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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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From the:
THERMAL SCIENCE RESEARCH CENTER (TSRC)

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The physical phenomenon of forced convective boiling is probably one of the most interesting and complex transport phenomena. It has been under study for more than two centuries. Simply stated, forced convective subcooled boiling involves a locally boiling fluid: (1) whose mean temperature is below its saturation temperature, and (2) that flows over a surface exposed uniformly or non-uniformly to a high heat flux (HHF). The objective of this work is to assess and/or improve the present ability to predict local axial heat transfer distributions in the subcooled flow boiling regime for the case of uniformly heated coolant channels. This requires an accurate and complete representation of the boiling curve up to the CHF. The present results will be useful for both heat transfer research and industrial design applications. Future refinements may result in the application of the results to non-uniformly heated channels or other geometries, and other fluids.

Several existing heat transfer models for uniformly heated channels were examined for : (1) accurate representation of the boiling curve, and (2) characterizing the local heat transfer coefficient under high heat flux (HHF) conditions. Comparisons with HHF data showed that major correlation modifications were needed in the subcooled partial nucleate boiling (SPNB) region. Since the slope of boiling curve in this region is important to assure continuity of the HHF trends into the fully developed boiling region and up to the critical heat flux, accurate characterization in the SPNB region is essential. Approximations for the asymptotic limits for the SPNB region have been obtained and have been used to develop an improved composite correlation. The developed correlation has been compared with 363 water data points. For the local heat transfer coefficient and wall temperature, the over-all percent standard deviations with respect to the data were 19% and 3%, respectively, for the high velocity water data.

Two specific examples of the success that has been achieved is given below. A composite modified subcooled nucleate boiling model was developed which characterizes the single-phase, partial nucleate boiling, and fully-developed boiling regimes. The important point to note is that no apriori assumption are made except the heat flux in the partial nucleate boiling regime is characterized by $q''_{PB} = a + b\,\Delta T_{sat}^{m}$, where ΔT_{sat} is the wall superheat and a, b, and m **are not** curve-fitting parameters; but rather, they are uniquely related to the following physical conditions of the flow: (1) fluid identity, (2) fluid flow parameters, (3) heat fluxes at the onset of partial nucleate boiling and the onset of fully-developed nucleate boiling. The first example is shown in Figure 1 where data for water is compared with the developed correlation. As can be seen, several values of the mass velocity (G) are included in the comparison. It should be noted that in all cases, the CHF and eventual burnout occurred for each case shown just to the right of the highest value of the heat transfer coefficient shown for each mass velocity. Therefore, the developed correlation shows good predictability up to but on the stable side of the CHF. In Figure 1, the abscissa is the ratio of the applied heat flux to the heat flux necessary to cause saturated liquid conditions at the exit of the flow channel. The second example is shown in Figure 2 which contains comparisons with over three-hundred and fifty data points for water at different axial locations, different exit pressures, and different mass velocities. The agreement is very good.

