Loss-of-Coolant Accident Phenomena Identification and Ranking Table Licensing Technical Report

Wendell Wagner, Senior Safety Analyst

June 2, 2010

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

NuScale Power

Requirements and Interfaces

- 10 CFR 50.46, *Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors*
- SECY-08-189, *Advanced Reactor Design Policy*
- Regulatory Guide 1.203, *Transient and Accident Analysis Methods*
- NuScale Level B Software Quality Assurance Process & Procedures

Report Outline

- General Information
- Postulated Accident Scenario Description
- PIRT Process
- Discussion of Phenomena and Ranking Rationales
- Conclusions
- Appendix A – PIRT Panel Biographies

Purpose and Scope

- Independent assessment of the relative importance of phenomena that may occur in the NuScale module during postulated loss-of-coolant accidents (LOCAs)
- Support development of detailed evaluation models for analysis of LOCAs

References

1. **US NRC.** Regulatory Guide 1.203, *Transient and Accident Analysis Methods.* US NRC, 2005.
2. **US NRC.** 10 CFR 50.46, *Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors.* US NRC.
3. **US NRC.** SECY-08-189, *Advanced Reactor Design Policy,* US NRC, 2008.
4. **NuScale Power.** *Customer Requirements Document (Draft),* NuScale Power, 2008.
5. **NuScale Power.** NP-RF-03RP-003, *NuScale Preliminary Loss-Of-Coolant-Accident Phenomena Identification and Ranking Table (PIRT),* NuScale Power, 2010.
6. **Information Systems Laboratories.** *RELAP5 MOD3.3 Code Manual, Volume 4: Models and Correlations,* ISL, 2006.
7. **Saha, D., Cleveland, J.** *Natural Circulation in Nuclear Reactor System,* Science and Technology of Nuclear Installations, 2008.

Plant Description

- Based on Rev. A module design
- Key differences between Rev A. and Rev. B (current) designs
  - 1.63 m height core
  - Minor ECCS timing
  - Steam generator tube number and dimensions
- Design changes are not anticipated to change phenomena ranking

Scenario Description

- LOCA variation in NuScale design restricted by limited number of penetrations of primary system pressure boundary
  - Breaks in penetrations that would exceed normal makeup capacity
- Leads to limited set of LOCA scenarios
- Panel selected inadvertent actuation of an RVV as scenario that would cover the vast majority of phenomena to be expected in any LOCA
- Sample RELAP5/3.3 calculations developed to help inform panel deliberations

Process

- Step 1 – Issues
- Step 2 – Objectives
- Step 3 – Hardware and scenario
- Step 4 – Evaluation criteria
- Step 5 – Knowledge base
- Step 6 – Identify phenomena
- Step 7 – Important ranking
- Step 8 – Knowledge level ranking

Panelists

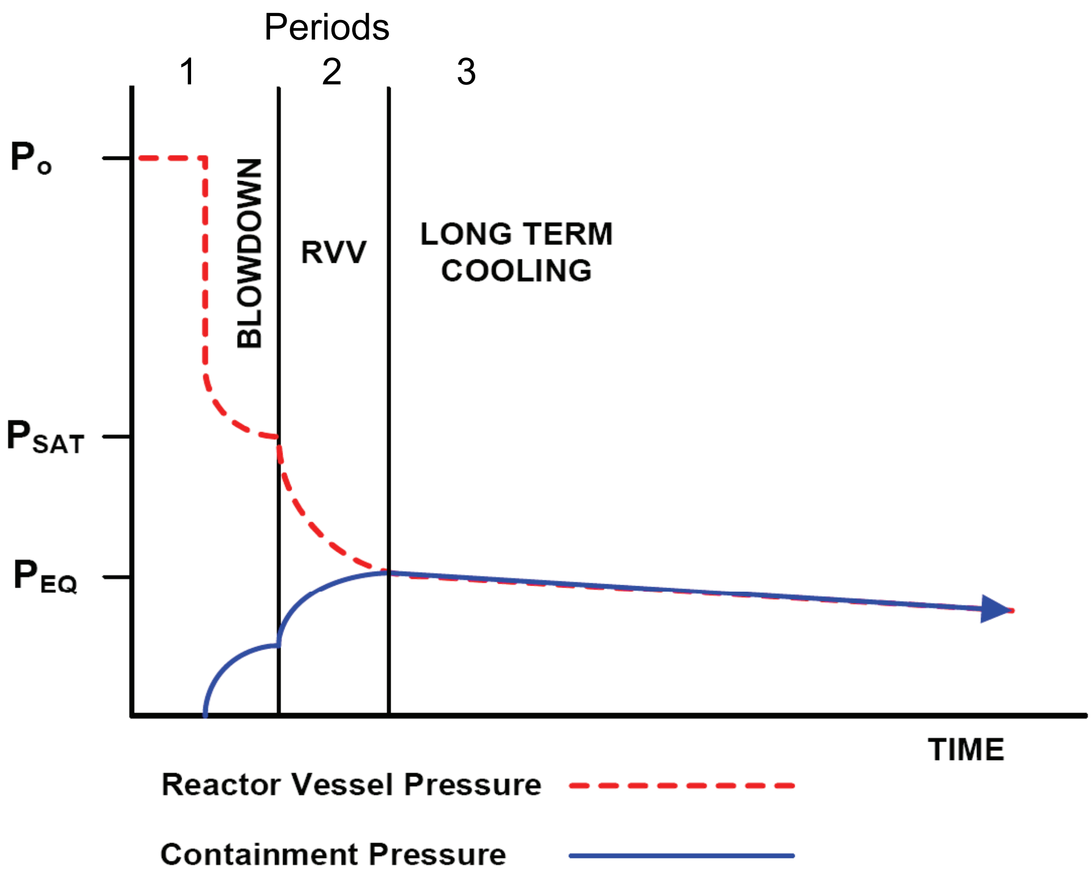
- Dr. Graham Wallis, Chair
- Dr. Lawrence E. Hochreiter
- Dr. Mujid S. Kazimi
- Mr. Brent Boyack
- Dr. Kord S. Smith
- Dr. José N. Reyes
- Dr. Kent B. Welter, Facilitator
- Dr. Eric P. Young, Assistant

