THERMAL HYDRAULIC ANALYSIS OF FIRE DIVERTOR*

C.B. Baxi,[1] M.A. Ulrichson,[2] D.E. Driemeyer,[3] P. Heitzenroeder[4]

[1]General Atomics, P.O. Box 85608, San Diego, California 92186-5608
[2]Sandia National Laboratories, P.O. Box 5800, Albuquerque, New Mexico 87185
[3]Boeing, P.O. Box 516, St. Louis, Missouri 63166-0516
[4]Princeton Plasma Physics Laboratory, P.O. Box 451, Princeton, New Jersey 08543-0451

The Fusion Ignition Research Experiment (FIRE) is designed for high power density and advanced physics operating modes. The outer divertor plate of FIRE will be actively cooled by water. There are 32 modules of outer divertor (16 upper and 16 lower). Each outer divertor module is 672 mm in width and 550 mm in length. Flow direction is poloidal so that power input to each channel is equal. Each of the modules is divided into 24 copper plates across the front surface. Each plate includes two 8 mm ID cooling channels for a total of 48 across the heated surface for each module. The copper finger plates include tungsten-brush armor as a plasma-facing component (PFC). 3 mm rods of the brush have a conical tip over 1 mm length, which is imbedded in the copper. A 5 mm thickness of the PFC is adequate because erosion of tungsten is expected to be negligible. The use of tungsten brush reduces the stresses in the PFC.

A finite element (FE) model of the divertor geometry was prepared to determine the ratio of surface heat flux to wall heat flux, the temperatures of the PFC and the time required for the components to reach steady-state. The heat transfer coefficient represented the forced convection, nucleate boiling and the transition regimes. The coolant temperature and pressure at the exit from the channel were used to calculate the heat transfer coefficients. Using a heat transfer enhancement method reduces the velocity, flow rate and pumping power. Hence, a swirl tape (ST) with a thickness of 1.5 mm and a twist ratio of 2 is used in the divertor cooling channels.

The worst thermal condition for the outer divertor is the baseline D-T operating mode (10 T, 6.6 MA, 10 s) with a plasma exhaust power of 67 MW with 2.32 MW of power to a module and a peak heat flux of 20 MW per meter square. The FE analysis shows that for an inlet pressure of 1.5 Mpa and a flow velocity of 10 m/s, an incident burnout heat flux is greater than 30 MW per meter square. The peak cooper temperature is 450 degrees C, peak tungsten temperature is 1560 degrees C and time to reach steady-state is 5 s. The pressure drop is less than 0.5 Mpa. All these results fulfill the design requirements.

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