Cryogenic Infrastructure for FAIR: Status and Future Tasks

Holger Kollmus for CSCY
Machine Advisory Committee
November 2014
Outline

- Status of the GSI Cryogenics Department (CSCY)
- Status Series Test Facility (STF)
- Status Helium Supply Unit (HeSu)
- Status Distribution System
- Design Studies from LKT and ALAT on the Cryogenic Supply
  - Followed by an Expert Meeting
- Status on the Heat Load Table
  - New Measurements from FoS
- Cryo Plant Options
Status of the CSCY Group

- Established in October 2012 with 6 people
- Presently we are 13 people (12.3 FTEs)
- External support from INFN, CERN
- Collaboration with ESS, TU Dresden

Responsibilities:

- Operation of the cryogenic infrastructure of the PTF
- Build-up and operation of the cryogenic infrastructure of the STF, incl. CC, HeSu
- Support magnet testing CERN and Dubna concerning cryogenic aspects in collaboration with PBMT
- All cryogenic supply on the whole GSI and FAIR campus
  - From the refrigerators through the transfer lines to the local cryogenics (polish *in-kind*, see next talk) up to the magnets incl. experiments (with small cryo plants)
• Building including technical infrastructure is ready
• Cryogenic components are all in place
• Warm gas storage is filled up with helium
• Last works on the warm gas piping are ongoing until week 51
Series Test Facilities II, Linde KT

- Commissioning beginning 2015
- Ready for magnet testing in spring 2015
- Visit after the MAC meeting is highly appreciated
- SIS 100 dipoles, quadrupoles and SuperFRS Magnets can be tested
Helium Supply for Small Users

- Liquefaction rate ~ 20+ l/h
- 3000 l LHe storage
- Commissioning done
• Commissioning done in October 2014, specified liquefaction rate reached
• 2000 l already liquefied
**Cryogenic Distribution System**

- **Normal operation**
  - Supply: 4.6 K, 3 bar
  - Return: 1.1 bar
- **Cool down distribution system**
  - Supply: 18 bar
  - Return: 4 bar
- **Intermediate level**
  - Supply: 50K, 18 bar
  - Return: 80K, 17 bar
- **Multipurpose line**
  - 1.1 (– 4) bar, pure helium

**Connection 80 K level**

**25 kW @4K cryo plant**

**70 kW 80 K pre cooler**

**Vacuum insulated lines**

Holger Kollmus, CSCY
Technical Study on the distribution system is ordered and in preparation

- Conceptual Design transfer lines including supporting
- Cross section of the transfer lines
- Number of spools and positions of couplings
- Position of flexible elements (bellows and/or flexible hoses)
- Sizing of safety valves
- Heat load calculation
- Pressure drop calculation
- Concept project schedule: design, engineering, manufacturing, installation, commissioning
- Budget price for transfer lines including installation
- Resource planning for GSI
  - which equipment and services (FTEs) are needed during installation

The study is ordered and in preparation, SIS100 part finished Jan. 2015
Cryogenic Supply: Planning Criteria, Milestones

Time scheduling
• Start Assembly: Q1/2018
  • Including SAT and first magnet cool-downs
• Ready for Operation: Q3/2019
• M4 Contract Signed: Q3/2015 latest

Technical requirements
• The cryogenic infrastructure has to cool down SIS100 and SuperFRS
  • We have to map the dynamic loads of SIS100
  • We have to cool down SuperFRS in a reasonable time (1300 t)
  • For both machines the cooling shall be supplied individually

Basis for technical requirements
• Heat load table
  • Estimations: transfer lines, distribution boxes, feed boxes, ...
  • Calculations: image current, beam loss, local current leads, ...
  • One measurement: SIS 100 dipole 70 W → 50 W
Change in the Heat Load, FoS Measurements

- Triangular cycle: load reduction from 70 W to 50 W
- Scaled to the quadrupoles
- But: First-of-Series, design changes might follow

Conversion factors:
- 1 g/s @4.4 K = 117 W@4.4K
- 1 W @50K = 0.1 W@4.4K
- 1 g/s @50 K = 50 W@4.4K
Design Study on the Cryogenic Supply

The aim of this study was to propose a cryogenic infrastructure that can provide the required needs in term of cool down time, redundancy and highest efficiency within the different operating modes. The Studies were placed at ALAT and Linde KT.

