The Cryogenic Moderator System for the European Spallation Source

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Introduction

The Cryogenic Moderator System (CMS) for the European Spallation Source (ESS) has to reliably supply parahydrogen at around 17 K and 1.5 MPa to moderate high-energy to cold neutrons as basis for scattering experiments. Design and fabrication of the system by FZ Juelich and TU Dresden is part of the German in-kind contribution to ESS.

Major design requirements

• High safety and availability demands
• Extract up to 28.8 kW overall heat load with a max. LH₂ temperature span of 3.5 K
• Provide hydrogen with at least 99.5 % parahydrogen

System design and components

• Parallel coolant flow through four moderators
• Two (redundant) pumps in series with shared overall pressure head and circulating the same mass flow
• Active pressure control buffer (vertical temperature, density and hence compressibility distribution)
• o-p-H₂ converter and analyzer in bypass
• Helium refrigerator to re- and precool H₂
• Three active control and spring loaded safety valve combinations (main on top of pressure control buffer)
• Helium gas inerted vent line guiding gas in case of an emergency release to the stack

Online o-p-H₂ monitoring

• Moderators are optimized for pure parhydrogen (o-H₂ diminishes cold neutron yield)
• Demand for continuous, in-situ concentration measurement
• Two complementary systems under development
• Stabilization with help of converter in bypass
• dT = 0.8 K for 1 % change in parahydrogen concentration over catalyst

Challenge: In-situ o-p-H₂ monitoring (top); Solution: A) Raman spectroscopy (center) and B) temperature increase over catalyst (bottom).

Feasibility of operation at pressures near or below \( p_{crit} \)

A hazard to the Cryogenic Moderator System?

• Excursion: what happens if the operating pressure falls below the critical pressure of parahydrogen
• Strong connection between neutronic, structural mechanic and hydro-thermodynamic effects
• Relevant components: pressure control buffer, pumps, moderator vessels

Functional evaluation prior to LH₂ commissioning

• Jumper Spool for independent commissioning of helium refrigerator and Cryogenic Moderator System
• Pressure control buffer performance test with (sub-)critical CO₂ at ambient temperatures
• Adiabatic catalyst in-situ o-p-H₂ monitoring and reaction kinetics in test cryostat

Conclusion

Based on preliminary design solution provided by ESS a detailed Cryogenic Moderator System has been elaborated. The design comprises all significant operating modes, safety measures and plans to validate the component performances as much as feasible prior to hydrogen commissioning.