U.S. Department of Energy

Integral Reactor Containment Condensation Model and Experimental Validation

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Program: Advanced Technologies and Analysis Methods

ABSTRACT

This proposed study will experimentally and analytically examine high-pressure steam condensation in a steel containment vessel connected to a water cooling tank, under forced and natural convective flows. The experimental results will be used to validate an updated containment condensation model for integral SMR reactor containment system safety analysis codes. Such a containment condensation model is important to demonstrate adequate cooling, particularly after the recent core meltdown accidents at Fukushima Daiichi Nuclear Power Stations after a devastating 8.9 magnitude earthquake followed by a catastrophic Tsunami.

The results are expected to be applicable to integral Small Modular Reactor (SMR) designs, including NuScale, mPower, Westinghouse SMR, and other integral reactors with small containments of relatively high pressures under accidental conditions. Testing will be conducted at the PI's (P1) laboratory in an existing DOE sponsored integral test facility with a high-pressure stainless steel containment model (2~5 MPa), scaled to a SMR design under development. Minor modifications to the model containment will be made to control the non-condensable gas fraction and to quantify the convectional effects of steam flow. The Co-PI (P2) will develop the containment condensation model, which leverages previous validated containment heat transfer work done by P2, and will extend the range of applicability of the model to integral SMR designs that utilize containment vessels of high heat transfer efficiencies. A SMR design firm agreed to support the investigation without cost to the NEUP program, by providing reference operation conditions for the scaling of the test facility.

The study consists of three primary tasks: (1) establish the scaling of the full pressure test facility to the reference design for condensation heat transfer process during design basis accidents (DBAs) and modify the existing test facility high-pressure containment vessel for negative pressure operation (P1 leads), (2) conduct a matrix of DBA and quasi-steady experiments using the full pressure test facility to provide a reliable high pressure condensation database (P1 leads), (3) analyze experimental data and develop (update) a condensation model for the experimental conditions, and predict the prototypic containment performance under accidental conditions (P2 leads).

The proposed investigation, if funded, will last for three years. The planned deliverables of this investigation will be an improved/updated condensation model as well as a high-pressure containment condensation database, which are valuable for the development and assessment of integral SMR designs.