



**UNITED STATES
NUCLEAR REGULATORY COMMISSION**
WASHINGTON, D.C. 20555-0001

Grant # 31310021M0002

Grantee: Virginia Polytechnic Institute

Title of Grant: Non-dimensional Analysis of Density-Wave Instabilities and Dryout-Rewet Cycles during an ATWS

Period of Performance: 3/15/2021-3/14/2024 (FY20 Notice of Funding Opportunity NOFO)

Executive Summary

In 2018, the Nuclear Energy Institute has issued a road-map for the development of Microreactors for deployment by the U.S Department of Defense (DoD). A critical point for a timely deployment is associated to the licensing process with U.S. NRC. This requires the development of accurate heat pipe simulation capabilities. The present proposal addresses the modeling challenges associated with the licensing of heat pipe microreactors by establishing a unique, high-resolution experimental database on sodium heat pipes behavior during stationary and transient conditions, including abnormal operation and close to thermal limits, leveraging the advanced experimental capabilities available at the University of Michigan; b) by complementing the experimental activity with high-fidelity Computational Fluid Dynamic (CFD) simulations to inform the development of Reduce Order Models (ROMs) for 1D thermal-hydraulic codes. The developed ROMs will enable best-estimate system code to correctly capture the thermal-hydraulic behavior of liquid metal heat pipes; c) by demonstrating the developed ROM in the BlueCRAB suite, including validation.

Benefits. The proposed work will advance the understanding of heat pipe behavior close to their thermal limits, will provide unique experimental data for model validation and will support the advancement of best-estimate analysis codes needed to perform safety analyses of heat pipe microreactors.

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Presentations and Publications

The list of publications was submitted with the final report after grant expiration.

Ph.D. Dissertation:

Hurley, P. R., Density-Wave Instability Characterization in Boiling Water Reactors under MELLLA+ Domain during ATWS, Ph.D. dissertation, Nuclear Engineering, Virginia Tech, 2023.

Journal Publications:

Hurley, P., Liu, Y., Kozlowski, T., and Duarte, J.P., TRACE Assessment of Density Wave Instability Onset with Void Reactivity Feedback under Natural Circulation, *Nuclear Engineering and Technology*, 2024. (under review)

Hurley, P. Pigg, C., Liu, Y., Kozlowski, T., and Duarte, J.P., "Density-Wave Instability Onset Analysis and TRACE Assessment in a Full-Scale BWR Rod Bundle", *Nuclear Technology*, 1-14, 2024.

Conference publications:

Pigg, C., Selligmen, G., Kozlowski, T., Liu, Y., Corradini, M., Duarte, J.P., "Sensitivity of Density Wave Oscillations to TRACE-PARCS Uncertainty Parameters", *ANS Winter Meeting*, Orlando, FL, November 17-21, 2024. (under review)

Pigg, C., Selligmen, G., Kozlowski, T., Hurley, P., Liu, Y., Corradini, M., Duarte, J.P., "Sensitivity of DensityWave Oscillation Instability Boundary to TRACE uncertainty parameters", *ANS Winter Meeting*, Orlando, FL, November 17-21, 2024. (under review)

Hurley, P., and Duarte, J.P., "A Comparison of Experimental Density Wave Instability Behavior with Analytical Model Prediction", *The 19th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-19)*, Washington D.C., August 20–25, 2023.

Hurley, P., and Duarte, J.P., "Prediction of Unstable Two-Phase Behavior using Dense Neural Network", *ANS Winter Meeting*, Phoenix, AZ, November 12-17, 2022.

Hurley, P., Liu, Y., Corradini, M., Kozlowski, T., Duarte, J., "Analysis of Flow Instability Onset in a BWR Rod Bundle Geometry," *Advances in Thermal Hydraulics (ATH 2022)*, Anaheim, CA, June 12-16, 2022.

Patents

N/A