February 28, 2019

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 438 (eRAI No. 9491) on the NuScale Design Certification Application

REFERENCES:

1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 438 (eRAI No. 9491)," dated April 26, 2018
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 438 (eRAI No.9491)," dated September 14, 2018

The purpose of this letter is to provide the NuScale Power, LLC (NuScale) supplemental response to the referenced NRC Request for Additional Information (RAI).

The Enclosure to this letter contains NuScale's supplemental response to the following RAI Question from NRC eRAI No. 9491:

- 15.09-2

This letter and the enclosed response make no new regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions on this response, please contact Paul Infanger at 541-452-7351 or at pinfanger@nuscalepower.com.

Sincerely,

Zackary W. Rad
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Enclosure 1: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9491

Enclosure 1:

NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9491

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Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 9491

Date of RAI Issue: 04/26/2018

NRC Question No.: 15.09-2

Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Appendix A, General Design Criterion (GDC) 10 – Reactor Design, states that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). GDC 12-Suppression of Reactor Power Oscillations requires that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be detected and suppressed. Design-Specific Review Standard (DSRS) 15.9 states that the reviewer verifies that all analysis methodologies, including treatment of uncertainties, are acceptable. DSRS 15.0 indicates that the reviewer verify that applicant has identified major input parameters and initial conditions used in the analyses, included the initial values of other initial values if they are used in the analyses, provided the bases and degree of conservatism for numerical values of the input parameters and initial conditions, and evaluate the applicant's claims that AOOs are limiting or nonlimiting, or bounded by other AOOs.

The applicant performed stability analyses over a spectrum of events that includes perturbation of steady state and transient operations where the initiating events are variations of selected anticipated operational occurrences (AOO) discussed in other FSAR chapter 15 subsections. The applicant states "The operation events are analogous to the licensing basis AOOs. However, typical licensing basis AOO scenarios are chosen to provide limiting system response and generally result in a reactor trip … The stability operational events are constructed to avoid a reactor trip in order to assess the stability of the NPM." The applicant considers events from six AOO classification types listed in DSRS 15.0. However, a list or table of key parameters, values, and uncertainty biases for each limiting event was not found in Section 15.9 of the FSAR. In addition, it is not clear if the events analyzed are the most limiting stability events for the given classification type. Several 15.9 subsections of the FSAR, including 15.9.3.1, 15.9.3.2, 15.9.3.5, 15.9.4.1, and 15.9.4.2 refer to the stability methodology topical report (TR), TR-0516- 49417-P, for additional event specific information, however staff was unable to find the aforementioned proposed key parameter tables in the TRTo make an affirmative finding associated with the above regulatory requirement important to safety, NRC staff requests NuScale to:

1. Provide, in the FSAR, tables of key initial conditions and parameters, their values, and their biases, that were applied to the limiting events for a given event category. Initial condition and parameter tables similar to those provided for AOO events in sections 15.1 and 15.2 of the FSAR are acceptable to staff. Examples include: Tables 15.1-2 – through 15.1-4, or Tables 15.2-1 through 15.2-3, of the FSAR. Initial values of amplitude and frequency (or period) should be included in key initial condition parameter tables for stability events where external oscillations are imposed on the reactor system model.

2. Provide, in the FSAR, tables containing acceptance criteria values for limiting stability events. The tables should include decay ratios.

NuScale Response:

As discussed during a public teleconference held January 29th, 2019, NuScale is revising FSAR Section 15.9 to address staff comments. The equivalent of the decrease in reactor coolant inventory event found in Section 9.2 of TR-0516-49417 "Evaluation Methodology for Stability Analysis of the NuScale Power Module" is now included in FSAR Section 15.9.3.6, updated to the final design information.

Additionally, clarification is provided to show that control rod insertion is "credited" in the stability analyses, but not simulated with the PIM code.

Impact on DCA:

FSAR Section 15.9 been revised as described in the response above and as shown in the markup provided in this response.

