System Code Evaluation

Dr. Nathan Carstens, Code Development Engineer

December 13, 2010

U.S. Nuclear Regulatory Commission
Pre-Application Meeting
Rockville, MD

NuScale Power

Outline

- Assessment Base
- Key Requirements
- Available Codes
- Evaluation Summary
- GOTHIC Considerations
- Conclusions

Background

- Since the last meeting, NuScale has been working to solidify the codes & methods licensing strategy for safety analysis applications,
  - LOCA and non LOCA (core wide) event analysis is the subject of the present discussion
  - Identified key elements for the development assessment base
  - Reviewed the quality assurance situation of several thermal-hydraulic system codes, particularly public versions of RELAP5 and TRAC-based codes
  - Performed check of code capabilities versus the PIRT

Today we are describing our conclusions
and listening to NRC comments

Assessment Base Considerations

- Range and applicability of data is a key consideration in selecting specific data
- The way phenomena are expressed in the data and code is important:
- No need to assess “traditional LOCA” phenomena
  - NuScale SBLOCA response does not involve cladding heat-up
  - No reflood phenomena
- Existing integral LOCA tests such as LOFT and Semiscale are not applicable
  - No loop seals to clear

Example of the Assessment Base

- Example vs highly ranked SBLOCA phenomena shown based on MASLWR SBLOCA PIRT (non-proprietary)

	Marviken	Condensation tests	GE Level Swell	PSBT - NUPEC PWR Sub-Channel Bundle Tests
Vent Valves: Valves: Mass Flow (Choked/Nonchoked)	✕			
Containment cooling: Inside containment structure: Wall condensation rate		✕		
Primary coolant system: Hot leg riser: Flashing	✕		✕	
Reactor system: Core subchannels: Mass flow				✕

Key Requirements

- Natural circulation
- Coupled containment and RPV
- Evaluation of importance of ‘3D’ effects
- High fidelity containment/condensation modeling
- Existing quality pedigree and maintainability

Available TH System Codes

- TRACE
- RELAP5
- MARS-KS
- RETRAN
- GOTHIC

Codes were evaluated based on key requirements, PIRT results, and design specific characteristics

Introduction to GOTHIC

- General purpose thermal-hydraulic analysis code developed and maintained by NAI
  - Three-field formulation, including liquid, vapor and drops – important for modeling condensation in the containment vessel during LOCA in the NuScale module
  - Three dimensional modeling capabilities for two-phase flow applications, solute (incl. boron), non-condensable gas fields
  - Full compliment of control and trip systems, valves, material properties modeling, etc.
  - Intuitive and well tested graphical user interface

Code Evaluation Results

- GOTHIC code selected for safety analyses applications
  - Broad validation matrix covering a vast array of applications (see example table next page)
  - Matrix includes many phenomenological validations directly applicable to NuScale target applications
  - Coupled primary and containment results
  - Cladding heat-up not a consideration for the NuScale power module, so lack of reflood modeling in present GOTHIC code not an issue
  - Developed and maintained in a rigorous QA program – NAI QA program is regularly audited for compliance with 10 CFR 50 Appendix B and 10 CFR 21

Sample of GOTHIC Validation Matrix

- Example GOTHIC validation base

	Test	Drop Entrainment	Drop Deposition	Drop Settling	Drop Breakup	Drop Evaporation	Drop Condensation	Drop Aglomeration	Mist Generation	Mist Depletion	Pressure Wave Propagation	Surface Wave Propagation	Impact Loads	Drag Loads	Pressure Drop / Single Phase	Pressure Drop / Bubbly Flow	Pressure Drop / Film-Drop Flow	Pressure Drop / Stratified Flow	Pressure Drop / Slug Flow	Stratified Flow Transition to Slug	Bouyancy Induced Stratification
45	Water Aerosol Leakage (WALE) Experiments	x	x	x	x	x															
46	Light Water Reactor Aerosol Containment (LACE) Tests																				
47	FLECHT SEASET Natural Circulation Tests														x	x	x	x			
48	CVTR Simulated DBA Tests		x	x		x	x		x	x											
49	Marviken Full Scale Containment Tests	x	x	x		x		x							x	x	x		x		x
50	Battelle-Frankfurt Containment Tests	x	x	x		x		x	x	x					x		x				x
51	HEDL Hydrogen Mixing Tests								x	x											x
52	HDR Full Scale Containment Tests		x	x		x		x	x	x					x		x				
53	Nuclear Power Engineering Corporation (NUPEC) Tests		x	x		x	x														x

Considerations for GOTHIC

- Some items in the GOTHIC validation matrix will be re-evaluated to look at other phenomena
  - Example, existing Marviken work looks at level swell and containment response – will expand work to incorporate critical flow as well
- Additional items to be added to address target applications based on evaluation of code

GOTHIC Evaluation Results

- Evaluation results
  - Reactor kinetics installation
  - Assessments on existing data
    - Christensen : subcooled boiling
    - PSBT : rod bundle void
    - Wilson Bubble Rise : large diameter void fraction
    - Marviken : critical flow
  - New Assessments
    - Steam generator performance
    - High pressure condensation / containment performance
    - Integral effects: ECCS/DHRS/CHRS performance
    - OSU Integral Test Facility: validation of primary and safety system performance

Conclusions

- NuScale is developing assessment base for the target applications consistent with EMDAP
- GOTHIC selected as system code for safety analysis applications
- Starting with the GOTHIC validation matrix, a rigorous approach to confirming applicability is being applied
  - GOTHIC validation items will be reworked as needed for applicability to target applications
  - Additional items will be added to build an assessment base specific to a target methodology

NuScale Power

1000 NE Circle Blvd, Suite 10310
Corvallis, OR 97330
541-207-3931
nuscalepower.com