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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 Thermal Science Research Center (TSRC) at Prairie View A&M University is involved in an international fusion reactor technology development program aimed at demonstrating the technical feasibility of magnetic fusion energy. This report highlights: (1) Recent accomplishments and pinpoints thermal hydraulic problem areas of immediate concern to the development of plasma-facing components, and (2) Next generation thermal hydraulic problems which must be addressed to insure safety and reliability in component operation. More specifically, the near-term thermal hydraulic problem entails: (1) generating an appropriate data base to insure the development of single-side heat flux correlations, and (2) evaluating previously developed single-side/uniform heated transformations and correlations to determine which can be used to relate the vast two-phase heat transfer and critical heat flux (CHF) technical literature for uniformly heated flow channels to single-side heated channels.

A conceptual design of a high heat flux experiment is underway to generate local (axially and circumferentially dependent) channel wall heat transfer data needed for the above noted evaluation. The experimental measurements will be used to deduce the fluid-side wall heat flux distributions for: (1) laminar and turbulent single-phase flow regimes, and (2) the subcooled flow boiling regimes below the CHF. Among the test section configurations to be studied are: (1) a circular tube with a single-side constant heat flux, and (2) a monoblock with a circular bore.

This experimental work will lead to future work which will: (1) lead to the local measurements of inside wall temperatures and in select cases a circumferentially varying heat transfer coefficient, (2) produce one of the first sets of whole field temperature and wall heat flux data for turbulent flow in single-side heated cylinders and hypervapotrons containing fluids with Prandtl numbers greater than 1.0, and (3) play a pivotal role in increasing our capability to scale from laboratory experimental conditions to prototypic conditions with reduced margins of uncertainty.

A conceptual design of a high heat flux (HHF) facility supports future development of prototypic high heat flux components for experimental or demonstration fusion reactors (e.g., ITER and DEMO). The facility will be housed in the Thermal Science Research Center (TSRC) which is in the College of Engineering on the campus of Prairie View A&M University. During this project, a design teams for the HHF facility have considered many options and approaches.

The new facility will consist of a new flow loop, two new HHF configurations, power supply source, power delivery system or bus bars, heaters, instrumentation, and data acquisition. Each experimental configuration will be used to examine different heat transfer and fluid mechanics characteristics of HHF coolant channels which have been used to study aspects of HHF removal from divertors, which are one of the plasma-facing components found in future fusion reactors. One experiment will focus on measuring local heat transfer and both critical and post-critical heat fluxes up to the highest power of the system. The second experimental configuration will be devoted to flow visualizations, which are intended: (1) for comparisons under selected conditions with the HHF experiment, and (2) to increase our intuitive understanding of local aspects of the heat transport in complex channel geometries.

Detail conceptual designs are in progress for various aspects of the facility which includes: flow loop development, test section development, heater design, bus bar design, data acquisition, electrical isolation/thermal transfer system, data correlation, and power supply design. A flow loop is being designed in order to achieve the steady state conditions for the entire high heat flux system. The flow loop is a closed loop which will operate at a pressure range of 0.1 to 4.0 MPa and a mass velocity range of 2.0 to 20 Mg/m^2s. The temperature, pressure, flow rate and some other major parameters will be monitored and measured during the experiment at several stations. A positive displacement pump will control the water volume flow rate through a calibrated flowmeter and into the test section. The test section is electrically heated by a direct current. The hot water leaving the test section will be cooled by a heat exchanger before returning to the reservoir. A dionizing unit, a degassing tank, filter, and accumulator are included in the loop for purification and degassing purposes. The flow loop will be designed to deliver an accurate amount of high quality water under a restricted and specified conditions to each test section. In most cases, there will be subcooled flow boiling occurring in each test section. Depending on the experiment, the test section will be completed insulated without containment or housed in a vacuum dome to minimize atmosphere aberrations in the optical interferometric measurements which will be made for selected conditions. In all cases, the test section will be heated from one side. The graphite heater will be separated from the test section by an aluminum nitride (AlN) layer and will be connected to bus bars that will current facilitate transfer to the test section via the AlN and the heaters. A 300 kW DC power supply was earmarked to feed the heaters. Due to the possible shock hazards and the large cable or bus duct sizes to implement the system, a power supply voltage range from 0 to 40 Volts maximum is considered adequate. Work is proceeding on other aspects of the conceptual facility development and design.