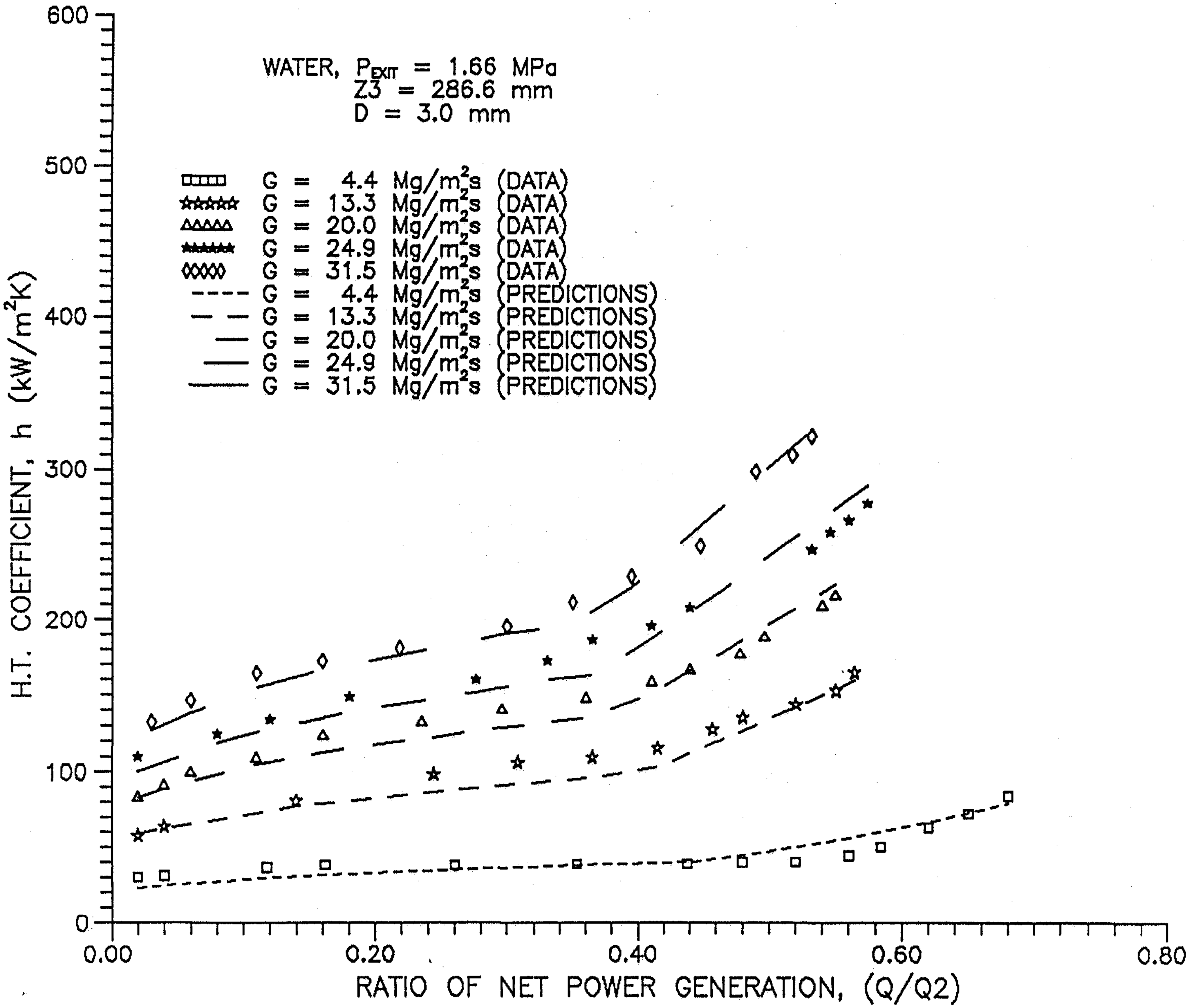

Figure 1: $Z = 286.6$ mm, $P_{exit} = 1.66$ MPa

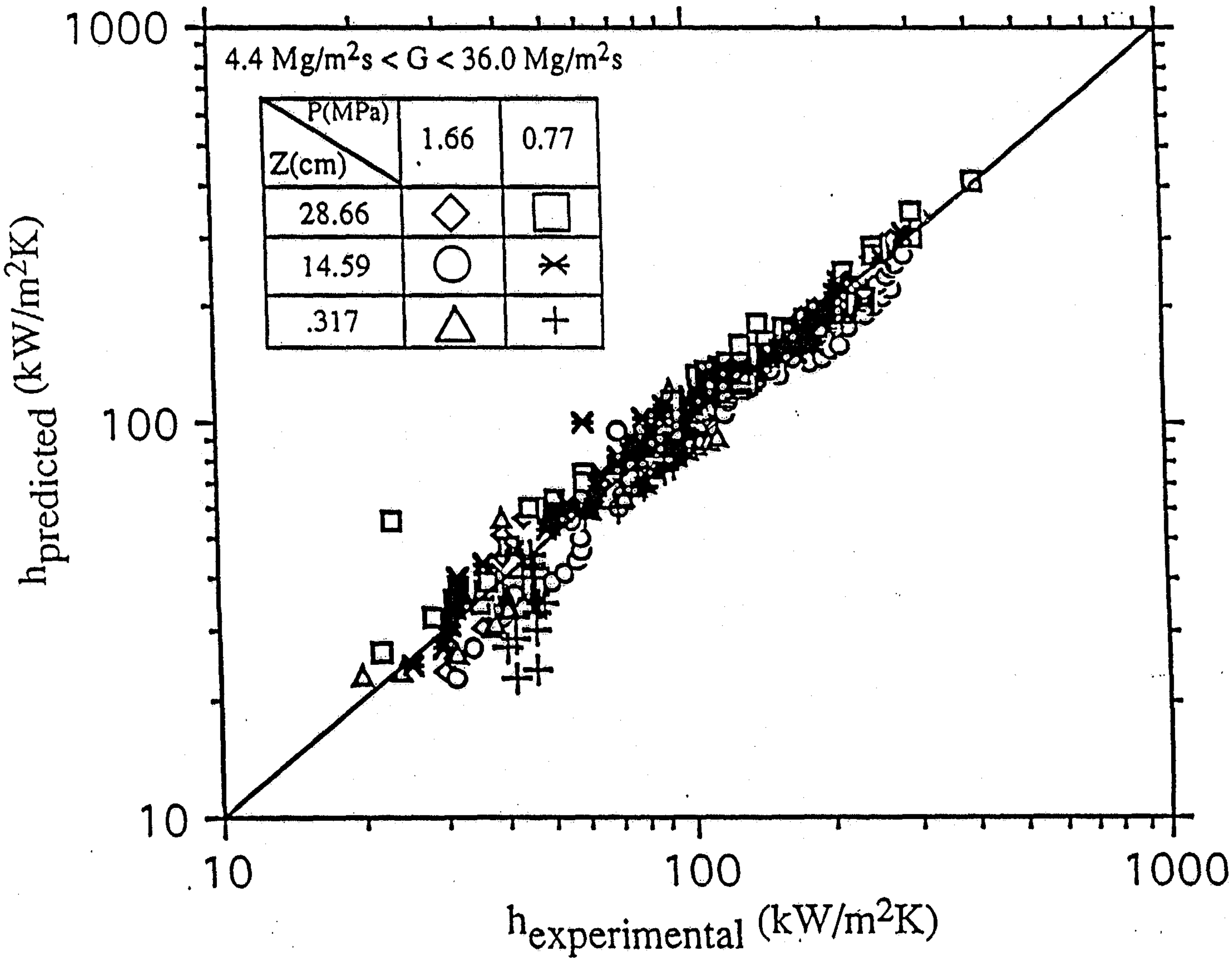

Figure 2: Local (axial) Subcooled Flow Boiling Curve Heat Transfer Coefficient Comparisons Between the Modified Correlation and Boyd's Water Data for a Flow Channel Diameter of 3.0 *mm*, and a Heated Length-to-Diameter Ratio of 96.6.