Neutronics Performance Characteristics of the EVOLVE First Wall/Blanket System

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The EVOLVE (Evaporation of Lithium and Vapor Extraction) concept has the potential for high power conversion efficiency and for accommodating high power density. The concept uses the heat of vaporization of lithium as the primary means for capturing and removing the fusion power. The first wall (FW) consists of a tube bank arranged in the toriodal direction. Within each tube is another tube which caries liquid lithium. Two FW design options are considered in which either spray cooling or capillary cooling is utilized at the inner surface of the FW tube to remove the large surface heat flux. The blanket consists of a number of trays, stacked poloidally, containing liquid lithium at 0.035 MPa (1200 degrees C). A space is left between trays to allow the Li vapor to be removed from the blanket. The choices for structural materials are limited to high temperature refractory alloys. A tungsten alloy, e.g. W-5%Re, is the primary candidate as a structural material. The FW tubes are either attached to the trays or separated from them. A secondary breeding blanket is utilized in the outboard region to enhance tritium breeding and to improve neutron shielding. Lithium is used as the breeder and coolant in the secondary blanket.

Two-dimensional neutronics calculations have been performed for the EVOLVE system. The FW design options were analyzed. Tray Li boiling analysis resulted in vapor fractions in excess of 50%. The detailed distribution of the vapor fraction was included in the neutronics model. The relatively high vapor fraction in the trays resulted in small impact on the overall neutronics performance parameters compared to the initial analysis with a uniform vapor fraction of 17%. The overall tritium breeding ratio (TBR) is greater than 1.3 at a lithium enrichment of 40% Li-6 indicating that tritium breeding has a comfortable margin. More than 60% of the total energy is deposited as high-grade heat in the front evaporation-cooled zone (FW and trays) which allows for achieving a very high thermal efficiency in the power conversion system. Nuclear heating and radiation damage profiles were calculated. No significant peaking was observed in the areas behind the poloidal gaps between the trays. The radial build required for vacuum vessel reweldability and magnet shielding was determined. Using a separate FW with more structure content was found to have minimal impact on the overal neutronics performance parameters.

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