NEUP Nuclear Energy University Programs
U.S. Department of Energy

Experimental Investigation of Forced Convection and Natural Circulation Cooling of a VHTR Core under Normal Operation and Accident Scenarios

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Program: Reactor Concepts: Computational Methodologies for Gas-Cooled Reactors

Collaborators: Sanjoy Banerjee – CCNY, Hitesh Bindra – Kansas State University, Richard. R. Schultz – ISU, Donald M. McEligot – Idaho National Laboratory

This project aims at an experimental study of heat transfer in a Very High Temperature Reactor (VHTR) being developed by DOE under the Next Generation Nuclear Plant program. The VHTR employs passive safety system designs, which will prevent reactor core meltdown and release of radioactivity to the environment even in severe accidents. An existing high pressure/high temperature gas heat transfer facility constructed at the applicant's laboratory under an existing NEUP project will be used along with a trained manpower to generate experimental data useful for the development of VHTRs. The proposed separate effects experiments will be useful in formulating risk quantification of passively safe nuclear power plants in the future. We will produce unique data not available from other NEUP and non-NEUP projects.

During an accident, the decay heat needs to be dissipated from the reactor core by natural circulation of the gaseous coolant and conduction/radiation heat transport to the Reactor Cavity Cooling System (RCCS). In this proposal, three types of separate effects experiments will be performed to experimentally investigate (1) the natural circulation flow and heat transfer, (2) effects of air ingress at pressures up to 70 bar (1,029 psi) and temperatures up to 600oC (1,112oF), (3) bypass flow phenomenon, and (4) radiative heat transfer across the gaps between the neighboring prismatic blocks. These experiments are relevant to Pressurized Conduction Cooldown (PCC) and Depressurized Conduction Cooldown (DCC) of a VHTR core following an accident. A scaling analysis will be performed to design the test section geometry and establish the experimental conditions. Benchmark data will then be obtained for validation of thermal-hydraulics codes such as NEK5000 in SHARP, FLUENT, and STAR-CC++.

The PI of this project is Prof. Masahiro Kawaji who is Associate Director of the CUNY Energy Institute and Professor of Mechanical Engineering at City College of New York (CCNY). He is a Fellow of ASME and the Canadian Academy of Engineering. The Co-PI, Prof. Sanjoy Banerjee, is CUNY Distinguished Professor and Director of the CUNY Energy Institute. He is a member of the Advisory Committee on Reactor Safeguards mandated to advise the NRC on all nuclear safety-related licensing decisions. The lead PI and Co-PI at CCNY have more than 70 years of combined experience in setting up and conducting experiments and modeling in the area of nuclear reactor thermal-hydraulics and safety related research. Their extensive contributions to heat transfer research have been acknowledged by the Donald Q. Kern Award, which Dr. Banerjee received in 2005, and Dr. Kawaji received in 2013.

The second Co-PI of this proposal, Dr. Hitesh Bindra, is an Assistant Professor at Kansas State University and will perform experiments on radiative heat transfer and oxidation of graphite test sections by air and steam at high graphite temperatures. The third Co-PI is Dr. Richard R. Schultz from Idaho State University who served as a PI for the NGNP thermal-hydraulic experiment validation and verification effort at Idaho National Laboratory. He has over 30 years of experience in designing experiments to obtain data to validate numerical models and validating numerical models, and will contribute an intimate knowledge of the needs and requirements of DOE's NGNP program to this project. The fourth Co-PI is Dr. Donald M. McEligot from Idaho National Laboratory who has done pioneering experiments and numerical analyses on transport property variation in internal turbulent, laminar and laminarizing gas flows, discovered a phenomenon of laminarization by heating, and measured effects of heat transfer to low-Prandtl-number gas mixtures. The project team possesses ample knowledge of reactor safety, fluid mechanics and heat transfer, as well as extensive research experience, experimental skills and well-equipped laboratories.