Response to NuScale Topical Report Audit Question

Question Number: A-NonLOCA.LTR-63

Receipt Date: 06/28/2024

Question:

Non-LOCA TR r4 Section 6 contains numerous instances of Figures and descriptions applicable to the NPM-160 design but inapplicable to the NPM-20 design. Update Section 6 such that it accurately describes the NRELAP5 non-LOCA base model "nl20r1-model.i" (r1) that is associated with EC-0000-8507 "NPM-20 NRELAP5 Non-LOCA Model" (r1).

Response:

The figures and descriptions provided in TR-0516-49416-P, Revision 4, "Non-Loss-of-Coolant Accident Analysis Methodology," are intended to be typical descriptions of the NuScale NRELAP5 plant model that is not specific to the details of the NuScale Power Module (NPM) that may vary between the NPM-160 and NPM-20. To this end, TR-0516-49416-P Section 6.0 states:

> *"The base model for a specific NPM design reflects the parameters and features of that design."*

Specific design features that differ between NPM designs do not change the methodology used to model important parts of the design for non-loss-of-coolant accident (non-LOCA) analysis. TR-0516-49416-P, Revision 4, Section 6.1 includes the following that is unchanged from Revision 3 (i.e., the version previously reviewed and approved by the NRC):

> *"Where precise noding is described in Section 6.1, the specified level of detail is considered the minimum level of detail required for the component of interest. Should additional detail be needed in the future, the relevant benchmarks, sensitivity studies, and transient analyses will be reviewed for continued applicability. If necessary, the relevant benchmarks, sensitivity studies, and transient analyses will*

be revised to demonstrate the higher level of detail for the component of interest is applicable to an NPM."

Precise noding details that are important, considering the non-LOCA evaluation model validation basis and relationship to the subchannel analysis, are unchanged between Revision 3 and Revision 4 of TR-0516-49416-P, and have been used in the application of the methodology to the NPM-20 design. These precise noding details include: {{

}}2(a),(c)

NRELAP5 provides the user considerable flexibility in using pipe, branch and various junction or valve components to model a physical system. Equivalent modeling can be accomplished with different combinations of components. For this reason, it is not necessary for the figures in Section 6 to match one specific design. Instead, the figures in Section 6 are identified as typical. The figures in Section 6 have corresponding text discussion in Section 6. The text in Section 6 of the topical report was reviewed to determine if additional clarification was necessary due to design changes between NPM-160 and NPM-20 or due to basemodel changes. As a result of the review, TR-0516-49416-P Section 6 is revised as shown in the attached markup to provide additional clarification related to model development when different design details are evaluated. In some cases, the revised text allows for different modeling options to be used. The reason for allowing multiple options is to retain the modeling option previously reviewed and approved in TR-0516-49416 Revision 3, while allowing for the alternative approach used in the basemodel for NPM-20. With these changes, Section 6 accurately reflects the NRELAP5 basemodel for NPM-20, consistent with the request in this audit question.

Markups of the affected changes, as described in the response, are provided below.

Steam Generator Primary

The SG is a helical coiled, once-through HX, with the primary system on the shell side and the secondary system on the tube side. The primary system water is cooled as it flows over the outer surfaces of the SG tubes before passing over the feedwater plena that are located above the elevation of the conical transition riser fairing in the RPV. On the secondary side, feedwater enters the bottom of the SG tubes via the feedwater plena and is heated as it flows upward, with superheated steam exiting the tops of the tubes. Two independent sets of interwoven SG tube banks occupy the SG region, each having independent feedwater and steam plena. If the tube banks experience different secondary side conditions, the primary coolant does not experience any corresponding asymmetries because of the interwoven design of the helical coiled tubes.