Important Level and Knowledge Rankings

Importance Rank	Definition
Inactive (I)	Phenomenon not present or negligible
Low (L)	Small influence on primary figure of merit
Medium (M)	Moderate influence on primary figure of merit
High (H)	Significant influence on primary figure of merit

Knowledge Level	Definition
1	Very limited knowledge, uncertainty cannot be characterized
2	Partially known, large uncertainty
3	Known, moderate uncertainty
4	Well known, small uncertainty

Scenario Periods



Phenomena-specific Systems, Components, and Processes

Core	Primary System	Containment Heat Removal System	Decay Heat Removal System
• Fuel rods • Subchannel Coolant flow • Core-wide flow • Control rods / guide tubes • Reflector / core barrel / baffle	• Downcomer • Hot Leg Riser • Lower plenum • Upper plenum • Pressurizer • Cold Leg (steam generator annulus) • Break	• Containment • Sump recirculation valves • Containment cooling pool • Reactor vent valves • Concrete / stainless steel liner of containment cooling pool	• Containment cooling Pool (During sparger venting) • Sump screen and piping • Steam generator tubes • Sparger and piping • Feedwater accumulators • Instrumentation

Figures of Merit

Period	Figure of Merit	Description
1	Critical heat flux (CHF)	Thermal limit of a phenomenon where a phase change occurs during heating (such as bubbles forming on a metal surface used to heat water), which suddenly decreases the efficiency of heat transfer, thus causing a localized temperature increase of the heating surface. Also called a departure from nucleate boiling (DNB), the CHF limit for the fuel cladding is an important figure of merit for assessing reactor safety.
2	Core collapsed liquid level and CHF	Single-phase collapsed liquid level is measured in relation to the top of the heated fuel region. CHF is important for any heated surface within the core region and is described for the previous period.
3	Core coolability	Conditional configuration described by the ability to supply sufficient coolant to prevent fuel temperatures that would result in fuel damage.

Summary of Results

	Phase 1 (Initial Blowdown)	Phase 2 (RVV Actuation)	Phase 3 (Long-Term Cooling)
High Importance (H)	• Subchannel/coolant flow	• Break • Reactor vent valves	• Concrete / stainless steel liner of CCP
Medium Importance (M)	• Fuel rods • Core-wide flow • Hot Leg Riser • Lower plenum • Upper plenum • Pressurizer • Cold Leg (SG annulus) • Break	• Fuel rods • Subchannel / Coolant Flow • Core-wide flow • Hot Leg Riser • Lower plenum • Pressurizer • Containment	• Break • Containment • Sump recirculation valves • Containment cooling pool • Reactor vent valves
Low Importance (L)	• Control rods / guide tubes • Reflector/core barrel/baffle • Downcomer • Containment • Containment cooling pool while sparger venting	• Control rods / guide tubes • Reflector/core barrel/baffle • Downcomer • Upper plenum • Cold Leg (SG annulus) • Containment cooling pool	• Fuel rods • Subchannel / coolant flow • Core-wide flow • Control rods/guide tubes • Reflector/core barrel/baffle • Downcomer • Hot Leg Riser • Lower plenum • Upper Plenum • Pressurizer • Cold leg (SG annulus)

Conclusions

- Approximately 160 phenomena related to figures of merit identified
- 54 (~34%) specified as highly important for at least one period of SBLOCA
- No phenomenon identified ranked highly important for all three periods of SBLOCA
- Knowledge levels for these 54 highly-ranked phenomena ranged from 2 (partially known) to 4 (fully known), with the large majority ranked as fairly well known
- 16 phenomena of high importance were assigned knowledge level of 2
- Majority of high-importance, low-knowledge phenomena associated with core subchannel flow and Hot Leg Riser

NuScale Power

201 NW 3rd Street
Corvallis, OR 97330
541-207-3931
nuscalepower.com