Contribution ID: **214** Type: **Poster**

Design optimization of Helium cooling systems for Indian LLCB TBM

Friday 26 October 2018 08:30 (4 hours)

India is developing the lead–lithium cooled ceramic breeder as the blanket concept to be tested in ITER. In the Indian Lithium cooled Ceramic Breeder (LLCB) Test Blanket Module (TBM), PbLi eutectic alloy is used as multiplier, breeder, and coolant for the CB zones, and Li2TiO3 ceramic breeder (CB) is used as a tritium breeding material. The outer box structure is made of India specific Reduced Activation Ferritic Martensitic Steel (IN-RAFMS) cooled by high pressure (8.0 MPa) and high temperature (300-500 C) helium gas named as First Wall Helium Cooling System (FWHCS). The Pb-Li flow velocity is kept moderate enough such that its self-generated heat and the heat transferred from the ceramic breeder bed is extracted effectively. The Pb-Li system is cooled by another high-pressure helium system named as lead-lithium helium cooling system (LLHCS). Eventually, the two helium systems transfer the heat to Component Cooling Water System (CCWS) of ITER. In the conceptual design of LLCB TBM and its ancillary systems, two independent helium circuits were considered for extracting heat separately from the FW and the Pb-Li system. These helium systems are thermally and hydraulically independent to each other and they have their own components for operation and control. However, after detailed study, it is found that Installation and assembly of all these components along with coolant purification system in the allocated space of Tokamak Cooling Water System (TCWS) vault annex is very difficult and the existing system to be optimized to fit into the space. Accordingly, studies were carried to reduce the number of components & their sizing and schemes to combine the two independent helium systems etc. In parallel, studies were also conducted to optimize the helium flow requirements for cooling the TBM FW. In the optimized configuration, a single helium system is proposed catering the cooling requirements of FW and Pb-Li system and the main components and piping of the optimized configurations of helium system are modeled in the modified version of RELAP/MOD4.0 and transient analysis is carried out. This paper discusses the results of the optimization studies and process parameters & features of the circuit diagram of the combined helium system. Thermo-hydraulic Analysis results with the chosen optimized process parameters of the First Wall are also presented.

Country or International Organization

India

Paper Number

FIP/P7-6

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Session Classification: P7 Posters

Track Classification: FIP - Fusion Engineering, Integration and Power Plant Design