The heat transfer to the SG tubes occurs in the upper downcomer. The heat transfer and pressure drop resulting from the presence of the SG tubes was assessed with data from SIET TF-2 (Section 5.3.5). This assessment used special heat transfer model options to determine the methodology for accurately predicting the pressure drop in the region. {{

}}2(a),(c)

Core and Lower Plenum

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}}2(a),(c)

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}}2(a),(c)

Figure 6-5 Typical core and lower plenum model

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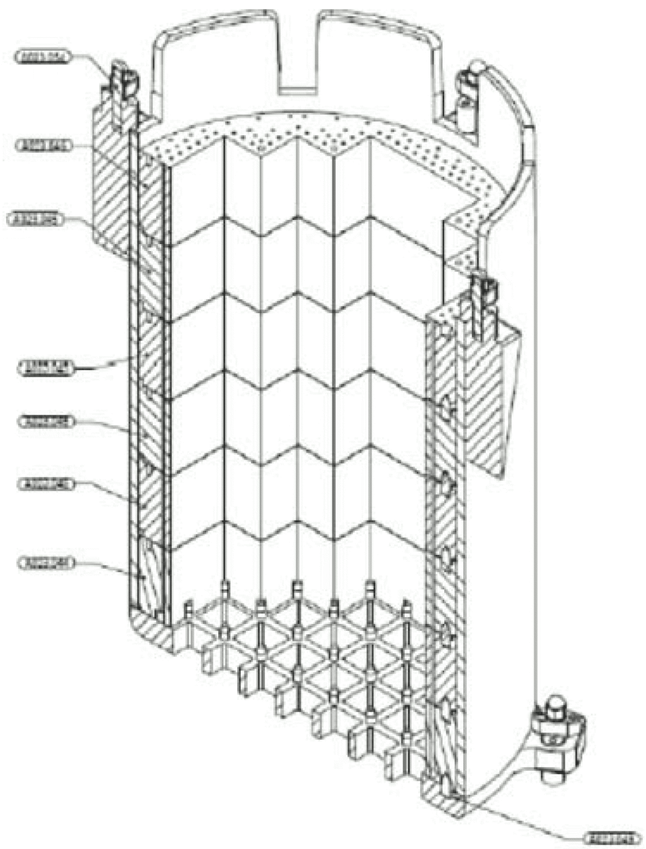
}}2(a),(c)

Figure 6-6 Reflector / core bypass without fuel assemblies (for illustration only)



Lower Riser

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}}2(a),(c)

Upper Riser

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}}2(a),(c) Normal flow in the riser is single-phase subcooled water. Transients that involve RPV depressurization or inventory loss can result in flashing and two-phase flow in the riser region.

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}}2(a),(c)

Figure 6-9 Typical reactor pressure vessel upper riser model

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}}2(a),(c)

Pressurizer

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}}2(a),(c)

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}}2(a),(c) The gap thermal conductivity is calculated at bounding values burnup to ensure that the fuel volume average temperature is appropriately bounded compared to fuel performance design data. This bounding method also accounts for gap closure over the fuel cycle.

6.1.4 Secondary System

6.1.4.1 Feedwater System

In an NPM design two feedwater lines penetrate the CNV immediately downstream of the FWIVs. Each feedwater line splits into two lines before connecting to the SGs. {{

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}}2(a),(c)

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}}2(a),(c)

Figure 6-12 Typical main steam system model

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}}2(a),(c)

6.1.5 Decay Heat Removal System

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An NPM incorporates two separate DHRSs that are treated individually in the NRELAP5 model. {{

}}2(a),(c) Figure 6-13 shows the typical nodalization for DHRS loop 1 {{

}}2(a),(c)~~.~~ Loop 2 is modeled similarly. While each DHRS line in an NPM features two parallel actuation valves, {{

}}2(a),(c)

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The number of hydrodynamic volumes in the DHRS condenser piping and HX regions are based on results from NRELAP5 assessments using data from the NIST-1 facility (Section 5.3.2). {{

}}2(a),(c)

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In an actual NPM, the DHRS ~~heat exchanger is~~condensers are located in the reactor cooling pool. {{

}}2(a),(c) The long-term use of DHRS is addressed separately in Reference 26.