Input parameters and initial conditions for the limiting event are presented in Table 15.9-3.

RAI 15.09-2, RAI 15.09-3

The event is analyzed for BOC reactivity conditions.

RAI 15.09-2, RAI 15.09-3

15.9.2.1.4 Results

RAI 15.09-2, RAI 15.09-3

The analysis that produced the most limiting results is described in Table 15.9-4 and in Figure 15.9-2 and Figure 15.9-3.

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. These boundary conditions include reactivity insertion (either directly in the core or via changes in primary system conditions) and realistic changes in primary and secondary conditions.

The results of these analyses demonstrate an acceptable operating region for the NPM where instability does not occur. Events considered fall into the following general classifications:

- increase in heat removal by the secondary system
- decrease in heat removal by the secondary system
- decrease in reactor coolant system (RCS) flow rate
- increase in reactor coolant inventory
- reactivity and power distribution anomalies
- decrease in reactor coolant inventory

RAI 15.09-2, RAI 15.09-2S1, RAI 15.09-3

The operational events considered are analogous to licensing basis AOOs. However, typical licensing basis AOO scenarios are chosen to provide a limiting system response and generally result in a reactor trip that mitigates the event. The stability operational events are constructed to initiate a reactor trip, which is not ~~credited~~simulated, in order to assess the stability of the NPM. This is a key consideration, because any event that quickly results in an MPS trip does not experience unstable flow oscillations; by not ~~crediting~~simulating the MPS trip, this effectively bounds any scenario in which MPS trip limits are not reached.

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. An input forcing function is applied to the appropriate boundary condition to initiate the transient, for example, a user-specified feedwater flow changing as a function of time to simulate a decrease in heat removal by the secondary system.

15.9.3.1 Increase in Heat Removal by the Secondary System

RAI 15.09-2, RAI 15.09-3

15.9.3.1.1 Identification of Causes and Event Description

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 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 generally bounded by changes in feedwater flow. This is because the potential for change in feedwater temperature is more gradual when considering the entire feedwater system train (preheaters, piping lengths, etc.) and large rapid changes in steam pressure are expected to cause either compensating control actions or MPS trips.

RAI 15.09-2, RAI 15.09-3

15.9.3.1.2 Sequence of Events and Systems Operation

RAI 15.09-2, RAI 15.09-2S1, RAI 15.09-3

A disturbance results in feedwater flow being rapidly increased by 10 percent in 0.1 seconds. This change is chosen because, while it would normally cause a reactor trip, this trip is not ~~credited~~simulated and, thus, it conservatively 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.

RAI 15.09-2, RAI 15.09-3

15.9.3.1.3 Input Parameters and Initial Conditions

RAI 15.09-2, RAI 15.09-3

The event is analyzed for both the reactor at 100 percent power and the reactor at 32 MW to simulate the expected power during startup at which the turbine comes on-line and feedwater heating begins. Input parameters and initial conditions for the 100 percent and 20 percent power cases are presented in Table 15.9-1 and Table 15.9-2 respectively. Both BOC and EOC reactivity conditions were considered in each analysis, but only EOC results are presented as they are the most limiting results.

RAI 15.09-2, RAI 15.09-3

15.9.3.1.4 Results

RAI 15.09-2, RAI 15.09-3

The results are presented in Table 15.9-5 and Figure 15.9-4 and Figure 15.9-5 for 100 percent of rated power and EOC reactivity. Additional results are presented in Table 15.9-6 and Figure 15.9-6 and Figure 15.9-7 for 20 percent of rated power and EOC reactivity. These results indicate that the plant is highly stable during a postulated increase in heat removal by the secondary system.

15.9.3.2 Decrease in Heat Removal by the Secondary System

RAI 15.09-2, RAI 15.09-3

15.9.3.2.1 Identification of Causes and Event Description

Stability following reduction of feedwater flow is addressed in this section. A hypothetical rapid decrease in feedwater flow occurs because of feedwater pump speed change, valve alignment changes, or other causes. However, complete loss of feedwater is not considered because it would result in actuation of the MPS and a trip.

