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C3Or4B-05: Commissioning results of the ESS cryogenic moderator system using helium

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At the European Spallation Source (ESS), a 5 MW beam of 2.0 GeV proton with a nominal current of 62.5 mA driven by an accelerator will impact a tungsten wheel target at a repetition rate of 14 Hz and a pulse length of 2.86 ms. Fast neutrons produced via spallation process are moderated to cold and thermal neutrons of lower energy levels by passing through a thermal water pre-moderator and, subsequently, up to two liquid hydrogen moderators. The nuclear heating is estimated to be 6.7 kW for the proton beam power of 5 MW, with a projected increase to 17.2 kW for the four moderators in the future. A cryogenic moderator system (CMS) has been designed to continually supply subcooled liquid hydrogen at 17 K with a parahydrogen fraction of exceeding 99.5% to each moderator placed in parallel. A flow rate of over 240 g/s is maintained to limit the average temperature rise across the moderator to within 3 K. Heat load is effectively removed via a heat exchanger by a large-scale 20 K helium refrigeration plant, the Target Moderator Cryoplant (TMCP), which provides a maximum cooling capacity of 30.3 kW at 15 K. The TMCP commissioning was completed independently, without connecting the CMS, in December 2022. Operational procedures, including a cooldown, warm-up and beam injection modes, were thoroughly studied to establish an automatic TMCP-CMS control system. Meanwhile, the CMS installation into the Target building was finalized by June 2024. Prior to hydrogen operation, CMS commissioning was performed using helium, bypassing the moderators. The CMS was successfully cooled down to 17 K utilizing the developed controllers while maintaining a pressure of 0.56 MPa, ensuring that the helium densities matched those of gaseous hydrogen at an operational cooldown pressure of 1.12 MPa. Performance tests were conducted at 17 K while evaluating pressure drops over the entire loop, heat load, and liquid hydrogen pump performances at varying pump speeds, all of which aligned with design specifications. Additionally, a newly developed 17-kW orifice type heater demonstrated outstanding fast-response characteristics, achieving a ramp-up to 500 W within one second. This paper presents detailed performance test results during the preliminary commissioning using helium.

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