New applications of integral effects tests for molten salt reactor development

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History and Context of Integral Effects Tests

Integral effects tests, in concert with separate effect tests, are traditionally used to validate evaluation models (i.e., system codes) for specific scenarios of interest such as operational transients and design-basis accidents in nuclear power plants. Integral effects tests are an important component of the U.S. Nuclear Regulatory Commission’s Evaluation Model Development and Assessment Process. Example integral effects test facilities important in the field of nuclear engineering thermal hydraulics are shown here.

Semiscale Integral Test Facility

Integral test facility for a commercial PWR to study LOCA response. Essentially power-to-volume (full-height volume scaled) scaling with a scaling factor on the order of 1.1705 to a commercial PWR.

PKL Test Facility

International integral test facility for PWR primary side and significant secondary side simulation. Scaling factors: 1:1 in height, 1:145 in volume, power rating, mass flows (1:12 hydraulic diameter reduction).

APEX (APEX600 and APEX1000) Facilities

Integral test facility to assess passive safety systems of the Westinghouse AP600 and AP1000. Scaling factors: 1:4 in height, 1:2 in time, reduced pressure.

MASLWR Test Facility

Integral test facility to assess operation of the OSU MASUR under nominal full pressure, full temperature conditions and to assess passive safety systems under transient conditions. Scaling factors: 1:3 in height and length, 1:1 in time, and 1:254.7 in volume.

Simulant-Based Integral Effects Tests for Molten Salt Systems

Integral effects test facilities for molten salt systems have the potential for significant reductions in size, temperatures, and input powers when simulant fluids are used. These reductions have the potential to significantly drive down the costs of experiments as well as drive-up the quality and resolution of data that is produced by using low-temperature, low-pressure high-accuracy instrumentation.

### TABLE V

<table>
<thead>
<tr>
<th>Heat transfer fluid/temperature</th>
<th>Fibre (60°C)</th>
<th>Fibre (90°C)</th>
<th>Flank (750°C)</th>
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<tbody>
<tr>
<td>Length scale, L/ΔLₕ</td>
<td>0.44</td>
<td>0.38</td>
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<tr>
<td>Velocity scale, Uₕ/Vₕ</td>
<td>0.66</td>
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<td>Reynolds number, Reₕ/Reₘ</td>
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<td>Froude number, Frₕ/Frₘ</td>
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<td>Weber number, Weₕ/Weₘ</td>
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<td>Prandtl number, Prₕ/Prₘ</td>
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<tr>
<td>τ₀ₕ/τ₀₁/τ₀₂/τ₀₃</td>
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<td>0.63</td>
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<tr>
<td>Grashof number, Grₕ/Grₘ</td>
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<tr>
<td>Pumping power, Wₕ/Wₘ</td>
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<td>0.017</td>
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<tr>
<td>Heating power, Qₕ/Qₘ</td>
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</table>

The ARCO Facility as a Case Study

The Advanced Reactor Control and Operations (ARCO) Facility showcases the evolution of Berkeley’s integral effects test research from a verification and validation facility into a full-scope plant-level testbed. Areas of interest:

- Digital control
- Fault detection
- Cybersecurity
- Human Factors

The hybrid experiment-simulation system supplements each area of study by anchoring them to the physical configuration and operating philosophy representative of a prototypical FHR.

Supporting Elements for Additional Applications

Additional elements to integral effects test facilities are necessary to explore new applications of these facilities’ varied capabilities. Two elements that have been critical for CIT and ARCO are:

- Distributed control system: The multi-interface distributed control system enables iterative development of FHR control, analysis, and operator support systems.
- Quality assurance program: A well-designed quality assurance system connects the research to the goals of the ENMDP and to licensing-related activities more generally, as well as provides the framework for sustained high-quality research to be performed over the lifetime of the facility.

Acknowledgements

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