Spatiotemporally Resolved Multiscale Measurements of Single- and Multi-Phase Flows Using State-Of-The-Art System of X-ray Tomography and Optical Sensors

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ABSTRACT: Project Objective Texas A&M is intending to enhance the measurement capabilities of the Thermal-Hydraulic Laboratory (THL) for performing flow measurements generally inhibited by the opacity of many fluids contained in opaque enclosures. X-ray imaging is one family of noninvasive measurement techniques that can be used to visualize and quantify opaque fluid flow characteristics in opaque enclosures. We propose to enhance our capabilities by adding the state-of-the-art X-ray tomography combined to high-frequency optical sensors to our advanced flow visualization systems to perform high resolution measurements of single- and multi-phase flows. The enhancement will enable the generation of high-resolution void fraction data in two-phase (liquidvapor) mixtures and solid concentrations in two-phase (liquid-solid) solutions. The promisingly generated data can be used to develop new correlations, to improve existing system and Computational Fluid Dynamic (CFD) codes (such as RELAP-5, RANS and LES models), and to validate codes under development (RELAP-7, Nek-500). The advanced system will enrich educational and research experience at the Department by providing state-of-the-art experimental tools to undergraduate and graduate students. Moreover, being able and willing to participate the NSUF Partnership Program, TAMU THL commits to promote, support and facilitate a full access of the requested infrastructure to NSUF members and other Universities. Methods The laboratory operates different experimental facilities to conduct research in the area of thermal-hydraulic, with various multiscale applications in single and multiphase flows. These facilities are also used for educational purpose, providing exemplar learning tools to undergraduate and graduate students. The combined system of X-ray tomography and optical sensors will be implemented to enhance capabilities of the following facilities with spatiotemporally resolved measurements of the void fraction. This includes:

- The Critical Heat Flux (CHF) facility. Implementing the combined system of X-ray tomography and optical sensors will significantly enhance the measurement capabilities by simultaneously measuring pointwise and volumetric void fractions, velocities, and wall temperatures inside the test section.
- The Pebble Bed facility. The X-ray tomography will maximize the high-resolution data, by adding local void fraction measurements together with local flow measurements. Such data is also very useful for non-nuclear applications,
- The Water-Cooled RCCS Facility, currently in operation to conduct experiments of two-phase flow to support other NEUP projects. The sophisticated system of X-ray tomography and optical sensors will strengthen previously planned measurements, and will produce a valuable and unique data set of twophase flows at various locations
- The Precipitation and Stratification Test Apparatus (PASTA), which has supported a wide variety of tests for boiling water with high concentration of boric acid to support NRC safety

issues on long-term core coolability of LWRs during accident scenarios. New capabilities will be added for estimation of the local boric acid concentrations in the core.

Potential Impact of the Project The X-ray tomographic system will enhance the experimental capabilities of the existing facilities, and will produce unique sets of new experimental data which will combine high-resolution void fraction measurements with other flow and heat transfer measurements. The investigators are also intending to use the new set of data for:

- Generating new empirical correlations
- Validating the performances of existing codes (commercial CFD, system codes) or codes under development (RELAP-7) The new system will be fully accessible to the undergraduate and graduate students, and will enrich educational and research experience of the students.