td>4.4% ‡</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Effusion Cell 60°C</strong></td>
<td>1.155</td>
<td>3.6% ‡</td>
<td>0.692</td>
<td>0.784</td>
<td>2.5% ‡</td>
<td></td>
</tr>
<tr>
<td>Carrier QCM</td>
<td>31.65</td>
<td></td>
<td>2.2% ‡</td>
<td>31.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shroud QCM</td>
<td>22% ‡</td>
<td></td>
<td>2.5% ‡</td>
<td></td>
<td></td>
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<tr>
<td><strong>Effusion Cell 70°C</strong></td>
<td>97.32</td>
<td>3.975</td>
<td>2.962</td>
<td>1.680</td>
<td>1.7% ‡</td>
<td></td>
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<tr>
<td>Carrier QCM</td>
<td>96.9% ‡</td>
<td>4.0% ‡</td>
<td>1.922</td>
<td>1.80%</td>
<td></td>
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</tr>
<tr>
<td>Shroud QCM</td>
<td>100.4</td>
<td>100.3</td>
<td>97.99</td>
<td></td>
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<tr>
<td><strong>Effusion Cell 80°C</strong></td>
<td>9.770</td>
<td>3.3% ‡</td>
<td>3.983</td>
<td>4.163</td>
<td>1.5% ‡</td>
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<tr>
<td>Carrier QCM</td>
<td>292.5</td>
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<td>1.4% ‡</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Shroud QCM</td>
<td>283.6</td>
<td></td>
<td>1.5% ‡</td>
<td></td>
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</tr>
</tbody>
</table>

† Background rates measured with the effusion cell at 10°C and the shutter closed before all depositions each day (0Å deposited on each QCM)
‡ Measured after calibrations at 30°C, 50°C, and 70°C (Approximately 240Å deposited on each QCM)
§ Carrier QCM Rate as a percentage of the Shroud QCM Rate during the same deposition
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Summary

• To what extent does a typical ascent particle filter limit the conductance of molecular contamination?

21 °C Single Filter Tests
• The filter reduced the mass accumulation on the Carrier QCM to between 3.0% and 4.4% of the accumulation on the unobstructed Shroud QCM

5 °C Single Filter Tests
• The filter reduced the mass accumulation on the Carrier QCM to between 1.2% and 3.1% of the accumulation on the unobstructed Shroud QCM

Note: Data recorded with the effusion cell at 30 °C is difficult to interpret because the deposition rates were very low.
Appendix: Data Archive
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Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
QCM Calibration
DOP on -75°C QCMs, Effusion Cell at 30°C

4/21/2008

\[
y = 5.2989x + 3489.1 \\
\text{Rate} = 1.060 \text{Å/hr}
\]

\[
y = 7.0473x + 3354 \\
\text{Rate} = 1.409 \text{Å/hr}
\]

- Crucible °K
- Lip Heater °K
- Shroud On/Off
- Carrier °K
- Shroud °K
- Carrier QCM °K
- Shroud QCM °K
- Carrier QCM Hz
- Shroud QCM Hz
- Carrier QCM Hz*
- Shroud QCM Hz*
- Carrier QCM Hz Fit
- Shroud QCM Hz Fit

* QCM data during deposition period.
For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
QCM Calibration
DOP on -75°C QCMs, Effusion Cell at 50°C

4/21/2008

\[ y = 53.505x + 1993.6 \]
Rate = 10.70 Å/hr

\[ y = 54.569x + 1877.5 \]
Rate = 10.91 Å/hr

* QCM data during deposition period.
For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
QCM Calibration
DOP on -75°C QCMs, Effusion Cell at 70°C

\[ y = 486.58x - 13175 \]
Rate = 97.316 Å/hr

\[ y = 501.9x - 13789 \]
Rate = 100.38 Å/hr

- Crucible "K
- Lip Heater "K
- Shroud On/Off
- Carrier "K
- Shroud "K
- Carrier QCM "K
- Shroud QCM "K
- Carrier QCM Hz
- Shroud QCM Hz
- Carrier QCM Hz*
- Shroud QCM Hz*
- Carrier QCM Hz Fit
- Shroud QCM Hz Fit

* QCM data during deposition period: For analysis purposes.
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Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
QCM Calibration
DOP on -75°C QCMs, Background with Effusion Cell at 10°C

4/21/2008

\[ y = 0.1885x + 4777.9 \]
Rate = 0.038 Å/hr

\[ y = 0.5735x + 4714.4 \]
Rate = 0.115 Å/hr

* QCM data during deposition period. For analysis purposes.
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Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Background with Effusion Cell at 10°C

