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C3Po1B-05: Study of operational modes of cool-down and warm-up processes for the ESS large-scale 20 K helium refrigeration system

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At the ESS target, high energy spallation neutrons are produced by impinging 5 MW proton beam on the high-Z material, tungsten. The proton beam is pulsed with a repetition of 14 Hz and a pulse length of 2.86 ms. The spallation neutrons are moderated to cold and thermal energies by the moderators. The moderator system consists of a thermal water pre-moderator and two liquid hydrogen cold moderators, all optimized to achieve a high cold neutron brightness. The nuclear heating is estimated to be 6.7 kW for the 5-MW proton beam power. A cryogenic moderator system (CMS) has been designed to continuously supply subcooled liquid hydrogen with a temperature of 17 K and a parahydrogen fraction of more than 99.5% to the two moderators. The heat load will be removed via a heat exchanger in the CMS cold box by a large-scale 20 K helium refrigeration system called the Target Moderator Cryoplant (TMCP) with a cooling capacity of 30.3 kW at 15 K. A temperature controller regulates the supply temperature of the TMCP cold box by acting two bypass valves for the two cold parallel turbines. The high-pressure helium stream with the temperature of 15 K is delivered to the CMS cold box through a 385-m long vacuum insulated cryogenic transfer line (CTL) and a valve box, which has functions to adjust the feed flow rate and the supply temperature to the CMS and the return temperature to the TMCP cold box. The first commissioning of the TMCP without the CTL and the valve box has been finished in 2019. The installation of the long CTLs and the valve box has been completed in summer 2022. Subsequently, the second commissioning of the overall TMCP has been performed without connecting to the CMS cold box until December 2022. The final installation of the connection between the valve box and the CMS cold box is planned for 2023. In this study, the TMCP cooldown and warm-up processes have been studied based on the simulation results for the CMS cooldown and warm-up operation conducted by the authors in advance. It turned out that the TMCP has to operate the two cold parallel turbines to achieve the required CMS cooldown operation because most of the cooling capacity was consumed to cool the long CTL. In the warm-up process, the supply temperature was successfully increased to 30 K at the desired warm-up speed, controlling the cooling capacity of the TMCP where one warm turbine and one cold one were operated. The TMCP operational procedures for the cooldown and warm-up have been established and its operational parameters have been optimized.

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