Other causes of decreased heat removal, such as increasing feedwater temperature or increasing steam pressure are generally bounded by changes in feedwater flow because larger changes would result in a trip on high reactor power.

RAI 15.09-2, RAI 15.09-3

15.9.3.2.2 Sequence of Events and Systems Operation

RAI 15.09-2, RAI 15.09-2S1, RAI 15.09-3

Feedwater flow is decreased rapidly by 10 percent in 0.1 seconds while maintaining feedwater temperature and steam pressure. This magnitude of change is chosen to determine the acceptability of a partial loss of feedwater. While this magnitude of change would normally cause a reactor trip, this trip is not ~~credited~~simulated and, thus, it conservatively bounds smaller changes to feedwater flow that would not result in a reactor trip.

RAI 15.09-2, RAI 15.09-3

The resulting reduction in the heat removal from the primary coolant flow initiates a transient in which primary coolant temperature starts to rise and negative moderator feedback reduces the fission power. The combined reduction of the heat sink and core power restore the primary coolant temperature to a value above its initial value. The Doppler reactivity compensates for the difference and the net average reactivity is restored to zero. The density head driving the primary coolant flow is also reduced and the flow changes from its initial value to about 90 percent of its initial value.

RAI 15.09-2, RAI 15.09-3

15.9.3.5 Reactivity and Power Distribution Anomalies

RAI 15.09-2, RAI 15.09-3

15.9.3.5.1 Identification of Causes and Event Description

The effect on NPM stability from a reactivity anomaly can be caused by changes in boron concentration, by an uncontrolled control rod assembly withdrawal or similar events that result in reactivity insertion.

RRAI 15.09-2, RAI 15.09-3

15.9.3.5.2 Sequence of Events and Systems Operation

RAI 15.09-2, RAI 15.09-2S1, RAI 15.09-3

Reactor power is 32 MW when enough reactivity is added to the core to initiate a high flux rate trip while other reactivity components perform normally. The choice of 32 MW allows margin to the reactor trip setpoint; the high flux rate trip is not ~~credited~~simulated to conservatively bound smaller reactivity insertions that would not initiate this trip.

RAI 15.09-2, RAI 15.09-3

15.9.3.5.3 Input Parameters and Initial Conditions

RAI 15.09-2, RAI 15.09-3

Input parameters and initial conditions for the limiting event are presented in Table 15.9-2.

RAI 15.09-2, RAI 15.09-3

The event is analyzed with the reactor at 32 MW. Both BOC and EOC reactivity conditions are considered, but only EOC conditions are presented as they were the most limiting. At EOC, 0.65 dollars of reactivity is added.

RAI 15.09-2, RAI 15.09-3

15.9.3.5.4 Results

RAI 15.09-2, RAI 15.09-3

The effect of a change in boron concentration is slow to develop and is bounded by the applied variations in reactivity conditions.

RAI 15.09-2, RAI 15.09-3

Reactivity increases that do not result in reactor trip on high flux or high flux rate develop slowly and are bounded by effects of increasing heat removal from the secondary side. These events cause pressurizer insurges that maintain or increase subcooling in the riser.

RAI 15.09-2, RAI 15.09-3

The results are presented in Table 15.9-9 and Figure 15.9-12 and Figure 15.9-13 for 20 percent of rated power and EOC reactivity. These results indicate that the plant is highly stable during a postulated addition of reactivity event.

15.9.3.6 Decrease in Reactor Coolant Inventory

Decreasing RCS inventory without changes in primary pressure is not important in the stability assessment. Riser subcooling will be maintained and the protection system will trip the NPM on low pressurizer level before any appreciable effect can be seen regarding stability.

