QUANTIFICATION OF HEAT FLUX IN SUPERCRITICAL HELIUM

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**EXPERIMENTAL APPARATUS AND PROCEDURE**

**Super critical discharge pressure**

- 3 m³, GN2 or GHe, 300K, 1.2 bar abs
- Fast opening valve
- DN50
- Helium tank
- Pressure sensors
- Temperature sensors
- Reservoir LHe
  - 10 liters
- Vacuum chamber
- LN2

**Test parameters:**
- Initial mass inventory of the reservoir
- Nature of the gas responsible (GN₂, GHe, Air) for the loss of vacuum
- Number of layers of MLI

**Poster presented at Aussois conference 2012**

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Isochoric pressure rise

First thermodynamic law: \( \Delta U = \Delta Q + \Delta W \)

\[
\varphi = \rho_i \times \frac{V}{S} \times \frac{\Delta U}{\Delta t}
\]

\( \Delta U = U(P_f, \rho_i) - U(P_i, \rho_i) \)

\( \varphi \) heat flux in W/m²

\( \rho_i \) initial density

\( V \) volume of the tank

\( S \) surface of the tank

\( \Delta U \) internal energy variation between a final and an initial time

\( \Delta t \) variation of time

\( P_f, P_i \) pressure at final and initial time
A first tank with electrical heaters has been used to qualify the instrumentation and the analysis method.

Gap: - a part of the initial mass goes to the dead volumes (0.5l)
- heat accumulation on the wall tank can not be determined precisely (response time for the temperature sensors)
TEMPERATURE RISE INSIDE THE TANK

Average temperature in different heights

- average level 1
- average level 2
- average level 3
- T4
- Tsat(Preservoir)

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- Peak of heat flux at the first moments < 1s: nucleate and film boiling inside the tank
- After the heat flux remains constant: free convection inside the tank
• Delay of peak nucleate/film boiling in comparison with the pressure at the first moments (Be careful with a safety device calculated at pressure close to 3 bars…)

• Constant heat flux 1.85 W/cm², steady state outside the tank? no variation of the thickness film condensation, free convection inside the tank.
High condensation coefficient because super heated gas, strong interfacial friction between the vapor and the liquid film, turbulent flow → very low film thickness (0.025mm)

Heat flux limited by free convection inside the tank

$H_{\text{condensation}} = 6200 \text{W/m}^2\cdot\text{K}$

$H_{\text{free convection}} = 330 \text{W/m}^2\cdot\text{K}$

$H_{\text{wall}} = 1945 \text{W/m}^2\cdot\text{K}$
LOSS OF VACCUM VESSEL WITH GHE AND AIR

- **GHe**
  
  heat flux: 0.15 W/cm², the heat flux is limited by free convection inside the vacuum vessel (h = 30 W/m².K to compare to 6200 W/m².K by condensation)

- **AIR (one test)**
  
  heat flux: 2 W/cm², close to the value obtained with GN₂
Currently, no reproducible values have been obtained, we have to continue to work on this point…

The value depends **strongly** on the way to install MLI on the reservoir!

Question: is it relevant to measure /give some values…..? (way to install the MLI, types of MLI…..)
### Past Results of a Brutal Loss of Vacuum with \( \text{GN}_2 \), Heat Flux for an Uninsulated HE Reservoir

<table>
<thead>
<tr>
<th>Experimentators</th>
<th>Initial conditions</th>
<th>Final conditions</th>
<th>Geometry tank</th>
<th>Filling rate</th>
<th>Heat Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lehman 1980</td>
<td>1bar 4.2K</td>
<td>1bar 4.2K</td>
<td>Ø=0.3m L=1m 70 liters</td>
<td>50%</td>
<td>3.8 W/cm(^2)</td>
</tr>
<tr>
<td>Harrison 2001</td>
<td>23mbar 1.9K</td>
<td>11bar 6K</td>
<td>Ø=0.2m L=0.4m 12 liters</td>
<td>90%</td>
<td>3W/cm(^2)</td>
</tr>
<tr>
<td>Van Sciver 2015</td>
<td>1bar 4.2K</td>
<td>1bar 4.2K</td>
<td>Not mentioned</td>
<td>Not mentioned</td>
<td>2.5W/cm(^2)</td>
</tr>
</tbody>
</table>

- Difference between Lehman and Van Sciver in sub-critical condition
- Difference between Harrison and CEA in super-critical condition

Different designs cryostat, different geometry of reservoirs and different analysis methods may lead to different results... **BE CAREFUL**

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A heat flux of 1.85 W/cm² has been measured with our facility in supercritical condition with a brutal loss of vacuum (GN₂). Value to compare with Harrison (3W/cm²)…….

Heat flux is limited by the free convection coefficient inside the tank (except for GHe break of vacuum)

Future work:
- Heat flux with MLI…..
- It will be interesting to compare the heat transfer condensation coefficient with bibliographic correlations.