TECHNISCHE UNIVERSITÄT DRESDEN

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The Cryogenic Moderator System for the European Spallation Source

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Motivation

The Cryogenic Moderator System (CMS) for the European Spallation Source (ESS) has to supply liquid hydrogen LH_2 at around 17 K and 1.1 MPa to moderate high-energy down to cold neutrons enabling science with neutrons. The design and fabrication of the system under the lead of Forschungszentrum Juelich GmbH is part of the German in-kind contribution to ESS.

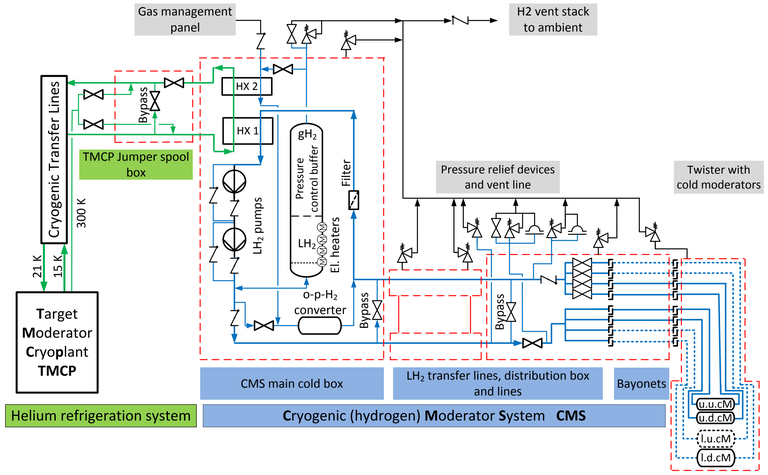

Figure 1. Flow schematic of the ESS Cryogenic Moderator System including the main components (first Twister generation will house two of finally four cold moderators cM) and its interface with the Target Moderator Cryoplant helium refrigerator.

Major Design Requirements

- Cryogenic hydrogen at an average temperature of 18.5 K and an elevated pressure of 10 bar.abs (subcritical, subcooled LH_2) with a parahydrogen content of > 99.5 % shall enable efficient neutron moderation inside the cold moderator vessels,
- The hydrogen shall be kept within operational boundaries at all times to ensure high availability,
- The hydrogen shall be provided in a safe and reliable way,
- The average temperature increase over the cold moderators due to a 5 MW proton beam and spallation neutrons shall be kept ≤ 3 K.

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CMS Design and Components

- Closed liquid hydrogen loop with 27 kg H_2 inventory
- Two (redundant) pumps in series with shared overall pressure head of ca. 1.6 bar and circulating a mass flow of 0.2 to 1 kg/s
- Parallel coolant flow through up to four cold moderators
- Actively controlled, cold Pressure Control Buffer with 60 l volume
- o-p-H_2 converter with 20 l volume utilizing Oxisorb® or IONEX type OP®
- Flexible helium refrigerator TMCP serving the cooling requirements
- Three actively controlled valves, passive spring-loaded safety relief valves and two burst disks at staggered set pressures
- Helium gas inerted common vent line directing the gas to the ambient

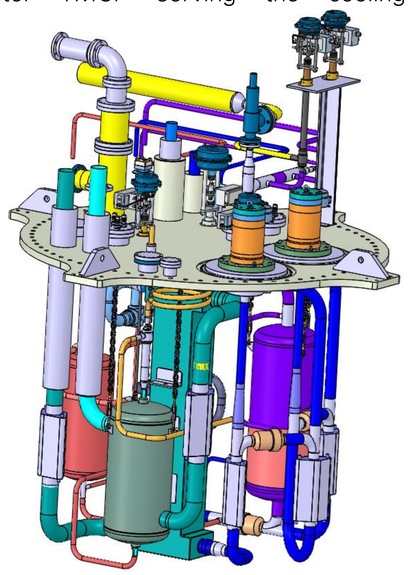

Figure 2. CAD design of CMS main cold box showing the valve/top plate, two turbo pumps (orange), the cold pressure control buffer (purple), the H_2-He plate fin HX 1 (turquoise), the precooling HX 2 (petrol), and the o-p-H_2-converter (red) among others.

Control Strategy

The CMS operation and transients impose the operating regime of the TMCP helium refrigerator:

CMS

- Hydrogen Loop Pressure (via cold Pressure Control Buffer)
- Hydrogen loop temperature (via TMCP)
- Cooling capacity (LH_2 turbo pump speed)
- Hydrogen inventory / pressure control buffer LH_2 fill level

TMCP

- Refrigeration power (variable process pressure, single or double warm compressor operation)
- Using warm helium gas to adjust feed temperature to CMS HX 1 in Jumper Spool box

Testing at FZ Juelich

Manufactured parts and pressure vessels, subassemblies and the complete CMS cryostat have to pass mechanical integrity tests (e.g. pressure test, leaks) with notified body approval. Furthermore, a Factory Acceptance Tests (FAT) including functional and performance validation of the hydrogen turbo pumps and the cold pressure control buffer (PCB) are going to be conducted. Instead of a helium refrigerator, a warm gN_2-LN_2-mixing unit provides a controlled cool down from 300 K and operation of the CMS close to 80 K. Process fluids are nitrogen or helium cold gas as well as liquid nitrogen.

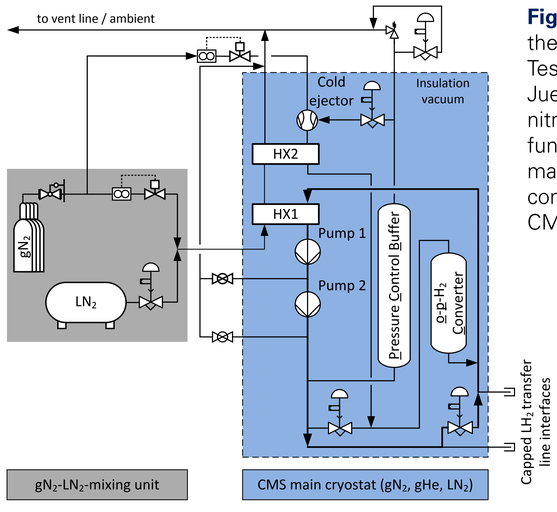

Figure 3. Schematic of the Facility Acceptance Test mock-up at FZ Juelich with surrogate nitrogen cooling unit for functional and performance evaluation of key components of the ESS CMS.

Summary

Based on the Preliminary Design Review (PDR) and the comprehensive requirements provided by the European Spallation Source a detailed Cryogenic Moderator System has been engineered to its final design. The process design enables all operating modes and provides a solid safety strategy. Ongoing work are procurement and manufacturing, the detail control scheme as well as preparation of the Factory Acceptance Test of the CMS cryostat without the LH_2 transfer line system in early summer 2018.

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