Local Cryogenics for the SIS100 at FAIR

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Content

- Introduction to FAIR and SIS100
- Magnet cooling
  - Balancing parallel flows
  - Coping with changing dynamic loads
- Polish In-kind
  - By Pass Line (BPL)
  - Current Lead Box and Feed Box
- Conclusion
Introduction

- **FAIR:** Facility for Antiproton and Ion Research
- **SIS100:** Synchrotron 100 Tm

### Layout
- **Deflecting magnets (Dipoles: DPs)**
- **Focusing magnets (Quadrupoles: QPs)**

### Technical Specifications
- **Synchrotron 1.083 km circ.**
  - 108 Dipoles
  - 192 Quadrupole units

[Map Image]
Cryo distribution system

Supply line 4.4 K
Return line 4.3 K 300 K
Shield cooling 50-80 K
Helium transfer lines
Cold electrical connection
Warm electrical connection
## Magnet cooling - general

**Process pipes**

<table>
<thead>
<tr>
<th>Process line</th>
<th>Outer Ø x thickness in mm</th>
<th>Operating temperature in K</th>
<th>Operating pressure in bara</th>
<th>Design pressure in bara</th>
</tr>
</thead>
<tbody>
<tr>
<td>He supply magnets</td>
<td>54 x 2</td>
<td>4.5</td>
<td>1.8 *</td>
<td>20</td>
</tr>
<tr>
<td>He supply vacuum chamber</td>
<td>32 x 2</td>
<td>4.5</td>
<td>1.8 *</td>
<td>20</td>
</tr>
<tr>
<td>He return magnets + vacuum chamber</td>
<td>108 x 3</td>
<td>4.3</td>
<td>1.1 *</td>
<td>20</td>
</tr>
<tr>
<td>He supply shield</td>
<td>42.4 x 2</td>
<td>50</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>He return shield</td>
<td>42.4 x 2</td>
<td>80</td>
<td>17</td>
<td>20</td>
</tr>
</tbody>
</table>

*The operation pressure during cool down is up to 18 bara.*
Parallel flow and recooling

\[ p_{LP} = 1.25 \ldots 1.3 \text{ bara} \]
\[ p_{HP} = 1.45 \ldots 1.8 \text{ bara} \]
\[ T_{LP} = T_{boiling}(p_{LP}) = 4.4 \ldots 4.5 \text{ K} \]
\[ T_{HP} = T_{LP} + \Delta T_{rc} = 4.6 \ldots 4.7 \text{ K} \]
Magnet cooling – balancing parallel flows

- **DPs, QP units parallel arranged, having same supply and return**
- **Different dynamic heat load**
- **Different hydraulic impedance (length of QP circuit 50% shorter)**

> **Restrictor in QP circuits (capillary with \( d_i = 2\text{mm}, \) no mech. valve)**

<table>
<thead>
<tr>
<th>Without beam chamber</th>
<th>Static load [W]</th>
<th>Dynamic load [W]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Proton cycle</td>
</tr>
<tr>
<td>DP circuit</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>QP circuits</td>
<td>3</td>
<td>5...7</td>
</tr>
</tbody>
</table>

[A. Bleile]
Magnet cooling – coping with dynamic loads

- No mechanical valves planned for adjusting cooling to dynamic loads – heaters will be applied at the inlet of each cooling circuit
- 1) Machine’s ramping cycles will change within seconds
  - Fast reacting heaters will simulate maximum dynamic load → constant load for refrigerator
- 2) Flooding of common return causes unstable operation

- 3) Individual adjustment of cooling for each magnet is possible (functionality of balancing valve)
- Advantages of heaters (compared to mech. valves): failure safe, no pressure drop switched off, small heat in leak, no thermo acoustic oscillations, easy integration, inexpensive

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**Graph:**

- Temperature [K] vs. Entropy [J/gK]
- Lines for different pressures:
  - p=1.5 bara
  - p=1.25 bara
  - p=1 bara

**Data:**

- "static heat load"
  - $p_{in} = 1.6$ bara,
  - $x_{out} = 0.17$, $m = 2.0$ g/s

- "static heat load + 14 W"
  - $x_{out} = 0.92$, $m = 1.1$ g/s
Magnet cooling – coping with dynamic loads

- Cartridge heaters
  - Closed hydraulic circuit
  - Redundancy: use of 2 heaters, each 10W, 0.28A, 35V PWM (if one is broken: 1 heater 20W, 0.4A, 48 V)
  - Clamped with Apiezon® N
  - Measurements performed
    - Thermal cycling, temperatures

[hotset-worldwide.com]
Polish In-kind (WrUT – Wroclaw Uni Techn.)

- By-pass lines
Polish In-kind

- **Design of first BPL piece**

![Diagram of BPL piece with labeled parts:
- Vacuum vessel
- Radiation shield
- He supply VC
- He return magnets + VC
- Process pipes and busbars
- He supply shield
- He return shield
- Slings; support cold mass
- He supply magnets
- Busbars pairs (total 4)
- Heat radiation shield

Courtesy of Maciej Chorowski
Polish In-kind

- Specifications of Current Lead Box
- contract with WrUT in work
Specifications of Feed Box is in work

- PID under discussion with Technical University Dresden (Ch. Haberstroh, H. Quack)
Conclusion

- **Magnet cooling**
  - Balancing parallel flows
  - difference in dynamic load and hydraulic impedance
  - use of capillary tubes
  - Coping with dynamic loads
  - cartridge heaters at the inlet of each magnet cooling circuit
    - load simulation during fast ramping
    - no flooding of the common return line
    - cooling control of individual magnets

- **Polish In-kind**
  - Design of first BPL piece
  - Current Lead Box and Feed Box