THERMAL HYDRAULICS OF WATER COOLED DIVERTORS*

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Divertors of several new machines, such as JT-60SU, FIRE, SST-1, ITER-RC and KSTAR, are water-cooled. This paper examines critical thermal hydraulic issues associated with design of such divertors.

The flow direction of coolant in the divertor can be either toroidal or poloidal. A quantitative evaluation shows that the poloidal flow direction is preferred, because the flow rate and pumping power are about an order of magnitude smaller compared to the toroidal flow direction. Use of heat transfer enhancement techniques leads to a lower water pressure requirement, lower flow rate, lower pressure drop, lower pumping power and lower flow velocity. A review of techniques to increase the heat transfer coefficient and critical heat flux, such as hypervapotron, swirl tube, wire insert, etc., was performed. It is concluded that swirl tube is the best available method due to a large amount of data and ease of fabrication.

The standard critical heat flux (CHF) correlations calculate the CHF value at the surface of the coolant channel, whereas divertor physics studies specify the value of the heat flux incident on the divertor surface. Hence, a finite element thermal analysis of typical divertor geometry was performed. Such an analysis requires computation of heat transfer coefficients over a number of heat transfer regimes such as forced convection, incipient boiling, nucleate boiling and post critical heat flux regime. The analysis shows that the ratio of incident heat flux to coolant channel heat flux varies between 1.1 to 1.5 and depends on the heat flux magnitude. The temperatures predicted by the analysis compare very favorably with experimental measurements. The method presented in this paper also correctly predicts incident burnout heat flux for a uniform as well as an axially-peaked heat flux profile. A typical axial distribution of heat flux results in about a 20% higher incident burnout heat flux compared to a uniform heat flux.

Recommended correlations and procedures for water-cooled divertor thermal analyses are presented. The expected peak heat flux of 20 MW/m^2 in tokamak divertors can be accommodated with a flow velocity of about 10 m/s and coolant pressure of 4 MPa.

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