

Prediction of Pressure Drop in the ITER Divertor Cooling Channels

S. T. Yin

Mandarin Thermal Systems, Toronto, Ontario, Canada Email: yinst@sympatico.ca

This study is dealing with the prediction of pressure drop in the cooling channels of divertor plates in the ITER (International Thermonuclear Experimental Reactor) fusion reactor. The divertor plates in the ITER fusion reactor directly contact the plasma stream and will be exposed to extremely high heat flux. The cooling channels embedded in the divertor plates must be adequately designed to serve as an effective heat sink so that safe operation can be assured.

The divertor cooling channels were designed with header-to-header parallel channels, which consist of straight and curved tubes. The simulated typical operating conditions for the cooling system are: coolant: water; channel diameter: 0.010 ~ 0.015 m; inlet header pressure: 3.5 MPa; inlet temperature: 50°C; mass flux up to 15 Mg/m²s; heat flux: up to 10 ~ 20 MW/m²; heat transfer modes: single-phase convection and subcooled flow boiling, with a twisted tape insert to generate swirl flow in the subcooled sections.

A user-friendly thermalhydraulics simulation package was needed and developed [Yin, 1991]* to predict, based on appropriate correlations, the heat transfer and pressure drop characteristics of the system. Given the channel geometry, heat flux distribution and inlet parameters, the program will calculate the overall pressure drop from the inlet to the outlet headers and the exit pressure of a specified section. Pressure drop due to frictional, accelerational, and gravitational effects are determined

The analytical models were based on existing formulations in the literature [Collier, 1981]. The correlations selected agree well with one set of subcooled boiling data generated at moderate heat flux levels [Chen, 1985]. However, no data is available from the open literature for subcooled boiling under the high heat flux conditions of the ITER fusion reactor. The modelling should therefore be tested against such data as such data become available.

Using the basic building blocks of the pressure drop software, it is possible to construct a piping system of an arbitrary layout. Any combination of straight sections, swirl flow sections, pipe bends and inlets and outlets can be constructed from the individual subroutines discussed. However, a code is required to interpret the specified geometry, and calculate the overall pressure drop and the exit pressure of a specified segment.

In conclusion, the method and code as presented can be used for design purposes to model the pressure drop in high heat flux coolant channels under subcooled boiling conditions. The correlations selected for predicting the pressure drop agreed well with one set of published data. However, the code should be validated with data obtained at ITER operating conditions as such data become available.

* References

Yin, S.T., [1991] (Contributing editor), "Proceedings of the 1991 Specialists' Workshop on NET/ITER Divertor Plates Thermalhydraulics", San Francisco, November 1991.

Collier, J.G., [1981], "Convective Boiling and Condensation", 2nd Edition, McGraw-Hill, London, UK.

Chen, J.L., [1985], "An Experimental Investigation of Subcooled Boiling Pressure Drop in a Vertical Channel", Masters Thesis, National Taiwan Institute of Technology.