RAI 15.09-2S1

Decreasing reactor coolant inventory that results in decreasing pressure but without a level trip is expected to produce no significant effect on stability as long as the primary coolant in the riser remains subcooled. ~~The MPS includes measurement of the hot leg temperature and system pressure, which generate MPS trip signals that protect against an instability event before loss of riser subcooling can occur.~~However, further depressurization beyond the trip setpoint that results in riser voiding can destabilize the system. This section provides analysis results using the PIM code that show the effects of depressurization and ability of the MPS to mitigate the event.

RAI 15.09-2S1

15.9.3.6.1 Identification of Causes and Event Description

RAI 15.09-2S1

Stability following a long depressurization is addressed in this section. This simulates a decrease in reactor coolant inventory, though in this analysis no loss of coolant mass is credited. This has no functional impact, as the first trip that would be reached would be the low-low pressurizer pressure instead of the low pressurizer level trip.

RAI 15.09-2S1

A decrease in RCS inventory without changes in primary pressure is not analyzed, as riser subcooling will be maintained and the protection system will trip the NPM on low pressurizer level before any appreciable effect can be seen regarding stability.

RAI 15.09-2S1

15.9.3.6.2 Sequence of Events and Systems Operation

RAI 15.09-2S1

Reactor power is 160 MW when a slow depressurization of approximately 0.5 psi/second is imposed as a boundary forcing function. This depressurization is done over 1000 seconds, resulting in the pressure reaching 1378 psia. No systems operations occur in response to the event.

RAI 15.09-2S1

15.9.3.6.3 Input Parameters and Initial Conditions

RAI 15.09-2S1

Input parameters and initial conditions for the limiting event is presented in Table 15.9-1.

RAI 15.09-2S1

The event is analyzed at various points throughout the cycle. BOC is analyzed as the least stable exposure point because the magnitude of the moderator reactivity is small. EOC is analyzed as, due to the stronger moderator reactivity feedback, the power response to a given flow oscillation will be larger if the oscillations do occur. Analysis at MOC was performed since the effect of exposure on different parameters is not in the same direction.

RAI 15.09-2S1

Results are presented at BOC as a sufficient example, as unstable oscillations will occur upon loss of riser inlet subcooling.

RAI 15.09-2S1

15.9.3.6.4 Results

RAI 15.09-2S1

The results are presented in Figure 15.9-14 to Figure 15.9-17. The results show that the reactor would be safely shut down well before the development of oscillations due to loss of subcooling in the riser. A reactor trip would be initiated before these oscillations develop, the low-low pressurizer pressure trip once the pressure reaches 1600 psia.

RAI 15.09-2S1

This trip would occur at approximately 530 seconds, while the oscillations begin to develop at approximately 927 seconds. The effect on CHFR was found to be quantitatively similar for all exposure points. This response, as seen in Figure 15.9-17 for BOC, is an increase relative to the initial value. The increase of CHFR is expected as a result of the increased natural circulation flow caused by voiding in the riser. This further confirms that this event is not a limiting event for stability.

