Sensitivity of micromachined Joule-Thomson cooler to clogging due to moisture

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Microcooling development at UT

- **165 K**
- **30 K**

Temperature reduction

- **1997**
- **2001**
- **2003**
- **2007**
- **2009**
- **2011**
- **2013**

**PhD: Johannes Burger**

**PhD: Pieter Lerou**

**PhD: Hendrie Derking**

**PhD: Haishan Cao**

Microcooling development at UT with temperature reduction from 30 K to 165 K.
First clogging, results in too low mass-flow rate and warm-up followed by declogging (sublimation).
Clogging phenomenon: Theory

- Molecular diffusion process
  Fick’s law: (Mass diffusivity, m²·s⁻¹)
  \[
  \dot{n}_{dep} = D_{12} \frac{(p_c - p_b)}{0.5hRT}
  \]

- Surface kinetic process
  Hertz-Knudsen-Langmuir formula: (Mass accommodation coefficient, 1)
  \[
  \dot{n}_{dep} = \alpha \frac{(p_b - p_{sat})}{\sqrt{2\pi MRT}}
  \]

- Diffusion and kinetics process
  \[
  \dot{n}_{dep} = (p_c - p_{sat}) \sqrt{\frac{0.5hRT}{D_{12}}} + \sqrt{\frac{2\pi MRT}{\alpha}}
  \]
Investigation on clogging rate: nitrogen purifiers

<table>
<thead>
<tr>
<th>Purifier</th>
<th>Purification theory</th>
<th>Outlet moisture level</th>
</tr>
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<tbody>
<tr>
<td>Getter-filter</td>
<td>Adsorption</td>
<td>Fixed, 1 ppb</td>
</tr>
<tr>
<td>Cryo-filter</td>
<td>Deposition</td>
<td>Unfixed, temp. dependent</td>
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Investigation on clogging rate: microcooler

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<td>4.4E-3</td>
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<td>&lt;= 192</td>
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High pressure (MPa) | Low pressure (MPa) | Working fluid
8.7                | 0.6               | N₂ (5.0)
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Influence of moisture level in nitrogen gas
Influence of cold-end temperature of microcooler

- Mass-flow rate (mg s⁻¹) vs. Time (h)
  - 110 K
  - 120 K
  - 130 K

- Temperature (K) vs. Time (h)
  - 110 K
  - 120 K
  - 130 K

- Parasitic losses (mW) vs. Time (h)
  - 110 K
  - 120 K
  - 130 K

- Image showing microcooler with labels for Front side and Back side, and a note indicating Deposited water.
Conclusions

- Reason of clogging: Deposition of water molecules.

- Influence of moisture level in nitrogen gas: Mass-flow rate during the cool down.

- Influence of cold-end temperature of microcooler: Clogging rate during the operation.

- Measures to increase the operation time: Decrease the amount of H₂O in N₂ gas and vacuum; Decrease the temperature along the restriction.
Thank you for your attention!