Contribution ID: **354** Type: **Poster**

C2Po3B-03: Results of fundamental operational function tests for the ESS cryogenic moderator system during preliminary commissioning with helium

Tuesday 20 May 2025 14:00 (2 hours)

At the European Spallation Source (ESS), two flat butterfly-shaped hydrogen moderator vessels have been designed and optimized to achieve a maximum neutron brightness under the condition of parahydrogen fraction higher than 99.5%. Currently, these hydrogen moderators are installed above the target wheel. Future plans involve replacing them with four moderators positioned both above and below the target. The nuclear heating at the moderators is estimated at 6.7 kW for the proton beam power of 5 MW, increasing to 17.2 K for the four moderators is 17.2 kW. To supply liquid hydrogen at 17 K with a parahydrogen fraction of 99.5% to each moderator, a Cryogenic Moderator System (CMS) was designed. The flow rate to each moderator is 240 g/s, ensuring the average temperature rise through the moderator remains within 3 K. For 5-MW proton beams, a heat load of 21.9 kW, including a static heat load of 4.6 kW, is removed by the Target Moderator Cryoplant (TMCP), a 20 K-helium refrigeration plant with a maximum cooling capacity of 30.3 kW at 15 K.

The CMS will operate automatically in combination with the TMCP, supported by an automated operation control system currently under development. This system includes seven operational modes: cooldown, steady-state, energy-saving, beam injection, warm-up, quick warm-up and ortho-to-parahydrogen measurement modes. The cooldown operation mode requires two compressors with the discharge high-pressure of 1.5 MPa and two parallel cold turbines, enabling the CMS to reach 17 K within 30 hours. Upon completing cooldown, the system automatically transitions to the steady-state mode. In this mode, liquid hydrogen is circulated at 17 K at a flow rate of 1 kg/s by two hydrogen pumps operating at 7,000 rpm, maintaining a pressure of 1.1 MPa through the pressure control system. This operation mode allows transitions to the beam injection and energy saving modes. During a brief maintenance period of approximately two weeks, the energy-saving mode will be used to maintain the CMS at 17 K without requiring a full warm-up. To conserve energy, one of the cold turbines will switch off, followed by the shutdown of one compressor. Additionally, the discharge pressure is decreased to 1.0 MPa.

In this study, fundamental operational function tests related to the mode transitions such as the transition from steady-state to energy saving mode, were conducted during the commissioning period with helium to establish the automated control logic. Additionally, a simultaneous trip of all turbines, caused by the water-cooling pump trip due to an electrical glitch, resulted in the safe shutdown of the CMS through the failure-action system, as designed. This paper presents the results of the operational function tests and the activation of the CMS failure-action triggered by the accidental turbine trip.

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Session Classification: C2Po3B - Large Scale Cryogenic Systems VI: Operation & Design V