4/29/2008

y = 2.4424x + 3584.3
Rate = 0.488 Å/hr

y = 0.4352x + 3493.8
Rate = 0.087 Å/hr

* QCM data during deposition period. For analysis purposes.
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Appendix. Data Archive

4/29/2008

Ascent Particle Filter Molecular Conductance Study
21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 30°C
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Ascent Particle Filter Molecular Conductance Study
21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 50°C

4/29/2008

Temperature (K)

Frequency (Hz)

Time (hr)

\[ y = 1.6481x + 3595.8 \quad \text{Rate} = 0.370 \, \text{Å/hr} \]

\[ y = 47.561x + 2105.1 \quad \text{Rate} = 9.512 \, \text{Å/hr} \]

- Crucible °K
- Lip Heater °K
- Shutter On/Off
- Carrier °K
- Shroud °K
- Carrier QCM °K
- Shroud QCM °K
- Filter °K
- Carrier QCM Hz
- Shroud QCM Hz
- Carrier QCM Hz*
- Shroud QCM Hz*
- Shroud QCM Hz Fit
- Carrier QCM Hz Fit

* QCM data during deposition period.
For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 70°C

\[ y = 501.45x - 13238 \]
Rate = 100.3 \( \text{Å/hr} \)

\[ y = 19.876x + 2985.4 \]
Rate = 3.98 \( \text{Å/hr} \)

4/29/2008

* QCM data during deposition period.
For analysis purposes.
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Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Background with Effusion Cell at 10°C

5/14/2008

\[ y = 3.5446x + 3599.7 \]
Rate = 0.709 Å/hr

\[ y = 2.2445x + 3276.5 \]
Rate = 0.445 Å/hr

- Crucible °K
- Lip Heater °K
- Shutter On/Off
- Carrier °K
- Shroud °K
- Carrier QCM °K
- Shroud QCM °K
- Filter °K
- Carrier QCM Hz
- Shroud QCM Hz
- Carrier QCM Hz*
- Shroud QCM Hz*
- Shroud QCM Hz Fit
- Carrier QCM Hz Fit

* QCM data during deposition period. For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 30°C

\[ y = 1.0615x + 3651.3 \]
Rate = 0.212 Å/hr

\[ y = 6.3047x + 3289.1 \]
Rate = 1.260 Å/hr

5/14/2008

* QCM data during deposition period. For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 50°C

\[
y = 2.1682x + 3621.3 \\
\text{Rate} = 0.434 \text{ Å/hr}
\]

\[
y = 49.372x + 2185.2 \\
\text{Rate} = 9.874 \text{ Å/hr}
\]

- Crucible °K
- Lip Heater °K
- Shutter On/Off
- Carrier °K
- Shroud °K
- Carrier QCM °K
- Shroud QCM °K
- Filter °K
- Carrier QCM Hz
- Shroud QCM Hz
- Carrier QCM Hz*
- Shroud QCM Hz*
- Shroud QCM Hz Fit
- Carrier QCM Hz Fit

* QCM data during deposition period.
For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Background with Effusion Cell at 10°C

5/28/2008

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\[ y = 2.3433x + 3657 \]
Rate = 0.469 Å/hr

\[ y = 6.203x + 3247.1 \]
Rate = 1.240 Å/hr
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Ascent Particle Filter Molecular Conductance Study
21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 60°C

5/28/2008

\[ y = 5.7767x + 3589.5 \]
Rate = 1.155 Å/hr

\[ y = 158.26x + 449.39 \]
Rate = 31.65 Å/hr

Legend:
- Crucible °K
- Lip Heater °K
- Shutter On/Off
- Carrier °K
- Shroud °K
- Carrier QCM °K
- Shroud QCM °K
- Filter °K
- Carrier QCM Hz
- Shroud QCM Hz
- Carrier QCM Hz*
- Shroud QCM Hz*
- Shroud QCM Hz Fit
- Carrier QCM Hz Fit

* QCM data during deposition period. For analysis purposes.
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Ascent Particle Filter Molecular Conductance Study
21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 70°C

\[ y = 500.14x - 7333.7 \]
Rate = 100.0 Å/hr

\[ y = 14.808x + 3382.8 \]
Rate = 2.962 Å/hr

\* QCM data during deposition period. For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
21°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 80°C

5/28/2008

Temperature (K)

Rate = 292.5 Å/hr

y = 1462.5x - 31220

Frequency (Hz)