RAI 15.09-2, RAI 15.09-3

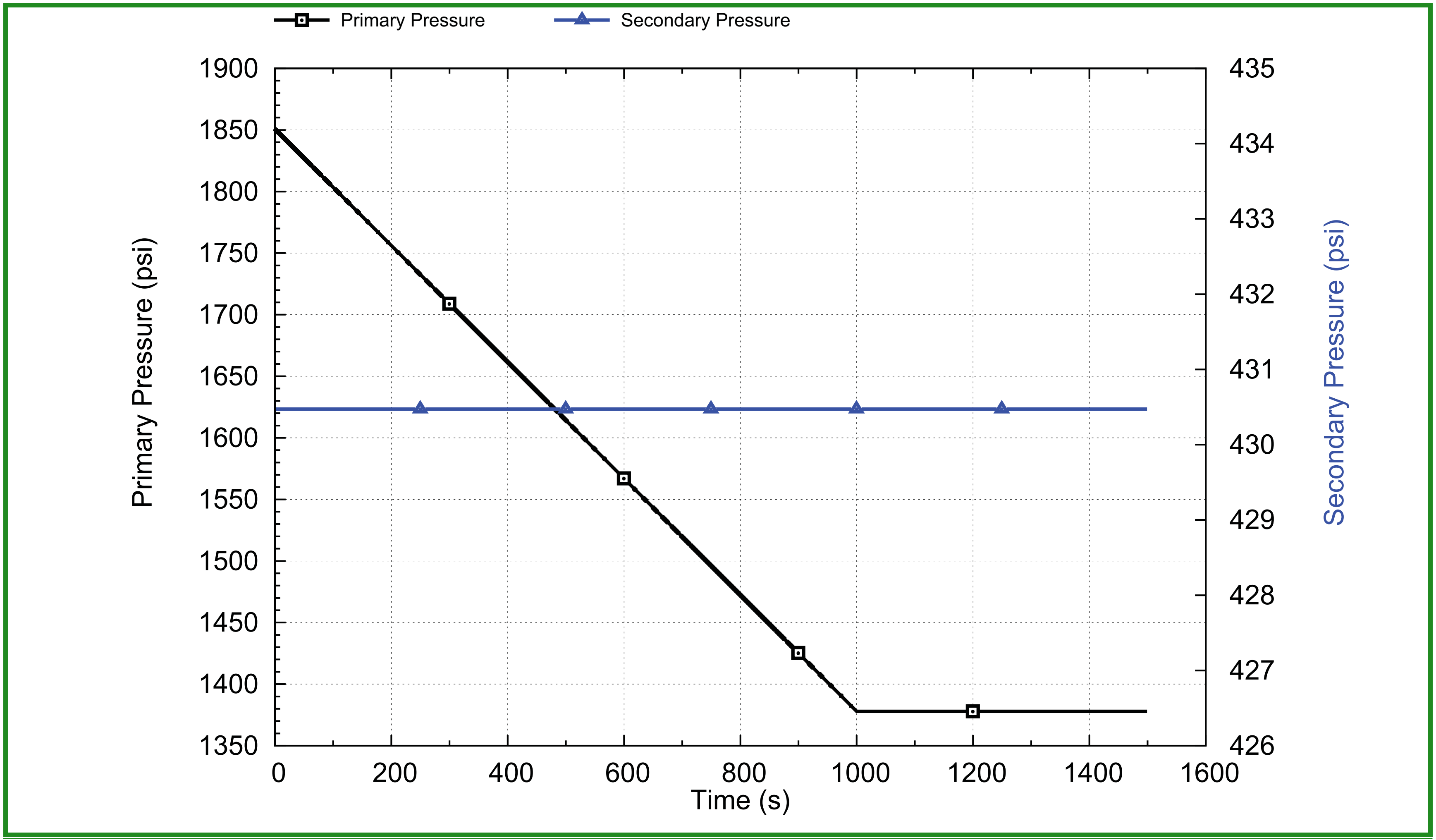
15.9.4 Demonstration of Module Protection System Functions to Preclude Instability

RAI 15.09-2, RAI 15.09-3

At rated power, the minimum loop time for the NPM is more than 60 seconds. The response delay for the MPS is no more than 8.0 seconds for setpoints that are pertinent to stability analysis and the scram time is less than 2.5 seconds. The time from the first scram setpoint being reached to the control rods being fully inserted is less than 11 seconds, which is

