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Establishing MIT's Experimental Capabilities for LWR Thermal-Hydraulics Investigations

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ABSTRACT:

We propose to upgrade the diagnostics and facilities of the thermal-hydraulics laboratory in the Nuclear Science and Engineering (NSE) department at MIT in order to establish new experimental capabilities in two phase flow and boiling heat transfer, and broaden our role as innovators and educators in this area. Our eventual goal is to develop a unique experimental platform for both teaching and advanced research, to perform cutting-edge, high-resolution boiling investigations in light water reactor (LWR) operating conditions, leveraging high-speed infrared and video imaging techniques. Such capability currently does not exist worldwide and would clearly be invaluable for the nuclear community to improve the design and the operation of current and future nuclear reactors. To this end, an upgrade of our current diagnostics is required.

In the past few years, our thermal-hydraulics group has developed advanced diagnostics and calibration techniques using high-speed infrared and high-speed video cameras, to shed light on the fundamentals of boiling heat transfer. Thanks to these developments, it is nowadays possible to quantify with a spatial resolution of 100 μm and a temporal resolution of 0.4 ms the temperature and heat flux distributions on the boiling surface. Importantly, these measurements have enabled the first direct quantification of heat flux partitioning in subcooled flow boiling, which is invaluable for the THM (Thermal-Hydraulics Methods) team within CASL, the department of energy (DOE) innovation hub for modelling and simulation of nuclear reactors.

These kind of experiments, performed at low pressure conditions until now, are game-changing in the understanding of boiling heat transfer. As such, there is a growing interest to perform the same kind of investigations at LWR pressures, with the goal to give a clear answer to the *vexata quaestio* about the scaling of mechanistic boiling heat transfer and CHF models to actual reactor conditions.

In the past, technical limitations have prevented these investigations to happen, the main limitation being the space and time resolution of the available high-speed cameras. However, ultra-high-speed cameras are nowadays available to enable these unprecedented, high-resolution investigations of LWR thermal-hydraulics.

With these requested upgrades we will be able to shed light on the fundamentals of boiling at high-pressure and specifically on a series of phenomena related to nuclear reactors, which include but are not limited to critical heat flux under PWR and BWR normal operating conditions and off-normal conditions, like loss of flow accidents or reactivity initiated accidents, or the investigation of flow boiling and CHF mechanisms in new materials, e.g. accident tolerant fuel materials or micro- and nano-engineered coatings aimed at improving the heat transfer performance of fuel claddings and steam generator tubes. Last but not least, the requested upgrades will be leveraged to create invaluable pedagogical supports, e.g. videos and demos, which could be shared with the scientific community to shape future faculty, researchers and engineers in nuclear energy.