Rate = 9.770 Å/hr

y = 48.852x + 2541.5

* QCM data during deposition period. For analysis purposes.
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Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Background with Effusion Cell at 10°C

\[ y = 2.2591x + 3624.7 \]
Rate = 0.452 Å/hr

\[ y = 3.3378x + 3341.6 \]
Rate = 0.668 Å/hr

- Crucible °K
- Lip Heater °K
- Shutter On/Off
- Carrier °K
- Shroud °K
- Carrier QCM °K
- Shroud QCM °K
- Filter °K
- Carrier QCM Hz
- Shroud QCM Hz
- Carrier QCM Hz*
- Shroud QCM Hz*
- Shroud QCM Hz Fit
- Carrier QCM Hz Fit

* QCM data during deposition period. For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

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Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 50°C

\[ y = 0.5695x + 3674 \]
Rate = 0.114 Å/hr

\[ y = 47.132x + 1938.5 \]
Rate = 9.426 Å/hr

5/28/2008

* QCM data during deposition period. For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

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Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 60°C

5/28/2008

**Crucible °K**
**Lip Heater °K**
**Shutter On/Off**
**Carrier °K**
**Shroud °K**
**Carrier QCM °K**
**Shroud QCM °K**
**Filter °K**
**Carrier QCM Hz**
**Shroud QCM Hz**
**Carrier QCM Hz**
**Shroud QCM Hz**
**Shroud QCM Hz Fit**
**Carrier QCM Hz Fit**

* QCM data during deposition period. For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

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Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 70°C

\[ y = 489.96x - 14740 \]
Rate = 97.99 Å/hr

\[ y = 9.6075x + 3340.7 \]
Rate = 1.922 Å/hr

5/28/2008

* QCM data during deposition period
For analysis purposes
Ascent Particle Filter Molecular Conductance Study
Appendix: Data Archive

Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 80°C

$y = 1418.1x - 52324$
Rate = 283.6 Å/hr

$y = 19.915x + 2930.2$
Rate = 3.983 Å/hr

5/28/2008

- Crucible °K
- Lip Heater °K
- Shutter On/Off
- Carrier °K
- Shroud °K
- Carrier QCM °K
- Shroud QCM °K
- Filter °K
- Carrier QCM Hz
- Shroud QCM Hz
- Carrier QCM Hz
- Shroud QCM Hz
- Shroud QCM Hz Fit
- Carrier QCM Hz Fit

* QCM data during deposition period.
  For analysis purposes.
Ascent Particle Filter Molecular Conductance Study

Appendix: Data Archive

May 29, 2008

Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Background with Effusion Cell at 10°C

\[ y = 6.7895x + 3676.7 \]
Rate = 1.368 Å/hr

\[ y = 3.5206x + 3428.2 \]
Rate = 0.704 Å/hr

- Crucible °K
- Lip Heater °K
- Shutter On/Off
- Carrier °K
- Shroud °K
- Carrier QCM °K
- Shroud QCM °K
- Filter °K
- Carrier QCM Hz
- Shroud QCM Hz
- Carrier QCM Hz*
- Shroud QCM Hz*
- Shroud QCM Hz Fit
- Carrier QCM Hz Fit

* QCM data during deposition period.
For analysis purposes.
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Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 50°C

May 29, 2008

\[ y = 1.4548x + 3683.2 \]
Rate = 0.291 Å/hr

\[ y = 47.585x + 3293.8 \]
Rate = 9.517 Å/hr

* QCM data during deposition period. For analysis purposes.
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Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 60°C

May 29, 2008

\[ y = 3.9179x + 3667.1 \]
\[ \text{Rate} = 0.794 \text{ Å/hr} \]

\[ y = 158.94x + 2576.7 \]
\[ \text{Rate} = 31.79 \text{ Å/hr} \]

* QCM data during deposition period. For analysis purposes.
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Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 70°C

May 29, 2008

\[ y = 489.73x + 558.85 \]
Rate = 97.95 Å/hr

\[ y = 8.399x + 3826.9 \]
Rate = 1.680 Å/hr

* QCM data during deposition period.
For analysis purposes.
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Ascent Particle Filter Molecular Conductance Study
5°C Single Filter Test, Filter Shielding Carrier QCM
DOP on -75°C QCMS, Effusion Cell at 80°C

May 29, 2008

y = 1421.1x - 11293
Rate = 284.2 Å/hr

y = 20.815x + 3493
Rate = 4.163 Å/hr

* QCM data during deposition period.
For analysis purposes.
Acknowledgements

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