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C1Or2B-03: Simulation of the cool-down process for the ESS cryogenic moderator system

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The European Spallation Source ERIC (ESS) will provide long-pulsed cold and thermal neutron fluxes at very high brightness to the research community. At the ESS target, high energy spallation neutrons are produced by impinging a 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. In the beginning, the ESS will install two hydrogen moderators, which have been designed and optimized to achieve a maximum neutron brightness under the condition of parahydrogen fraction higher than 99.5%. The current plan is to replace them with four (two above and two below the target wheel, respectively) in the future. A cryogenic moderator system (CMS) has been designed to continuously supply subcooled liquid hydrogen with a temperature of 17.5 K and a parahydrogen fraction of more than 99.5% to the two moderators placed in parallel and to maintain an average temperature rise at the moderators within 3 K. The liquid hydrogen will be circulated at the flow rate of 0.5 kg/s for the two moderators (1 kg/s for the four moderators in the future) by two centrifugal pumps in series. The CMS is cooled through a plate-fin type heat exchanger (HX-1) by a 20 K large-scale helium refrigeration plant with a maximum cooling capacity of 30.3 kW at 15 K. The author developed a simulation code for the J-PARC CMS, which could predict the dynamic behaviors of the temperature fluctuation caused by the proton beam switching on or off for 300 and 500-kW proton beam operations. In this study, a one-dimensional simulation code has been developed in order to understand the temperature behaviors and the pressure distribution during the ESS CMS cool down process based on the code for J-PARC. The CMS cooldown process was divided into three phases (I: vapor state, II: condensation state and III: liquid state). The cooldown process analysis has been performed and the operational methods and parameters such as cooldown speed, pump speed and valve positions have been optimized. It was verified that the CMS would be able to be cooled down to the nominal condition within 27 hours.

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