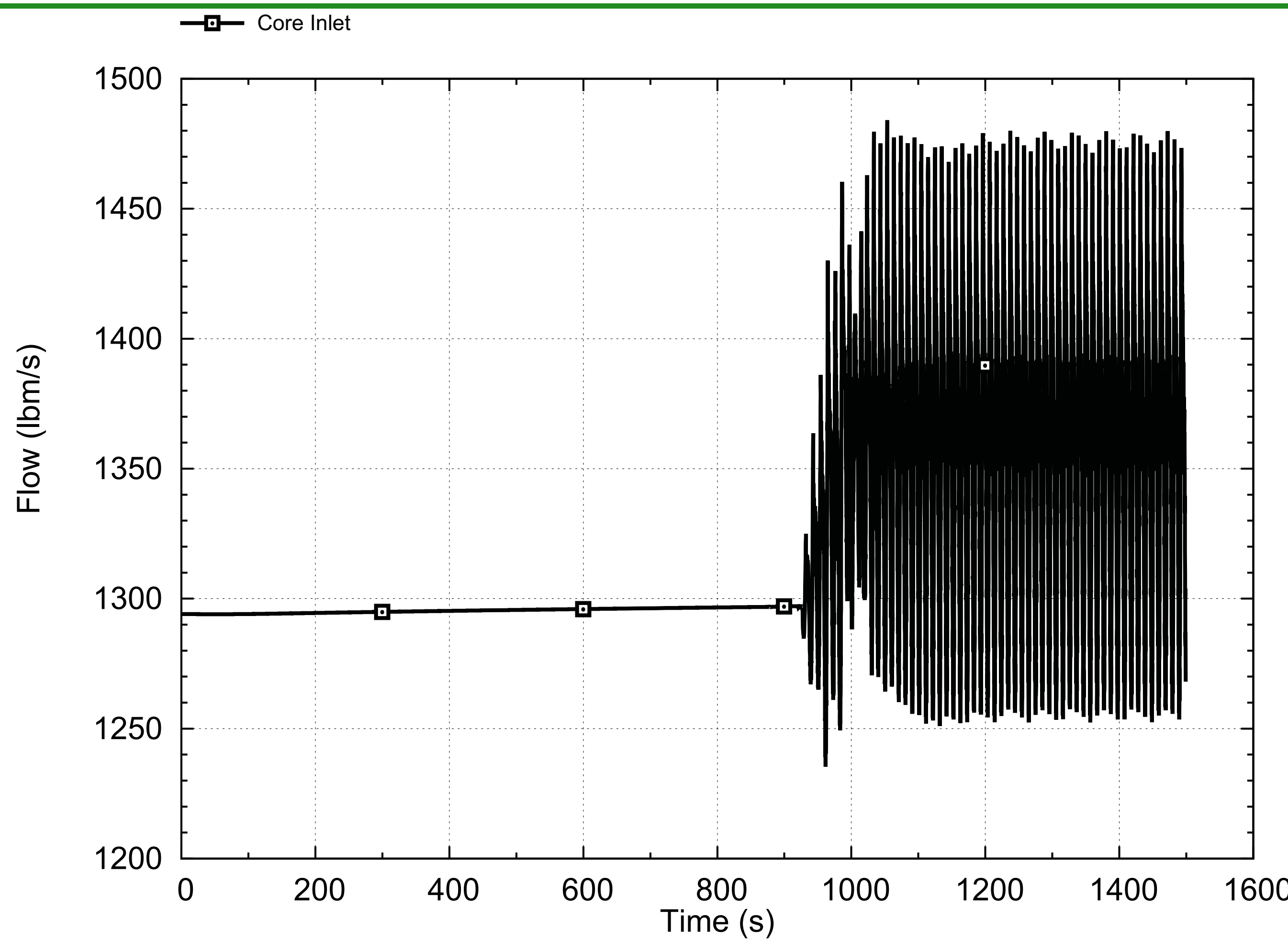
RAI 15.09-2S1

Figure 15.9-14: Time Trace of Pressure Boundary Function Representing the Effect of Decrease in Reactor Coolant Inventory