• Proposal on the cryogenic supply system for SIS100, SuperFRS and HADES/CBM experiments
  • Evaluation of various plant configurations for Cryo 1 (SuperFRS)
  • Evaluation of various plant configurations for Cryo 2 (SIS100)
  • Evaluation of a one plant solution: Cryo 0
• Evaluation of suitable compressor stations with regard to investment costs and high availability
  • Usage of Kaeser compressors?
• All proposed plant configurations shall be compared with respect to reliability, operation and investment costs (LN2 cooling?)
• Elaboration of the expected minimal pressures on the cold end low pressure side
• Estimate for the manpower required by GSI to follow-up during the design, installation and commissioning phase
• Estimation of the required space for the refrigerators and compressor systems
• Provision of budget prices and delivery time for the refrigerators and the compressor systems
Refrigerator Options

Version 1

- Independent operation of SIS100 and SuperFRS
- DB2 <-> DB3 not necessary or could be a cheap 4K supply, RT return line
• Independent operation of SIS100 and SuperFRS
• DB2 ↔ DB3 not necessary or could be a cheap 4K supply, RT return line
• Energy-efficient shutdown cooling
• Shield cooling could be one or two Turbo Braytons (50 K and 80 K)
• Dependencies in SIS100 and SuperFRS cooling
• DB2 ↔ DB3 has to be a full featured/expensive transfer line
• Energy-efficient shutdown cooling
• Shield cooling could be one or two Turbo Braytons (50 k and 80K)
• Dependencies in SIS100 and SuperFRS cooling
• DB2 <-> DB3 has to be a full featured/expensive transfer line
• Less energy-efficient shutdown cooling with the same cold box on 50 K level for both machines
• No Kaeser compressors
Cost Comparison

Version 1

In Linde Study VAR II (p.14)

3 pressure levels

Compressor station

No LN₂ pre-cooling

<table>
<thead>
<tr>
<th>SIS100 – Variation II</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Compressor system (3)(4)</td>
<td>T€</td>
<td>17'920</td>
</tr>
<tr>
<td>Coldbox system (5)</td>
<td>T€</td>
<td>13'460</td>
</tr>
<tr>
<td>Total investment costs</td>
<td>T€</td>
<td>31'380</td>
</tr>
<tr>
<td>Total operating costs (4) (5)</td>
<td>T€</td>
<td>25'380</td>
</tr>
</tbody>
</table>

(3) Incl. spare compressor system
(4) Only cycle A / B taken into account. Values have to be extrapolated for cycle C
(5) 50'000 h / 0.18 € per Nm³ LN2 / 0.10 € per kWh

Ratio based on budget offer from Aerzener

m = 1650g/s

SIS100 19 kW

Linde Study VAR II

3 pressure levels

Compressor station

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Cryogenic Supply Options within a similar Budget

1. Cryo 1 (6 kW) + booster and Cryo 2 (19 kW)

2. Cryo 0 (25 kW) + transfer line DB2 ↔ DB3 +cool-down, warm-up unit

<table>
<thead>
<tr>
<th>option</th>
<th>SIS100 (\Lambda) cycle</th>
<th>SIS100 (p) and rib</th>
<th>SFRS+(\Lambda) cycle</th>
<th>safety SIS100</th>
<th>safety SFRS+(\Lambda) cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>?</td>
<td>+</td>
<td>?</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>2.</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

1. State of the art (CERN 18 kW)
   - No safety margin for SIS100 \(\Lambda\) cycle

2. SIS100 full operation, but maybe with SuperFRS in stand-by
   - The “booster” is more difficult to guarantee independency
   - Transfer line is needed as a full featured line
   - Every upgrade might be very unbalanced
Conclusion of the Studies

• Both suppliers are in favor for two independent plants
• Both suppliers recommend not to exceed 25 kW for a single plant
• One plant solution + cool-down and warm-up unit for the SuperFRS is a new option (due to the reduced heat loads)!
• The two plants could be from different suppliers (no common compressor usage)
• ALAT is proposing the independent shield cooling by a Turbo Brayton Cycle machine, which is not offered by LKT
• Both considered options with and without permanent LN2
  • significant investment cost reduction using LN2 only for SuperFRS plant (Kaeser compressors!)
• Both studies confirm a suction pressure not lower than 1.22 bar
• From both studies the available space for the refrigerator(s) and the cool-down and warm-up unit is still sufficient, allow the maintenance and later upgrade for SIS300
Conclusion II, Cool-down and Warm-up Unit

- Due to the cold mass of the SuperFRS of approximately 1300 t a dedicated pre-cooler with a heat capacity of 60 to 70 kW at 80 to 100 K is required. Since the warm-up of the SuperFRS magnets has to be performed independent of the SIS100 operation, this pre-cooler has to overtake in addition the warm-up in case of a single plant solution.

- The cooling is realized by a LN2 heat exchanger. During cool-down approximately one truck of LN2 per day over a range of three to four weeks is necessary.

- The cool-down and warm-up unit is switched off during normal operation but is usable for SuperFRS emergency cooling at 80 K with LN2.
Summary

• Series Test Facility close to finalization
• HeSu is running according to design specification
• Study on the distribution system is ongoing
• Studies on the cryogenic supply have been performed
• Different cryo plant configurations are presently investigated
  • Tendency for one single plant
• But:
  • Still a dynamic heat load table (frequent changes)
  • First measurements of a magnet including vacuum chamber in Jan. 2015
  • New Civil Construction Milestones in spring 2015
Summary II

- Refurbishment of a TCF20 according to CERN standard including UNICOS and WinCC OA
- Two prototype heaters for the SIS100 magnets were built in collaboration with PBMT:
  - → hydraulic adjustment to different heat loads
- Local cryogenics is good progress
  - → see the talk by M. Chorowski