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C2Po3B-02: Verification and optimization of cooldown operation mode for the ESS cryogenic moderator system during preliminary commissioning using helium

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At the European Spallation Source (ESS), a cryogenic moderator system (CMS) was designed to continuously supply subcooled liquid hydrogen at 17 K with a parahydrogen fraction exceeding 99.5% to the two moderators. Heat loads are removed via a heat exchanger in the CMS cold box, which is cooled by a large-scale 20 K helium refrigeration system, the Target Moderator Cryoplant (TMCP), with a cooling capacity of 30.3 kW at 15 K. A temperature controller regulates a supply temperature by operating two bypass valves for two cold parallel turbines. A high-pressure helium stream at 15 K is transported to the CMS cold box via a 385-meter-long vacuum-insulated cryogenic transfer line (CTL) and a valve box adjacent to the CMS cold box. The valve box adjusts the feed flow rate and the supply temperature to the CMS cold box, as well as the return temperature to the TMCP cold box. Installation of the CMS began in 2022. Concurrently, TMCP commissioning without the CMS was conducted over five months, concluding in December 2022, confirming that the TMCP met the design requirements. By May 2024, the CMS installation was completed and subsequently the preliminary commissioning, cooled by the TMCP, was conducted without connecting the moderators using helium prior to hydrogen operation.

In this study, the cooldown process was investigated during the preliminary commissioning. These studies were guided by the results of the TMCP commissioning and simulations of the CMS cooldown process. The CMS operational pressure was set to 0.6 MPa, matching the helium density to that of gaseous hydrogen at the CMS cooldown operational pressure of 1.2 MPa. Operational parameters were optimized, and effective controllers were developed to complete the cooldown operation within 30 hours. It was demonstrated that the TMCP must operate its two cold parallel turbines and maintain a compressor discharge pressure of 1.5 MPa to achieve the required CMS cooldown speeds, as the majority of the cooling capacity was consumed in cooling the long CTL. The operational procedures for cooldown process have been established, and their parameters have been optimized in preparation for the CMS commissioning with hydrogen, scheduled for Spring 2025.

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