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A REPORT FROM THE

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LOCAL HEAT TRANSFER AND CHF FOR SUBCOOLED FLOW BOILING

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THERMAL SCIENCE RESEARCH CENTER (TSRC)

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For the past decade, efforts have been growing in the development of high heat flux (HHF) components for many applications, including fusion and fission reactor components, advanced electronic components, synchrotron and optical components, and other advanced HHF engineering applications. From a thermal prospective, work in the fusion reactor development arena has been underway in a number of areas including: (1) Plasma thermal, and electro-magnetics, and particle transport; (2) Fusion material, rheology, development, and expansion and selection; (3) High heat flux removal; and (4) Energy production and efficiency.

Many international engineering activities are underway to support fusion reactor implementation for the production of economical energy in the distance future. Among the many key technological issues is the development of plasma-facing components for the International Thermonuclear Experimental Reactor (ITER), TPX, DEMO, and the related engineering design activity. Such components will be exposed to a single-side [i.e., internal flow channels will be heated externally from one side, only] heat flux ranging from 0.1 to 10.0 MW/m^2 over lengths up to 0.5 m. Although other heat transfer techniques such as liquid metal and high velocity helium cooling are being seriously considered, subcooled flow boiling (with water) is the leading contender for high heat flux fusion accommodation. Accordingly, interest must be focused on the local heat transfer, the critical heat flux (CHF) phenomena and flow excursion. However, irrespective of the convective fluid used (helium, water, or liquid metal) the advantages and adverse consequences associated with single-side heating must be explored and accommodated in future component designs.

Because of the simplicity involved, many previous investigators and designers have approximated single-side heated coolant channels with an equivalent uniformly heated channel. Since this approximation may not apply in all cases, more investigators are now interested in accurately including the effect of single-side heating into their experimental investigations and final designs. With the addition of this needed complexity, new approaches must be identified to relate these two heating configurations.

Based on a recent CHF assessment, it was concluded that CHF correlations should not be used outside their range of applicability. In some cases where correlations were used out of their parameter ranges (e.g. Lee and Mudawar, Weisman and Ileslanlou, Tong-68, and Vandervort et al.), either erroneous predictions resulted or excessive error resulted which could have been otherwise avoided by using a more appropriate correlation. For example using a selective data set from the Celata et al. data bank, that assessment showed that some CHF correlations had less than a 10.0 percent standard deviation (psd) when used within the limits of their parameter ranges. The correlations which fell into this recommended group included those by Katto and Tong (1975 Version). Although not included in that study, it is anticipated that Celata's et al. version of a combination of Katto's and Lee and Mudawar's correlations will also fall into that category. Out of eight correlations assessed: (1) seven correlations (Katto, 7.9 psd; Tong-75, 8.3 psd; Weisman and Ileslanlou, 10.2 psd; modified Tong, 11.3 psd; Tong-68, 13.3 psd; Lee and Mudawar, 15.3 psd; and Gambill, 23.7 psd) had a psd less than 25.0% when the data parameter ranges were inside the correlation parameter ranges; but (2) only four correlations (Katto, 17.1 psd; Tong-75, 22.0 psd; Weisman and Ileslanlou, 27.3 psd; and Gambill, 32.8 psd) had a psd less than a 35.0% when the correlation parameter ranges were exceeded significantly by the CHF data. Finally, it was found that: (1) Convergence was not attained with Katto's correlation for mass velocities less than 15.0 Mg/m^2s, and (2) Vandervort's et al. correlation could not be used for $\frac{L}{D} < 40.0$.

Thermal-hydraulic subcooled flow excursions (FE) can be as devastating as the CHF phenomenon, both of which can eventually lead to component burnout or destruction when water is the working fluid. However, little or no attention has been given this phenomenon as more high heat flux components are developed. Previously, Boyd noted the importance of FE in high heat flux components with multiple channels having common flow manifolds. To this principal investigator's (P. I.) knowledge, there has been only one recent attempt by Simon-Tov et al. to measure static FE at moderate subcooling and relate it to CHF and flow rate channel by-pass ratios for "stiff" and "soft" flow systems. They examined the onset to significant void fraction (OSV) correlations. OSV is known to proceed FE and these investigators, rightly so, assumed the occurrence of FE could be approximated [or at least establish a lower bound] by OSV predictions. Their data $\left(\frac{L}{D} \approx 200.0\right)$ was compared with three other OSV correlations, and was best characterized by the Saha and Zuber model.

As it relates to high heat flux removal and energy transport, the next generation problems for fusion and other high heat flux (HHF) applications are all design-driven and near-term-application driven. As a result, many important aspects are disregarded which are associated with understanding parametric trend influences and instability mechanisms (e.g., subcooled CHF or dynamic FE) associated with high heat flux removal using as the working fluid highly subcooled water for some fusion applications and still other fluids for other HHF applications. Among the several effects which need further study, the magnitude of the variation in the local heat transfer coefficient (h) in a single-side heated circular channel with high velocity subcooled water flow was examined. As a result of a conjugate analysis, it was found that: (1) h increases by almost a factor of two circumferentially from the bottom to the top of the flow channel, and (2) the top 120.0 degrees of the channel is nearly isothermal.