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C2Po1A-05: Performance assessment of liquid hydrogen pump for the ESS cryogenic moderator system during initial commissioning using helium

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At the European Spallation Source (ESS), the high-energy neutrons produced through spallation reaction are moderated to cold and thermal energies using a combination of hydrogen moderators and a light water pre-moderator, which are optimized to achieve a high cold neutron brightness. The ESS employs two hydrogen moderators positioned above the target wheel, with an estimated nuclear heating of 6.7 kW for a 5-MW proton beam power. A cryogenic hydrogen moderator was designed to circulate subcooled liquid hydrogen at 17 K and 1.0 MPa to the moderators. Each moderator requires a flow rate of 250 g/s to limit temperature rises at the moderators to below 3 K, resulting in a total circulation flow rate of 0.5 kg/s for the two-moderator configuration. The associated pressure drop for this flow rate is estimated to be 100 kPa. To overcome the significant pressure drop, the ESS incorporates two centrifugal pumps with ball-bearings arranged in series, providing the necessary pump head to sustain the required flow rate. The pump revolution speeds are adjustable, ranging from 1,000 to 14,000 rpm. The pump motor is cooled using a glycol-water system at a flow rate of 5.7 L/min. During cooldown, particularly at ambient temperatures where hydrogen density is significantly low, both pumps must operate at a high speed of 13,000 rpm to maintain adequate circulation.
During preliminary commissioning using nitrogen and helium prior to hydrogen operation, the pump performances were measured at 120 K and 17 K. The results demonstrated that, when expressed in terms of dimensionless expression of head and discharge coefficients, all measured data aligned on the same curve, regardless of working fluid (nitrogen or helium). Additionally, thermal properties, including adiabatic efficiencies, pump flange temperatures, and pump casing temperatures were also measured. The performance test identified an operational flow coefficients range of 0.027 to 0.034 as necessary to maintain the flange temperature above 10℃. However, deviations from the maximum efficiency point resulted in flange temperatures dropping as low as 4℃. To address this issue, a water-radiator jacket was designed and integrated onto the pump flange. This provides an effective solution to stabilize the flange temperature and ensure reliable sealing performance.

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