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}}2(a),(c)

6.1.8 Reactor Cooling Pool

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}}2(a),(c)

6.2 Material Properties

Thermal properties (thermal conductivity and volumetric heat capacity) are specified by user input in the NRELAP5 non-LOCA base models for the following materials typically used in the heat structures. These material properties may be amended or revised as the NPM design evolves:

1. fuel cladding (AREVA's M5® cladding)
2. inconel 690 (SG tubes)
3. uranium dioxide (UO_2)
4. stainless steel (SA-240 304L)
5. fuel-to-cladding gas gap (initially pressurized helium at BOC; mixture of fission product gases and helium after irradiation)
6. carbon steel (SA-508)
7. martensitic stainless steel (SA-336, F6NM)
8. austenitic stainless steel (SA-965, FXM-19)
9. {{

}}2(a),(c)

6.3 Control Systems

With its combination of trips, control functions, and user-defined tables, NRELAP5 provides flexibility to accurately simulate plant control and protection system responses during both steady-state and transient operation. The NRELAP5 non-LOCA base models contains logic for "normal controls" that simulate normal operational plant response, as well as user-convenience controls that make it easier to initialize the model for particular

6.3.1.3 Reactor Coolant System Temperature Control (Nonsafety-related)

The MCS model controls RCS average temperature by changing reactivity in the core to increase or decrease core power. This reactivity change is accomplished with a control rod controller and a boron controller. The control rod controller uses design data to model a calculated rate of reactivity insertion due to maximum or nominal rod movement rates. {{

}}2(a),(c) Neither controller accounts for all the actual core physics including the effect of xenon or other decay products or poisons that could be expected with control rod repositioning.

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The average coolant temperature is controlled by adjusting core power, which is accomplished by moving the control rods or changing the boron concentration of the reactor coolant. The choice of which method is based on the desired rate of change for core power. The control rods are moved to achieve faster power changes to meet the target average coolant temperature; slower power changes are accomplished by changing the boron concentration of the reactor coolant. At full power, the rod control system is set to 'insert only' mode to prevent automatic withdrawal of the control rods during a transient. If this design feature is neglected in the model, the rod control system will allow control rods to be withdrawn even if reactor power is at or above full power, resulting in a conservative power response to a transient.

6.3.1.4 Steam Pressure Control (Nonsafety-related)

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In an NPM design, the turbine throttle and bypass valves are used to control steam pressure at the programmed values, {{

}}2(a),(c)

6.3.1.5 Feedwater and Turbine Load Control (Nonsafety-related)

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An NPM prototypic control scheme design for the feedwater system is based on turbine load demand. The feedwater pumps are variable speed and can provide variable flow for module operations over a wide range of power without adjustments to the feedwater regulating valve. {{

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}}2(a),(c)

6.3.1.6 Containment Pressure Control (Nonsafety-related)

The containment pressure is established at sub-atmospheric conditions via operation of the containment evacuation system. The impact of this system continuing to operate is considered for the non-LOCA transient analyses.

6.3.2 Module Protection System (Safety-related)

6.3.2.1 Analytical Limits and Delays

The MPS implemented in the NRELAP5 base models is intended for the purposes of performing safety analysis transient simulations. As such, the logic and actuation points are based on the NPM safety analysis analytical limits. Fixed delay times are specified considering different sensor response times. {{

}}2(a),(c) In addition to the sensor delays, a given safety signal is subject to instrumentation string delays, an MPS processing delay, and an actuation delay. The NRELAP5 non-LOCA model incorporates the methodology assumption that a bounding total for these additional delays is applied as a signal delay in addition to the individual sensor delay.

The MPS actuation signals in an NPM design are typically based on the following types of parameters:

- power range power
- power range power rate
- intermediate range log power rate