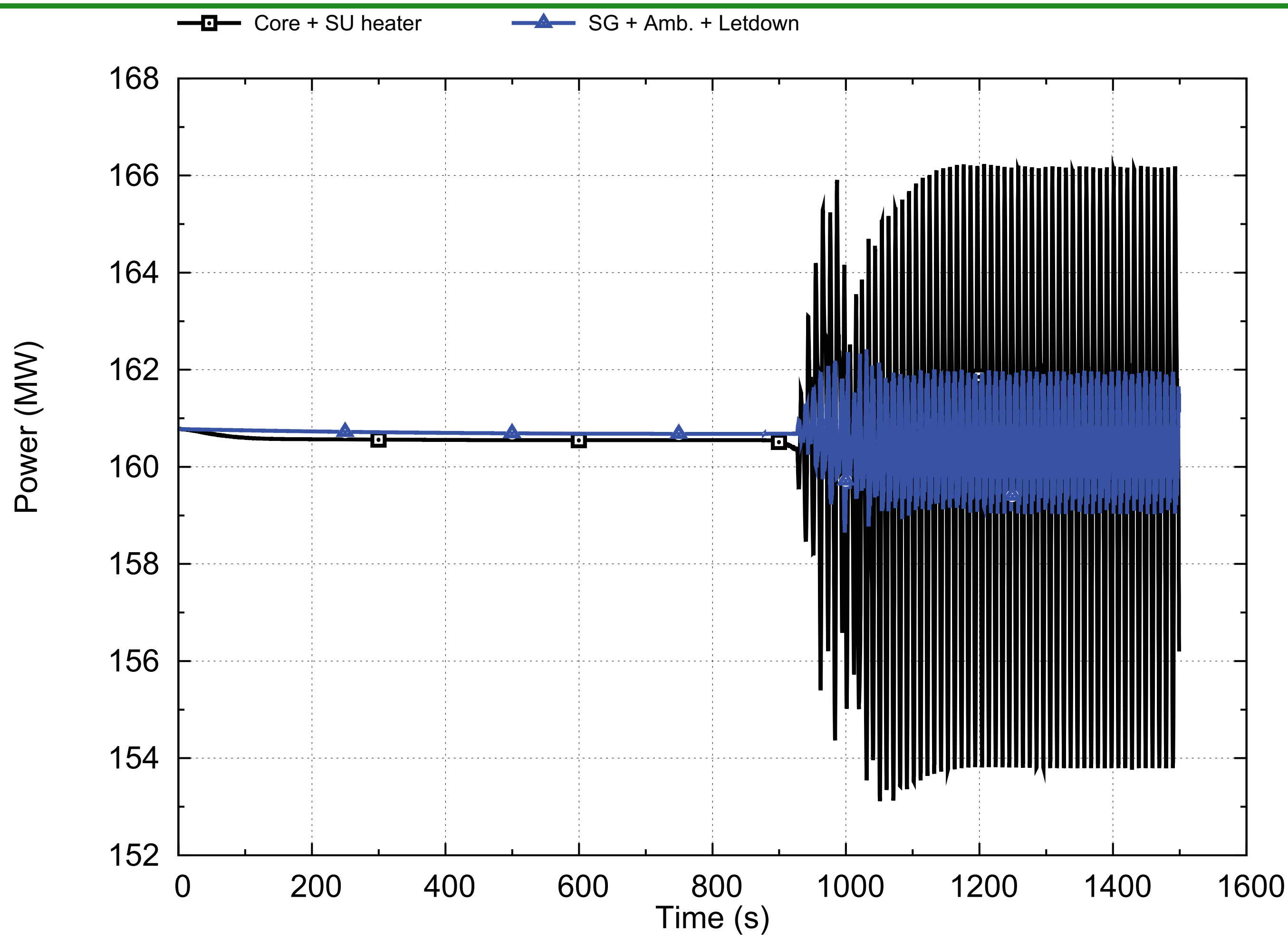
RAI 15.09-2S1

Figure 15.9-15: Time Trace of Flow Response to a Decrease in Reactor Coolant Inventory at 100 Percent of Rated Power and Beginning of Cycle Reactivity



RAI 15.09-2S1

Figure 15.9-16: Time Trace of Power Response to a Decrease in Reactor Coolant Inventory at 100 Percent of Rated Power and Beginning of Cycle Reactivity



RAI 15.09-2S1

Figure 15.9-17: Time Trace of CHFR Response to a Decrease in Reactor Coolant Inventory at 100 Percent of Rated Power and Beginning of Cycle Reactivity