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Characterization of Plenum to Plenum Natural Circulation flows in a High Temperature Gas Reactor (HTGR)

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ABSTRACT:

To ensure passive cooling in High Temperature Gas Reactors (HTGRs) such as a General Atomics 350 MWt MHTGR in case of loss of forced circulation or pressure, it is necessary to conduct separate effects experiments and produce an experimental database for validating the CFD models and DOE's multi-physics toolkits such as SHARP and NEK5000, which are used to analyze VHTR's thermal-hydraulics and safety. The main objective of this experimental investigation is to obtain and provide experimental data on the plenum-to-plenum natural circulation (NC) flows in a typical HTGR design. Experiments will be performed using helium, nitrogen, helium-nitrogen mixture and air as a working fluid for a wide range of temperatures and pressures up to 750 ^{o}C and 70 bar to simulate plenum-to-plenum gas dynamics under both Pressurized and Depressurized Conduction Cooldown (PCC/DCC) events. Gas circulation rates, and velocity and temperature distributions between upper and lower plena connected by multiple parallel vertical tubes both in the riser and downcomer will be measured using novel measurement methods, such as optical fiber velocity probes and thermal time-of-flight velocity measurement methods. This work will build on two previous NEUP projects completed at CCNY in which forced and natural circulation of helium, nitrogen and helium/nitrogen mixtures were investigated in a single channel flow loop at both high and low pressures.

A new test facility will be designed and constructed to study the plenum-to-plenum natural circulation flows in multiple, parallel riser and downcomer tubes, as well as the flow characteristics and temperature distributions in the upper and lower plena since the flow characteristics in both plena would strongly influence the flow in the parallel tubes of the riser and downcomer. This project is intended to yield new data and complement other VHTR-related studies conducted under NEUP.

The overall scheme of this project consists of the following five different tasks.

Task 1: Scaling Analysis

Task 2: Design and fabrication of a test facility with multiple riser and downcomer tubes

Task 3: Development of Low Gas Velocity Measurement Techniques

Task 4: Natural circulation experiments under PCC and DCC Conditions

Task 5: Validation & Verification Database

CCNY will carry out Tasks 2-5 while Idaho State University will perform Task 1 and University of Pittsburgh will also work on Task 2. INL and Framatome will provide guidance and suggestions on all Tasks 1 - 5 as needed from both fundamental and industrial perspectives, respectively.

The deliverables from this project include new experimental data on (1) the total plenum-to-plenum gas flow rate, (2) gas velocities in multiple riser and downcomer tubes, and (3) gas temperature/velocity distributions and concentrations (in the case of gas mixture NC experiments) in the upper and lower plena.