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C3Po1A-05: Effect of a thermal fluctuation caused by a proton beam injection on the ESS large-scale 20 K helium refrigeration system

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At the European Spallation source (ESS), 2 GeV proton beams with a power of 5 MW are injected on a rotating tungsten target wheel with a repetition of 14 Hz and a pulse length of 2.86 ms to produce high energy spallation neutrons. The high-energy neutrons are slowed down to cold and thermal energies by the moderators, which consists of a thermal water pre-moderator and two liquid hydrogen cold moderators, all optimized to achieve a high cold neutron brightness. The two hydrogen moderators are located above the target wheel and the nuclear heating is estimated to be 6.7 kW for the 5-MW proton beam power. The current plan is to replace them with four (two above and two below the target wheel, respectively) in the future. The nuclear heating for the four moderators is calculated to be 17.2 kW. A large-scale 20 K helium refrigeration system, which is called Target Moderator CryoPlant (TMCP), has a cooling capacity of 30.2 kW at 15 K. A 385 m-long cryogenic transfer line (CTL) and a valve box have been installed in summer 2022, because all the ESS helium cryoplants are co-located in order to facilitate maintenance and consolidate utilities. The purpose of it is to cool the cryogenic moderator system (CMS) that provides subcooled liquid hydrogen with a temperature of 17.5 K to the hydrogen moderators and remove the nuclear heating generated at the moderators. When the proton beams are injected or tripped, the enormous heat load is suddenly changed. The available cooling capacity has to be changed by adjusting the feed helium flow rate in order to maintain the hydrogen temperature to the moderator at 17.5 K within temperature fluctuation of ≤0.1 K. The valve box has functions to adjust the feed flow rate, the supply temperature to the CMS and the return temperature to the TMCP cold box without changing the cooling capacity of the TMCP cold box. In this study, we investigated the stability of the TMCP operation when the heat loads of 5.92 kW and 17.5 kW for the two- and four-moderator arrangements were rapidly applied and how to mitigate the propagation of the temperature fluctuation in order not to affect the CMS supply temperature. For the transient heat load of 5.92 kW, the fluctuation of the CMS supply tempeature was able to be mitigated by only a PID control of the return temperature within the allowable one of 0.4 K. The result indicates that for 17.5 kW, the combination of the PID and the feedforward control is essential to mitigate not only the CMS supply temperature within 0.1 K but also the pressure fluctuation.

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