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First commissioning of the ESS cryogenic moderator system using nitrogen and 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. The fast neutrons produced via spallation process are reduced 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. Initially, the ESS is to install two hydrogen moderators above the target wheel and plans to replace them by four moderators positioned above and below the target in the future. The calculated nuclear heating is 6.7 kW for the proton beam power of 5 MW, whereas that for the four moderators is 17.2 kW. A cryogenic moderator system (CMS) has been designed to continually supply subcooled liquid hydrogen with a temperature of 17 K and a parahydrogen fraction of more than 99.5% to each moderator placed in parallel at the flow rate of more than 240 g/s to maintain an average temperature rise at the moderator within 3 K. The heat load is effectively removed by a large-scale 20 K helium refrigeration plant, which is called the Target Moderator Cryoplant (TMCP), with a maximum cooling capacity of 30.3 kW at 15 K. The TMCP commissioning was carried out independently without connecting the CMS until December 2022. Operational procedures, including a cooldown, warm-up and beam injection modes, were thoroughly studied to establish an automatic TMCP-CMS control system. The installation of the CMS was completed in January, 2024. Initially, CMS-TMCP commissioning took place without connecting the moderators, utilizing nitrogen and helium before hydrogen operation. The CMS cooldown and warm-up processes were studied based on prior simulation results conducted by the authors and operational parameters were optimized. Additionally, performance tests, such as hydrogen pumps, a He-H2 heat exchanger, pressure drop and heat load have been conducted.

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