Response to SDAA Audit Question

Question Number: A-15.9-2

Receipt Date: 06/28/2024

Question:

Please confirm the subcooling margins at the analytical design operating limits (shown in Figure 4.4-2) are consistent with the exclusion region protection specified in the referenced “Evaluation Methodology for Stability Analysis of the NuScale Power Module,” TR-0516-49417-P-A, Revision 1. Further, although FSAR Section 15.9.1 notes that the referenced LTR has been verified to be applicable to the US-460 design, the section does not specify that the MPS trip is the method of enforcing the exclusion region for the SDAA design, nor does it provide the subcooling value associated with the MPS trips (or reference to the specified subcooling values). Please provide proposed markups.

Response:

TR-0516-49417-P-A, Revision 1, “Evaluation Methodology for Stability Analysis of the NuScale Power Module,” states the following in Section 10.3:

> “In conclusion, the selected stability protection solution for the NPM is the regional exclusion solution. The region is defined by a single point specifying riser subcooling margin. The stability exclusion region is protected by automatic action.”

Figure 10-1 of TR-0516-49417-P-A, Revision 1, provides an illustration of the relationship between riser subcooling margin and the region of allowed operation. The region of allowed operation is enforced automatically by the trips associated with the module protection system (MPS). In the Design Certification Application (DCA) for the US600 design, Final Safety Analysis Report (FSAR) Figure 15.0-9 demonstrated how subcooling margin is protected by the MPS.

For the Standard Design Approval Application (SDAA) for the US460 design, the equivalent demonstration of how subcooling margin is protected by the MPS is provided in FSAR Figure 4.4-2. A subcooling margin of 5 degrees F or more is maintained by the operational boundaries enforced automatically by the MPS trips identified in FSAR Figure 4.4-2. Therefore, the analytical design operating limits shown in FSAR Figure 4.4-2 are consistent with the exclusion region protection specified in TR-0516-49417-P-A, Revision 1.

FSAR Section 15.9 is revised to identify that MPS trips provide protection of the subcooling margin as shown in Figure 4.4-2, consistent with TR-0516-49417-P-A, Revision 1.

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

15.9 Stability

Events that could result in thermal-hydraulic instability within the reactor pressure vessel are considered significant only for boiling water reactors (BWRs), where individual fuel assemblies with high power-to-flow ratios may undergo instabilities or the neutronic conditions may lead to power oscillation. Pressurized water reactors use pumps for forced circulation, which keeps core flow essentially constant with power level. The NuScale Power Module (NPM) employs natural circulation. With this design feature, flow through the core is not held constant by pumps providing forced circulation. Thus, variations in flow may result in changes in power level and vice versa. The identification and evaluation of the significance of these mechanisms is addressed in Section 4.4.7. Perturbations and bounding flow instability are evaluated in this section. The evaluation includes reactivity coefficients that span beginning of cycle (BOC) to end of cycle (EOC), and demonstrates that the NPM is protected from unstable flow oscillations provided that operation is limited by a defined pressure-temperature exclusion zone such that no boiling in the riser area above the core is allowed. The negative moderator reactivity coefficient may stabilize flow even if riser boiling occurs, but this is conservatively not credited in the stability methodology.

15.9.1 Consideration of Thermal-Hydraulic Stability

The NuScale Stability Evaluation Methodology Topical Report (Reference 15.9-1) presents an analysis of the thermal-hydraulic stability of a representative NPM and demonstrates compliance with 10 CFR 50, Appendix A, General Design Criteria (GDC) 10 and GDC 12. The topical report considers potential power and hydraulic stability mechanisms during anticipated operational occurrences (AOOs) and normal operating conditions. Thermal-hydraulic instability during infrequent events or accidents is not considered because the acceptance criteria for such events allow for conditions beyond the specified acceptable fuel design limits imposed on AOO events experiencing instabilities. The topical report considers flow stability without making assumptions based on comparisons to other nuclear systems. The topical report describes computational methods developed for the analysis of the limiting instability modes for a representative NPM design during steady state, normal operation, and anticipated transients.

Audit Question A-15.9-2

The region exclusion stability protection solution is shown in Reference 15.9-1 to be an acceptable approach for preventing the occurrence of instabilities in an NPM. The region exclusion is defined by specifying riser subcooling margin. The riser subcooling margin is maintained by the operational boundaries enforced automatically by the module protection system (MPS) as shown in Figure 4.4-2.

The limiting instability mode is a natural circulation instability as described in Reference 15.9-1.

The Reference 15.9-1 methodology and conclusions, as well as the conditions and limitations of the associated Safety Evaluation Report, have been reviewed and verified to be applicable to the NPM for the NuScale Power Plant US460 standard design. Updated stability analyses using inputs in a manner consistent with

15.9.2.1.4 Results

Table 15.9-2, Figure 15.9-1, and Figure 15.9-2 provide the analysis case that produced the limiting results.The figures show the transient response for the time period over which the decay ratio is calculated.

15.9.3 Stability Analysis for Operational Occurrences

The nature of the natural circulation system performance narrows the analysis down to examining transients that are credible in the NPM. Several operational events are investigated with externally imposed boundary conditions applied to influence the system response as described in Section 8.2 of Reference 15.9-1.

The analyses demonstrate an acceptable operating region for the NPM where instability does not occur.

The NPM system response is obtained by the computer code, PIM, which is used in demonstrating system stability at initially steady-state operation. The PIM code is described in Section 4.4.7.

15.9.3.1 Increase in Heat Removal by the Secondary System

15.9.3.1.1 Identification of Causes and Event Description

Audit Question A-15.9-2

Stability perturbations can occur from a rapid increase of feedwater flow. The flow increase can be caused by feedwater pump speed increase, valve alignment changes, or other causes. However, the analyzed change is sufficiently small that the ~~module protection system (~~MPS~~)~~ does not actuate, and control systems, such as those for steam pressure, maintain other parameters at the original value.

Other causes of increased heat removal, such as decreasing feedwater temperature or decreasing steam pressure (that causes increased boiling in the SGs), are bounded by changes in feedwater flow. The change in feedwater flow is bounding because the potential for change in feedwater temperature is more gradual when considering the entire feedwater system train (e.g., preheaters, piping lengths) and large rapid changes in steam pressure are expected to cause either compensating control actions or MPS trips.

15.9.3.1.2 Sequence of Events and Systems Operation

A disturbance results in feedwater flow being increased by 30 percent in 0.1 seconds. This change is chosen because, while it would normally cause a reactor trip, this trip is not simulated and, thus, it bounds smaller changes to feedwater flow that would not result in a reactor trip. No systems operations occur in response to the event, so no sequence of events table is generated.