15th March 2012

Review of FAIR Cryogenics, 27-28 February 2012.

General

At the request of the FAIR Management and the Machine Advisory Committee, a two-day review of the cryogenic systems for FAIR was undertaken on 27-28 February 2012. The list of reviewers and their affiliations is given in Annex 1. The agenda of the review is shown in Annex 2.

The committee appreciated the quality of the presentations and the efficient organization of the review.

The design of FAIR cryogenics appears to be proceeding in "concurrent engineering" mode, addressing technical details in parallel with the identification or revision of major requirements. While this may be needed due to schedule requirements and very limited human resources it will require tight technical and organizational management to succeed. In particular, global coherence will only be achieved through an iterative process of technical reviews and interface management between the different contributing teams.

An important consequence of this is the urgent need to implement a formal change control procedure where all consequences of any change are fully documented and approved by all parties concerned. It is particularly important to document the cost implications of any changes so that cost escalation can be traced (and defended) at a later date. This is important for the whole FAIR Project, not just cryogenics.

Basic requirements need to be established at the Project level. Examples include staged installation and commissioning, operational flexibility, in-situ repair of cryomagnet or cryostat, acceptable dead time for cool down/warm-up, accessibility, reliability (in particular the need for hot spares), redundant refrigeration capacity or ability to operate with a failed component as well as high-level technical parameters such as design pressure of components.

The committee appreciates that the cryogenics team feels responsible for not only the production and distribution of refrigeration but also for the proper cryogenic operation of the superconducting magnets. In view of the size and complexity of the FAIR cryogenics the committee feels that the size of the present team is insufficient to carry out all the tasks attributed to it.

S-FRS

S-FRS contains 24 superferric warm-iron dipoles and 31 superconducting multiplets containing several cold-iron mutipole magnets in a common cryostat, all operating at 4.5 K. The dipole coils and the multipoles are enclosed in stainless steel helium containment vessels equipped with service turrets for cryogen and electrical feeds (vapour-cooled current leads). A prototype dipole has been built and tested. The multiplets are under design. The committee strongly recommends that the final multiplet design be subjected to a review by an expert panel when completed.

There seems to be a lack of clear understanding and late changes in the cooling method of these magnets. Whilst final cool-down is performed by injecting liquid helium into the bottom of the helium vessel and recovering vapour in the service turret, the magnets normally operate in baths of saturated helium with a controlled level ensuring complete immersion of the coils. Such a level control is reasonably easy to achieve by transferring liquid helium from a phase separator through an insulated line to the top of the bath which then operates as a decanter of the liquid from the vapour coming from the transfer losses. Feeding at the bottom of the bath prevents this decanting and may disrupt the level control.

The design pressures of the dipoles and multiplets are rather low and different from each other, with no justification given for their values. The low design pressure makes it more difficult to control the large helium inventory in case of operational problems, which could result in large helium loss. The committee recommends that the choice of design pressure be reviewed and substantiated.

The committee was presented with very tight constraints in allowable temperature gradients during cool down and warm up without a firm design basis. They seem to have been taken from other projects and are very conservative. These constraints should be defined, based on actual design requirements.

The multiplets are cooled in small clusters. It should be clarified if clusters can be cooled as single units or if there is a real need for independent cool down of individual multiplets in a cluster.

The cryogenic distribution system (compound transfer lines and boxes) is very complex and its routing very constrained, leading to a large number of singularities and large intrinsic consumption of liquid helium (60% of the cooling power at 4.5 K is used in the distribution system). There is a very long transfer line transporting helium to the first elements of the S-FRS. The justification for this (expensive) transfer line should be re-examined. If it is found to be indeed necessary, a simpler routing should be studied.

SIS 100

Cryogenic operation of SIS 100 will be governed by the dynamic loads due to the accelerator cycles. A number of different cycles covering the variety of operational modes have been identified and the corresponding heat loads defined. Together with the static heat loads resulting from cryostat design,this serves as a sound basis for the specification of SIS 100 cryogenic requirements.

The magnet cooling scheme for the Nuclotron at JINR Dubna which serves as a reference for SIS 100 was comprehensively presented. This enabled the committee to understand how this scheme, which violates some basic principles of cryogenic flow systems, e.g. large number of parallel channels without active balancing, two-phase flow path crossing the entire liquid-vapour dome, still works sufficiently well to maintain the superconducting coils in sound operating conditions. This, however requires a very careful balancing-by construction-of hydraulic impedances of the different magnets as well as the circulation of excess liquid helium in the parallel circuits, resulting in some cryogenic inefficiency.

The cooling scheme of SIS 100 is based on the same principle but with fewer parallel cooling channels and should therefore operate satisfactorily. The proposal to build a thermo-hydraulic model for experimental verification is welcome. Experience from real magnets and the prototype string will also be valuable. Care should be taken to ensure that the balancing of the parallel circuits is not hampered by contamination of the pipes during machine installation.

The committee notes that the design pressure is 1.8 MPa (18 bar), which should help contain most of the helium inventory in case of magnet quench or a stop of the cryoplant. It also appreciates that provision is made for the vacuum and cryogenic sectorization of the machine into 150 m sectors, which eases leak detection during installation and allows localised intervention on the machine.

Two possible cooling schemes were presented for the electrical feed boxes housing the high-current HTS leads. The committee firmly favours one with a liquid helium phase separator, which can be used as a fixed-temperature heat sink for the joints at the bottom of the current leads.

