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C1Po1A-06: Updated design of the ESS cryogenic moderator system

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In 2024, ESS installed two hydrogen moderators, designed and optimized to achieve maximum neutron brightness while maintaining a parahydrogen fraction exceeding 99.5%. The cryogenic moderator system (CMS) was designed to meet two critical requirements: (1) a temperature rise of less than 3 K across each moderator, and (2) a parahydrogen fraction exceeding 99.5%. Subcooled liquid hydrogen at 17 K and 1.0 MPa is circulated at a flow rate of 1 kg/s using two centrifugal pumps arranged in series. The distribution lines to each moderator are configured in a parallel arrangement to ensure consistent inlet temperatures across all moderators. To achieve a parahydrogen fraction of 99.5%, an ortho-to-parahydrogen catalyst is incorporated within a bypass line. This configuration minimizes pressure drop, as the catalyst bed presents significant flow resistance. A 65-liter buffer tank stabilizes pressure and mitigates pressure fluctuations induced by changing the stepwise heat input at the proton beam injection or trip. The static and dynamic heat loads are removed via a heat exchanger connected to a 20 K large-scale helium refrigerator, Target Moderator CryoPlant (TMCP), with a cooling capacity of 30.3 kW at 15 K. Dynamic heat loads are compensated using a valve box adjacent to the CMS cold box, which adjusts the feed helium flow rate to the heat exchanger, and a developed fast-response heater that address thermal disturbance within the CMS loop. In 2020, the fabrication of the CMS cold box was completed by the ESS in-kind partner, Forschungszentrum Jülich GmbH (FZJ). The cold box underwent acceptance cryogenic tests using gaseous and liquid nitrogen until September 2021, and was subsequently installed at the ESS site in November 2021. Meanwhile, we designed and manufactured additional components, including hydrogen transfer lines connected from the cold box to the moderators, a hydrogen vent line, an in-situ ortho-to-parahydrogen measurement system using Raman spectroscopy, the fast-response heater to compensate for the nuclear heating, and a hydrogen filling station. Additionally, heaters wrapped around the buffer tank were redesigned, as the acceptance testing revealed that the initial design did not meet the required specifications. All installations were completed in May 2024. This paper presents the updated design status of the ESS CMS.

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