Microreactor Reference Plant Model

Stephen M. Bajorek, Ph.D.
Senior Technical Advisor for Thermal-Hydraulic Code Development
Office of Nuclear Regulatory Research
United States Nuclear Regulatory Commission
Ph.: (301) 415-2345 / Stephen.Bajorek@nrc.gov

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Introduction

• “Strategy 2” of the Implementation Action Plan (IAP) is directed at identification & development of computer codes and tools to prepare the staff for evaluation of advanced non-LWRs.

• An important step in code readiness is development of a “reference plant” model which will:
  – Contain many / most features expected in a design
  – Exercise code(s) to be used in analysis
  – Provide early identification of technical issues
Reg Guide 1.203 Code Development

Identify Plant & Scenario

PIRT
(Phenomena Identification & Ranking Tables)

Establish Assessment Matrix

Experimental Testing & Data Evaluation

Model Development

Analysis Code
Model Acceptable?
Yes

Deficiency

Code Assessment
Compare Code vs. IET and SET

Application

Uncertainty Methods

Yes
PIRT and Scenarios: “Micro Reactors”

**Scenarios**
- loss of heat sink
- inadvertent reactivity insertion transients, including ATWS events
- localized heat pipe failure
- cascading loss of heat pipes
- seismic event (causing reactivity increase)
- events related to coupling the reactor to the power conversion unit
- monolith temperature and stress under normal operating conditions
- monolith temperature and stress under postulated accident conditions.

**Phenomena**
- monolith thermal stress (thermal expansion)
- single heat pipe failure (localized thermal conduction, gap conductance)
- machining and inspection of the monolith
- heat pipe performance (evaporator/condenser heat transfer, solidification)
- reactivity and core criticality (neutron leakage, reactivity feedback)
Comprehensive Reactor Analysis Bundle
BlueCRAB - MicroReactor

- SCALE: Cross-sections
- PARCS: Neutronics
- TRACE: System T/H
- FAST: Fuel Performance
- SERPENT: Cross-sections
- GRIFFIN: Neutronics
- PRONGHORN: Core T/H
- MOOSE: Tensor Mechanics, Data Transfers
- BISON: Fuel Performance
- SAM: System and Core T/H

- NRC Code
- Int’l Code
- Commercial
- DOE Code

Planned Coupling
Completed Coupling
Input/BC Data

Current View; Sept. 2019
NRC’s Microreactor “Reference Model”

- Based on the “Design A” microreactor described by Sterbentz et al [INL/EXT-17-43212, Rev. 1], with several simplifications.
SERPENT: Monte-Carlo Reference Solution

- SERPENT Calculations-
  - Cross-sections
  - Initial power distribution
Coupled Code Simulations

<table>
<thead>
<tr>
<th>Reactivity Feedback Coefficients [pcm/K]</th>
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</thead>
<tbody>
<tr>
<td>Doppler Effect</td>
</tr>
<tr>
<td>Axial Expansion</td>
</tr>
<tr>
<td>Radial Expansion</td>
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<tr>
<td>Combined Effect</td>
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</tbody>
</table>

- MAMMOTH: Neutronics
- MOOSE: Tensor mechanics, conduction
- SAM: Heat pipes, secondary side HX
“MultiApp Code Coupling

Diagram showing interactions between different components such as RCCS, HC, TM-Plate (radial), TM-Fuel (axial), HPs, and various power and temperature inputs and outputs.
SAM Heat Pipe Model

Heat pipe

Condenser

Adiabatic

Evaporator

Heat from fuel cell

Coolant supply

Coolant out

Heat pipes

$r$

$T_{src}$

$Q$

$T_{sink}$

$Q$

Evaporator

Adiabatic

Condenser

Wall

Wick

Vapor core
Single Heat Pipe Failure

Fuel temperatures increase near failed HP and surrounding elements.

Heat removal by failed HP drops quickly, but increases in surrounding HPs.
Heat removal by HPs stops and fuel temperatures increase. Strong negative reactivity due to core expansion results in decrease in core power.
• BlueCRAB system of codes has been demonstrated as capable of microreactor simulation.

• Verification & Validation remain important steps. Tests such as KRUSTY, MAGNET, MARVEL, Godiva can provide data for coupled code simulations.

• Improvement of heat pipe model, secondary side HX, “exterior” cooling models.

• Development of microreactor models to assist regulatory review and investigate safety margins.