Cryogenic refrigeration and controls

The committee was presented with the general cryogenic architecture, containing two helium plants with very different capacities (CRYO1 of 6 kW for the S-FRS and CRYO2 of 24 kW for SIS 100, 4.5 K equivalent). While the common compressor station provides some redundancy, the committee notes that the strict allocation of the plants to their respective devices precludes mutualisation of over-capacity and redundancy.

Calculated heat loads were presented for both S-FRS and SIS 100 with a breakdown of the cooling duties for the refrigeration plants. While it was stated that a factor of 50% over-capacity was included, the correspondence between heat load and plant sizing was not given explicitly.

Specifications of CRYO1 and CRYO2 stipulate some preservation of efficiency at part load, which is certainly welcome. However, CRYO2 is required to operate with full efficiency with loads as low as 25% of nominal, which will most likely require the construction of two different heat exchanger lines and specific turbo-expanders able to handle efficiently such different cycle flow rates, thus increasing the complexity and the cost of this plant. The committee recommends that this requirement be reconsidered.

The committee takes note of the need for an additional 1.5 kW at 4.5 K plant dedicated to the magnet test station, to be procured on the same timescale as the other two plants. The manpower for the specification, procurement, industrial follow-up and commissioning of these three plants in parallel does not seem to exist in the present cryogenics team.

The architecture and technical choices for the control system, based on UNICOS in collaboration with CERN was presented. The committee supports this approach, which minimises additional work. However, the committee points out that the resources of the cryogenics group will once more be pushed to the limit in providing the input required by the controls group.

15th March 2012

Annex 1

Panel members

L. Evans (CERN), Chairman

J. Fydrych (WUT)

P. Lebrun (CERN)

B. Petersen (DESY)

T. Peterson (FNAL)

L. Tavian (CERN)

U. Wagner (CERN)

15th March 2012

Annex 2

Agenda

Review on Cryogenics at FAIR

from Monday 27 February 2012 at **10:00** to Tuesday 28 February 2012 at **20:00** (Europe/Berlin)
at **FAIR Darmstadt (KBW Hörsaal/Lecture Hall)**

Participants Alexander Bleile; Anna Breidert; Ralph Bär; Hartmut Eickhoff; Lyn EVANS; Egbert Fischer; Marion Kauschke; Holger Kollmus; Hans-Dieter Krämer; Philippe LEBRUN; Inti Lehmann; Hanno Leibrock; Eva Maas; Anna Mierau; Eugen Momper; Edil Mustafin; Carsten Mühle; Franziska Obst; Carsten OMET; Dieter Prasuhn; Günther Rosner; Pierre Schnizer; Claus H. Schroeder; Jens Stadlmann; Gertrud Walter; Udo Weinrich; Martin Winkler; Yu Xiang

Material Slides | Technical Guidelines Cryogenics

Go to day

Monday 27 February 2012

10:00 - 10:15	Welcome and FAIR Update *15'* (Universe (KBW Hörsaal/Lecture Hall)) Speaker: Dieter Krämer (FAIR GmbH)
10:15 - 10:35	Super-FRS: Machine and magnets *20'* (KBW Hörsaal/Lecture Hall) Speaker: Hanno Leibrock (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI))
10:35 - 11:05	Super-FRS Multiplets cooling (inner piping optimization and ANSYS simulation for cool-down) *30'* Speaker: Yu XIANG
11:05 - 11:20	C o f f e e B r e a k
11:20 - 12:05	Local cryogenics for Super-FRS (flow scheme, feedbox, cryogenic transfer lines, Branch box) *45'* Speaker: Yu XIANG
12:05 - 12:35	Layout (digital mock-up) of cryogenic facility in Super-FRS tunnel and buildings *30'* Speaker: A. BREIDERT
12:35 - 14:00	L u n c h _ B r e a k (GSI Canteen)
14:00 - 14:30	SIS100: Machine, magnets and operation cycles *30'* Speaker: Jens Stadlmann (GSI Ges. für Schwerionenforschung mbH)
14:30 - 15:00	Analyses of the SIS100 SC magnets cooling *30'* Speaker: Alexander BLEILE
15:00 - 15:30	Experiences at Dubna/Nuclotron *30'* Speaker: Hamlet KHODZHIBAGIYAN
15:30 - 15:45	C o f f e e _ B r e a k
15:45 - 16:15	Hydraulic analysys, operation scenarios and special installations *30'* Speaker: Marion Kauschke (Gesellschaft für Schwerionenforschung mbH)
16:15 - 16:55	Cryogenics hardware (Polish In-kind) *40'* Speaker: Jaroslaw Fydrych
16:55 - 18:00	Open Discussion *1h05'* Speaker: Jaroslaw Fydrych
18:00 - 20:00	E n d _ o f _ D a y _ 1 ()

Tuesday 28 February 2012

09:00 - 10:30	Cryo 1, Cryo 2 *1h30'* Speaker: Marion Kauschke (Gesellschaft für Schwerionenforschung mbH)
10:30 - 10:50	Control system *20'* Speaker: Ralph Bär (GSI Helmholtzzentrum für Schwerionenforschung GmbH)
10:50 - 11:00	Coffee_Break
11:00 - 11:30	Prototype Test Facility Operation, Series Test Facility Planning *30'* Speaker: Claus SCHROEDER
11:30 - 11:45	Reliability at Super FRS *15'* Speaker: Eugen MOMPER
11:45 - 12:00	Test of radiation hardness *15'* Speaker: Edil Mustafin (GSI Helmholtzzentrum für Schwerionenforschung GmbH)
12:00 - 13:00	Lunch_Break (GSI Canteen)
13:00 - 15:00	Final Discussion *2h00'*
15:00 - 15:10	We wish all participants a safe trip home ! Location: