RAIO-0517-54213

May 24, 2017

Docket No. 52-048

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information (eRAI No. 8764) on the NuScale Design Certification Application

REFERENCE: 1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 08 (eRAI No. 8764)," dated April 25, 2017

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

The Enclosures to this letter contain NuScale's response to the following RAI Questions from NRC eRAI No. 8764:

- 15.04.02-1
- 15.04.02-2

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

If you have any questions on this response, please contact Darrell Gardner at 980-349-4829 or at dgardner@nuscalepower.com.

Sincerely,

Zackary W. Rad
Director, Regulatory Affairs
NuScale Power, LLC

Distribution: Greg Cranston, NRC, TWFN-6E55
Samuel Lee, NRC, TWFN-6C20
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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 8764 RAI 15.04.02-1

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 8764 RAI 15.04.02-2

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Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 8764 - RAI 15.04.02-1

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

eRAI No.: 8764
Date of RAI Issue: 04/25/2017

NRC Question No.: 15.04.02-1

Standard Review Plan (SRP) Section 15.4.2, "Uncontrolled Control Rod Assembly Withdrawal at Power," provides guidance for complying with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criteria (GDC) 10, "Reactor design"; 13, "Instrumentation and control"; 17, "Electric power systems," 20, "Protection system functions"; and 25, "Protection system requirements for reactivity control malfunctions." Per SRP Section 15.4.2, the reviewer is to review the results of the analysis compared to the acceptance criteria for anticipated operational occurrences.

FSAR Tier 2, Figure 15.4-11, "CHFR (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)," shows that the minimum critical heat flux ratio (MCHFR) occurs at about 9 seconds, while the FSAR states that the most limiting MCHFR occurs at the time of the power peak (at about 80 s according to FSAR Tier 2, Table 15.4-3, "Sequence of Events (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)," and Figure 15.4-7, "Reactor Power (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)"). It is unclear to the staff from the docketed information why there is a discrepancy in when the MCHFR occurs and why the timeline of the MCHFR plot does not match the timeline of the power plot in FSAR Tier 2, Figure 15.4-7. Please either ensure the trends are plotted on matching time scales or justify the use of different time scales and update the FSAR as necessary.

The staff also notes that the RCS pressure verses time given in Figure 15.4-12 (RCS Pressure for Maximum Pressure Case) looks similar to the Figure 15.4-8 (RCS Pressure for Limiting MCHFR Case) except for the offset caused by plotting Figure 5.4-12 against the RPV lower plenum pressure instead of the pressurizer pressure in Figure 5.4-8. Based on the description of the maximum pressure case given in Section 15.4.2.3.3, "Results", the staff expected a more rapid increase in RCS pressure due to the loss of AC power and corresponding turbine trip at the beginning of the transient. Explain why the RCS pressure for the MCFH and maximum RCS pressure cases have similar pressure verses time responses and include a sequence of event table for the maximum pressure case.

Finally, in FSAR Tier 2 Section 15.4.2.5, “Conclusions,” reference is made to a CRA withdrawal from a subcritical or low power startup condition instead of the at power cases associated with Section 15.4.2. Please correct the FSAR.

NuScale Response:

NuScale has noted the timescale differences between the results from RELAP and VIPRE1. The subchannel analyses using VIPRE1 focused on the narrower time interval when RELAP predicted MCHFR and not from event initiation. However, the timescales of the VIPRE1 plots provided in the FSAR were not synchronized with the original RELAP plots. FSAR Figure 15.4-11 (CHFR) has been updated to synchronize the event timelines. It was also noted that the incorrect limiting MCHFR case for the uncontrolled control rod assembly (CRA) withdrawal at power event was presented in the FSAR. The MCHFR for the limiting uncontrolled CRA withdrawal at power is 1.316, as reported in FSAR Section 15.4.2.5. However, the event occurs at 75% power, not 102% power. FSAR Section 15.4.2 and associated tables and figures have been updated to present the correct limiting MCHFR event.

FSAR Figure 15.4-8 shows pressurizer pressure from the CHFR limiting case. FSAR Figure 15.4-12 incorrectly shows RCS pressure from the CHFR limiting case but was intended to show the limiting pressure case. FSAR Figure 15.4-12 has been updated to show the RCS pressure from the pressure limiting case. The RCS pressure from the pressure limiting case shows a more rapid increase in RCS pressure at the beginning of the transient, as expected.

The text in FSAR Section 15.4.2.5 has been corrected to reflect the at power event analyzed.

Impact on DCA:

FSAR Sections 15.4.2.2, 15.4.2.3, 15.4.2.5, FSAR Tables 15.4-3 and 15.4-4, and FSAR Figures 15.4-6, 15.4-7, 15.4-8, 15.4-9, 15.4-10, 15.4-11, and 15.4-12 have been revised as described in the response above and as shown in the markups provided in this response.

15.4.1.5 Conclusions

The two applicable acceptance criteria for this AOO are met for the limiting cases. These acceptance criteria, followed by how the NuScale design meets them are listed below:

- The thermal margin limits departure from nucleate boiling ratio for PWRs as specified in SRP Section 4.4, subsection II.1, are met.
  - The MCHFR for the limiting case is 8.657, which is above the design limit.
- Fuel centerline temperatures as specified in SRP Section 4.2, subsection II.A.2(a) and (b), do not exceed the melting point.
  - The fuel centerline temperature of the limiting case is 890.8°F, which is below the fuel melting temperature.

RAI 15.04.01-1, RAI 15.04.01-2

The evaluation of an uncontrolled CRA withdrawal from a subcritical or low power startup condition demonstrates that the RCS pressure does not exceed the RPV design limit. The limiting peak RCS pressure for this event is 2038 psia, as shown in Figure 15.4-34.

15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power

15.4.2.1 Identification of Causes and Accident Description

A spurious CRA withdrawal that occurs when the reactor is at power leads to an unexpected addition of positive reactivity into the reactor. An uncontrolled CRA withdrawal at power results in an increase in core power with a corresponding increase in heat flux. Due to the time lag in the response of the secondary system, the heat removal from the steam generators follows the heat increase in the primary system. The result is an increase in RCS temperature and pressure. These conditions could challenge design pressures and the SAFDLs. The power range neutron excore detectors provide high power and high flux rate core protection. For cases where the reactivity insertion is sufficiently slow, the high pressurizer pressure and high hot leg temperature limits provide protection. These MPS limits are analyzed for a spectrum of uncontrolled CRA withdrawal conditions to ensure that protection functions are actuated to prevent the violation of the design safety limits.

An uncontrolled CRA withdrawal is expected to occur one or more times in the life of the reactor, and it is classified as an AOO. The categorization of the NuScale design basis events are provided in Table 15.0-1.

15.4.2.2 Sequence of Events and Systems Operation

RAI 15.04.02-1, RAI 15.04.02-2

The sequence of events for a representative uncontrolled CRA withdrawal at power is provided in ~~Table 15.4-2~~Table 15.4-3.

- Loss of Normal AC - In this scenario, the MPS remains powered, so none of the safety systems are automatically actuated. However, power is lost to the feedwater pumps, CVCS recirculation pumps, pressurizer heaters, and the condenser, resulting in a turbine trip.
  - Loss of normal AC at the time of the event initiation is analyzed in NRELAP5.
  - Loss of normal AC at the time of reactor trip is analyzed in NRELAP5.
- Loss of EDNS and Loss of normal AC - Power to the control rod drive mechanisms is provided via the nonsafety DC power distribution (EDNS), so this scenario is the same as discussed above, with the addition of the CRAs dropping at the time at which power is lost. For this event, this scenario is non-limiting because of the immediate loss of power to the CRDMs, resulting in the drop of the CRAs.
- Loss of EDSS, EDNS and Loss of normal AC - Power to the MPS is provided by the highly-reliable DC power distribution system (EDSS), so this scenario results in an actuation of RTS and all of the engineered safety features. This scenario is non-limiting because of the immediate reactor trip.

15.4.2.3 Thermal Hydraulic and Subchannel Analyses

15.4.2.3.1 Evaluation Models

The thermal hydraulic analysis of the plant response to an uncontrolled CRA withdrawal is performed using NRELAP5. The NRELAP5 model is based on the design features of a NuScale module. The non-LOCA NRELAP5 model is discussed in Section 15.0.2. The relevant boundary conditions from the NRELAP5 analyses are provided to the downstream subchannel CHF analysis.

The subchannel core CHF analysis is performed using VIPRE-01. VIPRE-01 is a subchannel analysis tool designed for general-purpose thermal-hydraulic analysis under normal operating conditions, operational transients, and events of moderate severity. See Section 15.0.2 for a discussion of the VIPRE-01 code and evaluation model.

15.4.2.3.2 Input Parameters and Initial Conditions

A spectrum of initial conditions is analyzed to find the limiting reactivity insertion due to an uncontrolled CRA withdrawal. Key inputs of the uncontrolled CRA withdrawal evaluation are provided in Table 15.4-4. The following initial conditions and assumptions ensure that the results have sufficient conservatism.

RAI 15.04.02-1, RAI 15.04.02-2

- Initial power level: 25 percent, 50 percent, 75 percent, and 102 percent of nominal power are analyzed in the uncontrolled CRA withdrawal evaluation. The power level for the limiting MCHFR and RCS pressure cases is 75 percent and 102 percent of nominal power, respectively.

RAI 15.04.02-1, RAI 15.04.02-2

- Reactivity insertion rate: The positive reactivity inserted by the CRA withdrawal is modeled as a constant reactivity addition beginning at the transient initiation. The uncontrolled CRA withdrawal evaluation considers reactivity addition rates up to 21 pcm/s. This value corresponds to the maximum CRA withdrawal rate of 15 in./min.

– The reactivity insertion rate for the limiting MCHFR case is ~~1.0~~0.9 pcm/s.

– The reactivity insertion rate for the limiting RCS pressure case is 15.2 pcm/s.

- Time in cycle: The BOC core conditions are implemented in the limiting uncontrolled CRA withdrawal cases. The least negative reactivity coefficients occur at the BOC, and provide the least amount of feedback to mitigate the power increase due to an uncontrolled CRA withdrawal.
- The turbine bypass system is not credited in this analysis to minimize heat removal by the secondary side.
- Conservative scram characteristics are used, including a maximum time delay, holding the most reactive rod out of the core, and using a bounding control rod drop rate.
- Allowances for instrument inaccuracy are accounted for in the analytical limits of mitigating systems in accordance with the guidance provided in Regulatory Guide (RG) 1.105.

The results from the thermal hydraulic evaluation are used as input to the subchannel analysis to determine the MCHFR for this event. The subchannel evaluation model is discussed in Section 15.0.2.

15.4.2.3.3 Results

The sequence of events for a limiting uncontrolled CRA withdrawal with respect to MCHFR is provided in Table 15.4-3. Figure 15.4-6 through Figure 15.4-11 show the transient behavior of key parameters for an uncontrolled CRA withdrawal.

RAI 15.04.02-1, RAI 15.04.02-2

The withdrawal of the regulating bank results in a reactivity insertion that increases reactor power. The power increase leads to a rise in RCS temperature, pressurizer level, and RCS pressure. Feedback from the rising fuel and moderator temperatures partially counteracts the reactivity insertion, slowing the power increase. For uncontrolled CRA withdrawal cases with higher reactivity insertion rates, the MPS trips the reactor on high hot leg temperature or high power rate. These cases are non-limiting because the reactor is tripped before the maximum amount of reactivity can be inserted. The limiting combination of reactivity insertion and reactivity feedback produces the maximum possible power increase prior to trip. The power increase in the limiting MCHFR case is terminated by a reactor trip after a signal delay. The high hot leg temperature limit, the high pressurizer pressure limit, and high power limit are all reached during the reactor trip delay time. The MPS trips the reactor and actuates the DHRS during this event. The most limiting MCHFR occurs at the time of the power peak. The MCHFR remains above the design limit, and no fuel centerline melting is predicted for the uncontrolled CRA withdrawal.

The maximum RCS pressure case is an uncontrolled CRA withdrawal at power with a loss of normal AC power at transient initiation. The pressure for the maximum pressure case is demonstrated in Figure 15.4-12. The loss of AC power at the beginning of the transient trips the turbine and stops feedwater, reducing the heat removal by the secondary side. Simultaneously, the reactivity insertion causes a rapid rise in power. The reactor trips on high power rate, reaching the high pressurizer pressure setpoint almost simultaneously. The pressure continues to rise after the reactor trip, and peaks at the time a reactor safety valve (RSV) opens. Following the RSV opening and reactor trip, the RCS temperature and pressure steadily decrease. The maximum RCS pressure stays below the RPV design limit.

The uncontrolled CRA withdrawal at power cases that result in a reactor trip, actuate DHRS, and maintain stable core cooling.

15.4.2.4 Radiological Consequences

The normal leakage related radiological consequences of this event are bounded by the design basis accident analyses presented in Section 15.0.3.

15.4.2.5 Conclusions

The two applicable acceptance criteria for this AOO are met for the limiting uncontrolled CRA withdrawal cases. These acceptance criteria, followed by how the NuScale Power Plant design meets them are listed below.

1) The thermal margin limits departure from nucleate boiling ratio for pressurized water reactors as specified in SRP Section 4.4, subsection II.1, are met.

    - The MCHFR for the limiting uncontrolled CRA withdrawal is 1.316, which is above the design limit. Therefore, this criterion is met.

2) Fuel centerline temperatures as specified in SRP Section 4.2, subsection II.A.2(a) and (b), do not exceed the melting point.

    - As discussed in Reference 15.4-1, a steady-state linear heat generation rate (LHGR) protection limit can be applied to an uncontrolled CRA withdrawal at power event to ensure that the fuel centerline temperatures do not exceed the melting point. The LHGR for the limiting CRA withdrawal is 8.44, which is below the limit.

RAI 15.04.02-1, RAI 15.04.02-2

The evaluation of an uncontrolled CRA withdrawal ~~from a subcritical or low power startup condition~~at power demonstrates that the RCS pressure does not exceed the RPV design limit. The limiting peak RCS pressure for this event is 2160 psia.

RAI 15.04.02-1, RAI 15.04.02-2

Table 15.4-3: Sequence of Events (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)

Event	Time [s]
CRA bank begins to withdraw	0
High hot leg temperature limit reached	~~72~~178
High ~~reactor power~~pressurizer pressure limit reached	~~78~~184
High ~~pressurizer pressure~~reactor power limit reached	~~78~~186
Reactor trip actuated	~~80~~186
Maximum RCS pressure occurs	~~89~~191
DHRS valves fully open	~~110~~217

RAI 15.04.02-1, RAI 15.04.02-2

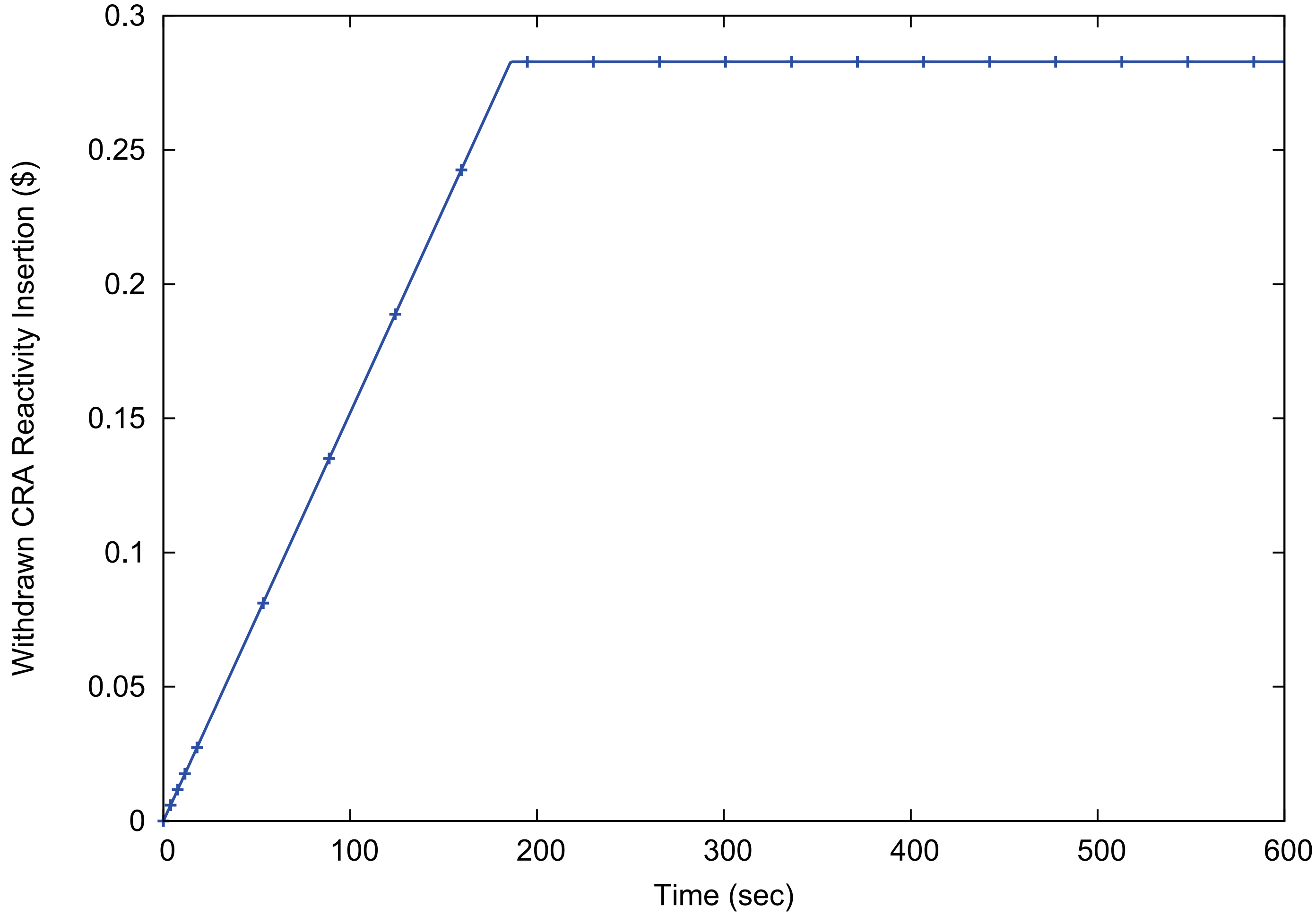
Table 15.4-4: Key Inputs for Limiting MCHFR Case (15.4.2 Uncontrolled CRA Withdrawal at Power)

Parameter	Nominal	Bias
Initial power	160 MW	~~+2~~Analyzed 75%
RCS Flowrate	See Table 15.0-6 for range	~~1178.2~~1056.7 lbm/s (low[1])
RCS Pressure	1850 psia	~~Nominal~~-70 psia
Pressurizer Level	60%	~~Nominal~~-8%
MTC	0.0 pcm/°F	Most positive
FTC	-1.40 pcm/°F	Least negative

[1] RCS flow rate is near the minimum for 75% power.

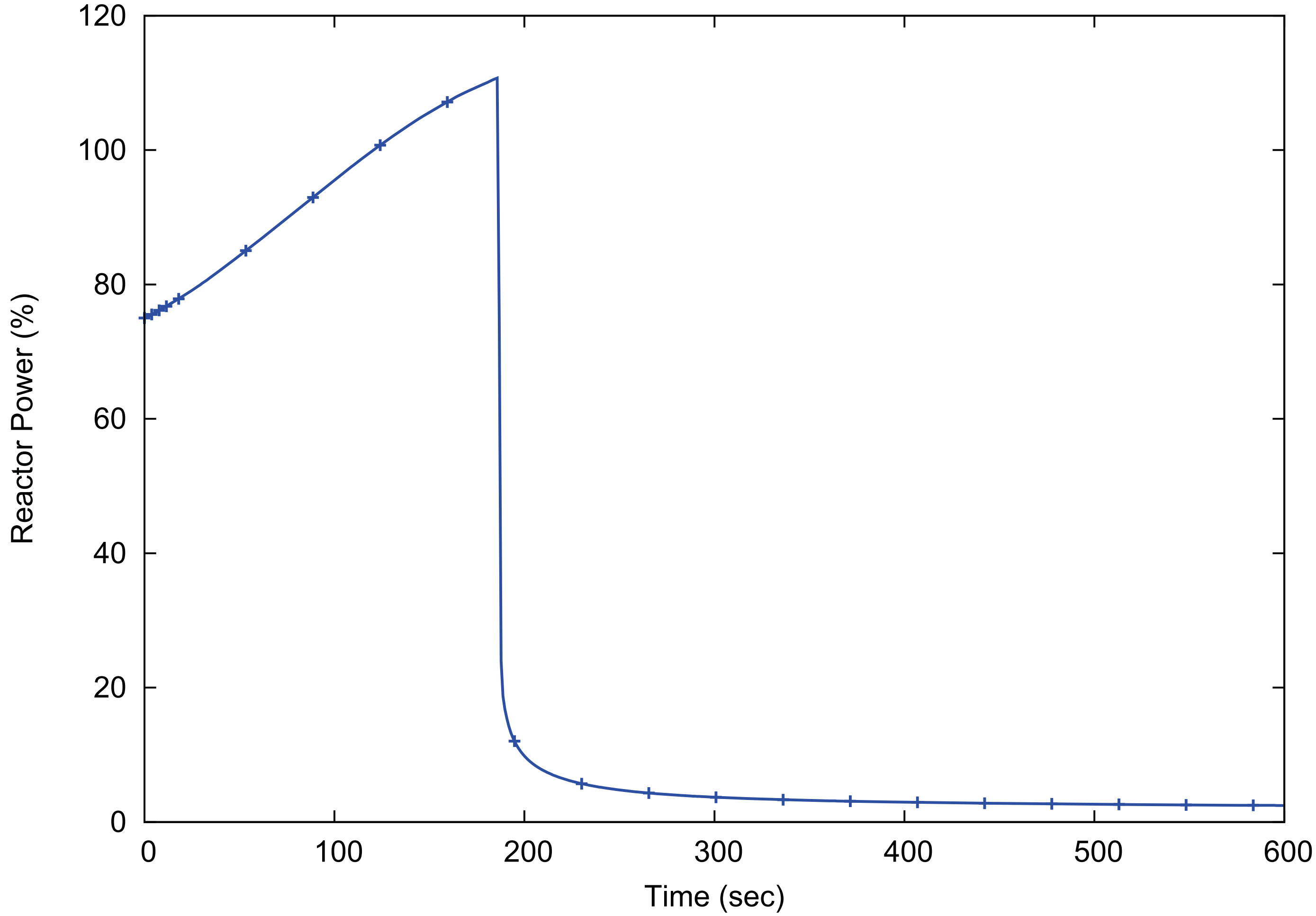
RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-6: Withdrawn CRA Reactivity Insertion
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



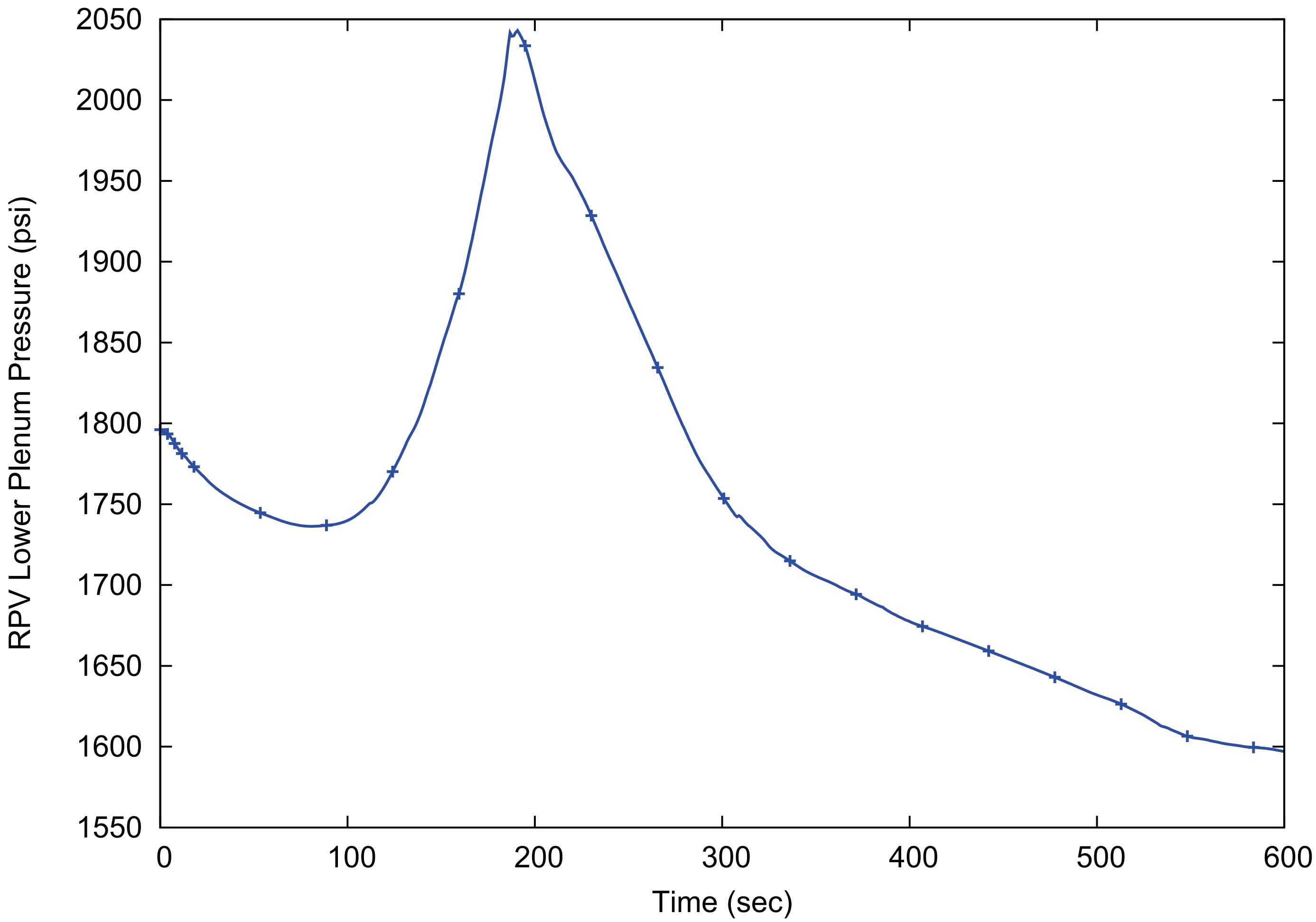
RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-7: Reactor Power
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



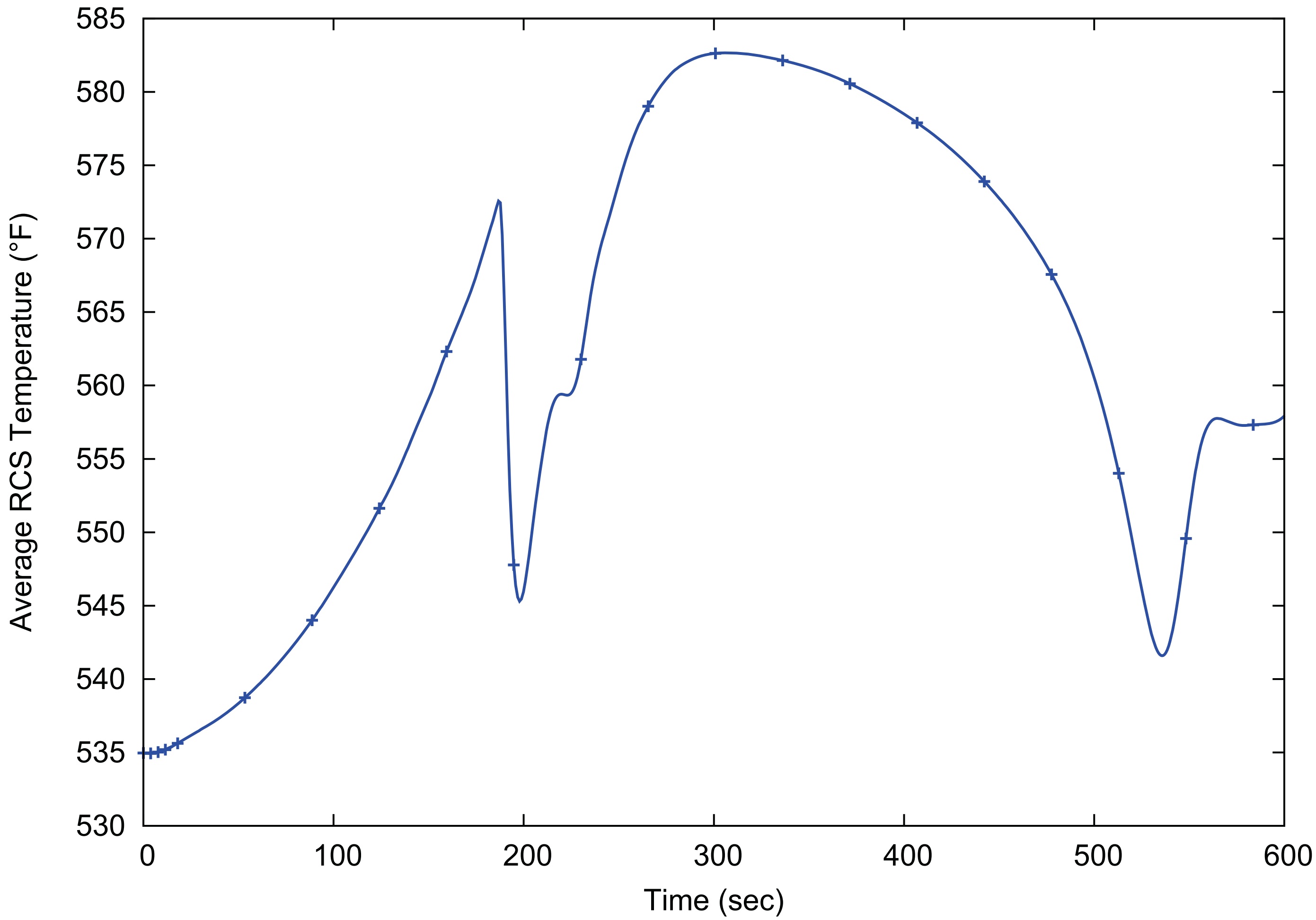
RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-8: RCS Pressure for Limiting MCHFR Case
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



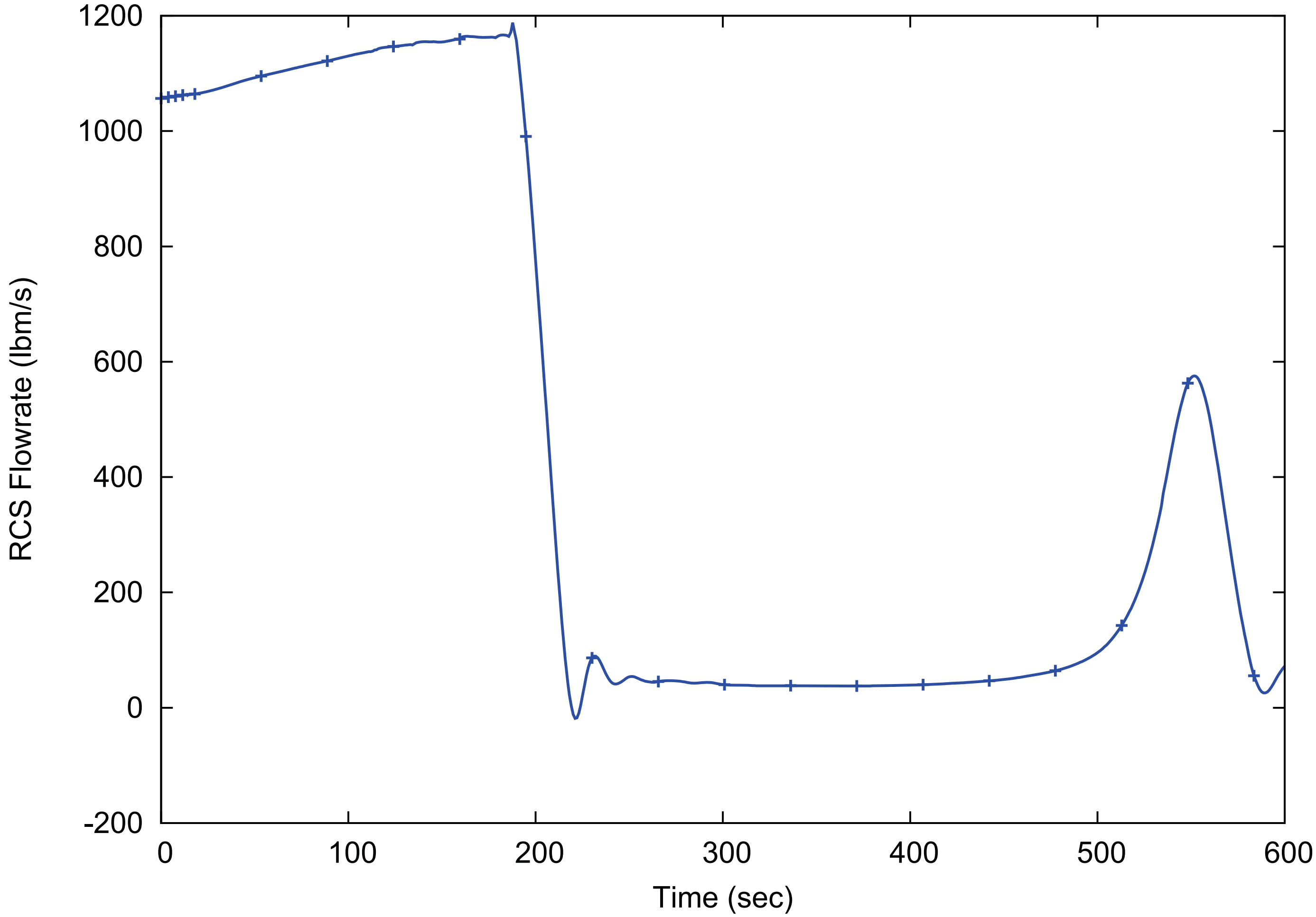
RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-9: Average RCS Temperature
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



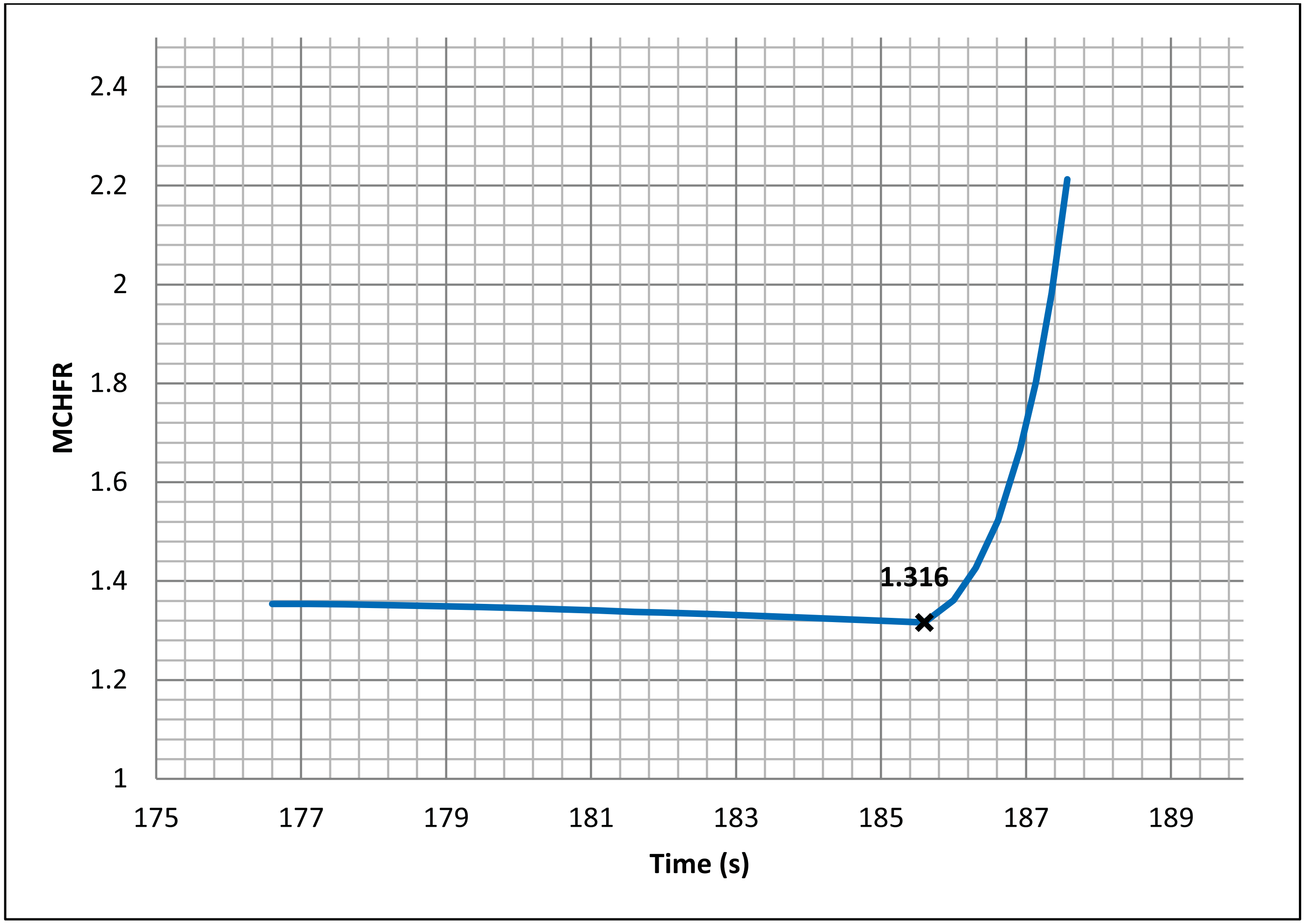
RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-10: RCS Flow
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



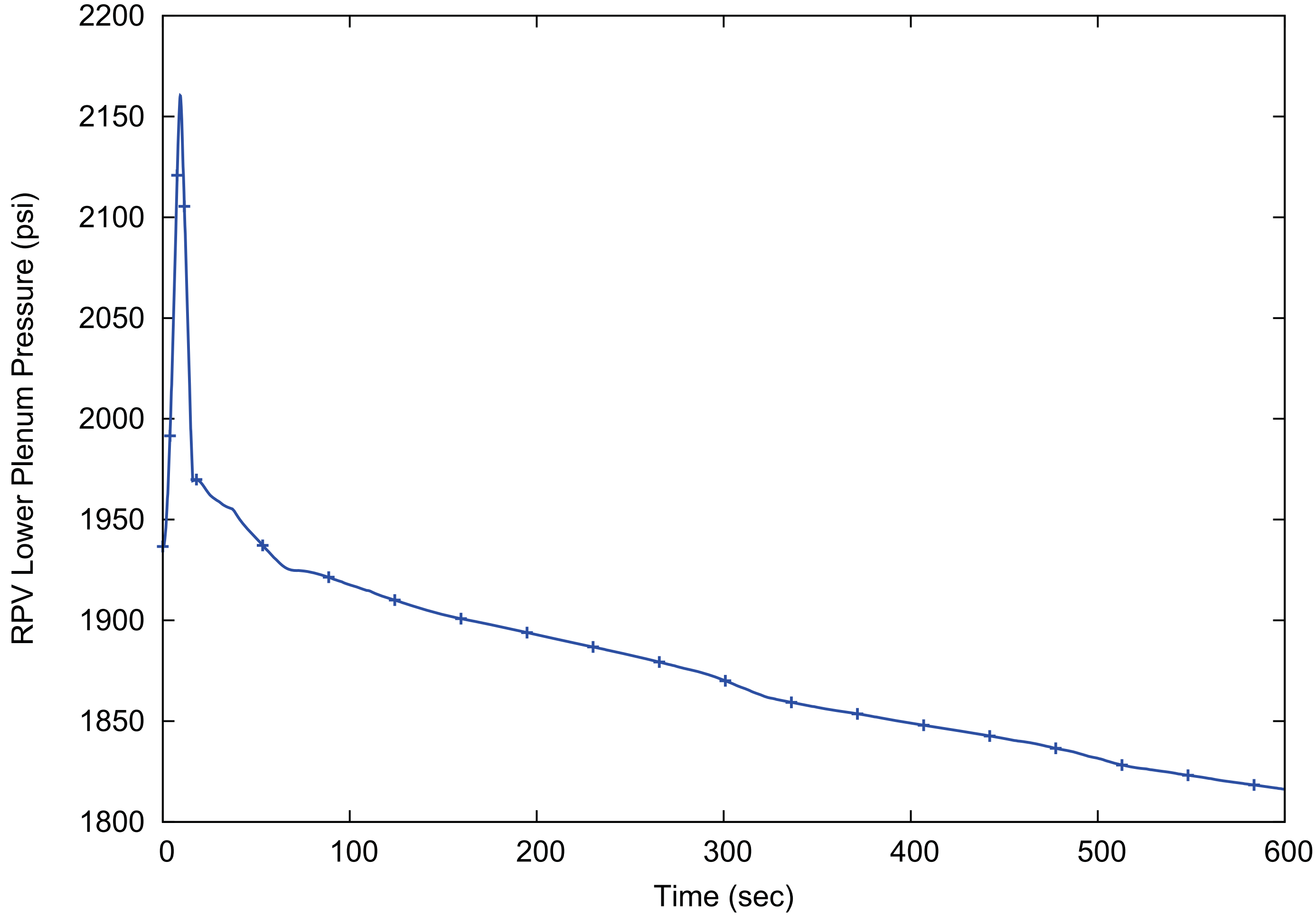
RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-11: ~~CHFR~~Critical Heat Flux Ratio
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-12: RCS Pressure for Maximum Pressure Case
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 8764 - RAI 15.04.02-2

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

eRAI No.: 8764
Date of RAI Issue: 04/25/2017

NRC Question No.: 15.04.02-2

SRP Section 15.4.2 provides guidance for complying with 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," GDC 10, 13, 17, 20, and 25. Per SRP Section 15.4.2, the significant results of the analysis should be presented and should include reactor pressure. The NRC staff needs to review the results of the analysis and compare them to the acceptance criteria for anticipated operational occurrences.

FSAR Tier 2, Figure 15.4-12, "RCS Pressure for Maximum Pressure Case (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)," shows a peak RCS pressure of about 2040 psia, whereas FSAR Tier 2, Section 15.4.2, states that the limiting peak RCS pressure for this event is 2160 psia. Because these pressures are not consistent, the NRC staff is unable to ascertain the limiting RCS pressure for the event. To enable the NRC staff to compare the results of the transient against acceptance criteria and thereby provide reasonable assurance that the relevant GDC is met, please clarify what the correct peak RCS pressure is, and update the FSAR to correct any erroneous information.

NuScale Response:

As stated in the response to RAI 15.04.02-1, FSAR Figure 15.4-12 has been revised to show the RCS pressure from the RCS pressure limiting case.

Impact on DCA:

FSAR Sections 15.4.2.2, 15.4.2.3, 15.4.2.5, FSAR Tables 15.4-3 and 15.4-4, and FSAR Figures 15.4-6, 15.4-7, 15.4-8, 15.4-9, 15.4-10, 15.4-11, and 15.4-12 have been revised as described in the response above and as shown in the markups provided in this response.

15.4.1.5 Conclusions

The two applicable acceptance criteria for this AOO are met for the limiting cases. These acceptance criteria, followed by how the NuScale design meets them are listed below:

- The thermal margin limits departure from nucleate boiling ratio for PWRs as specified in SRP Section 4.4, subsection II.1, are met.
  - The MCHFR for the limiting case is 8.657, which is above the design limit.
- Fuel centerline temperatures as specified in SRP Section 4.2, subsection II.A.2(a) and (b), do not exceed the melting point.
  - The fuel centerline temperature of the limiting case is 890.8°F, which is below the fuel melting temperature.

RAI 15.04.01-1, RAI 15.04.01-2

The evaluation of an uncontrolled CRA withdrawal from a subcritical or low power startup condition demonstrates that the RCS pressure does not exceed the RPV design limit. The limiting peak RCS pressure for this event is 2038 psia, as shown in Figure 15.4-34.

15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power

15.4.2.1 Identification of Causes and Accident Description

A spurious CRA withdrawal that occurs when the reactor is at power leads to an unexpected addition of positive reactivity into the reactor. An uncontrolled CRA withdrawal at power results in an increase in core power with a corresponding increase in heat flux. Due to the time lag in the response of the secondary system, the heat removal from the steam generators follows the heat increase in the primary system. The result is an increase in RCS temperature and pressure. These conditions could challenge design pressures and the SAFDLs. The power range neutron excore detectors provide high power and high flux rate core protection. For cases where the reactivity insertion is sufficiently slow, the high pressurizer pressure and high hot leg temperature limits provide protection. These MPS limits are analyzed for a spectrum of uncontrolled CRA withdrawal conditions to ensure that protection functions are actuated to prevent the violation of the design safety limits.

An uncontrolled CRA withdrawal is expected to occur one or more times in the life of the reactor, and it is classified as an AOO. The categorization of the NuScale design basis events are provided in Table 15.0-1.

15.4.2.2 Sequence of Events and Systems Operation

RAI 15.04.02-1, RAI 15.04.02-2

The sequence of events for a representative uncontrolled CRA withdrawal at power is provided in ~~Table 15.4-2~~Table 15.4-3.

- Loss of Normal AC - In this scenario, the MPS remains powered, so none of the safety systems are automatically actuated. However, power is lost to the feedwater pumps, CVCS recirculation pumps, pressurizer heaters, and the condenser, resulting in a turbine trip.
  - Loss of normal AC at the time of the event initiation is analyzed in NRELAP5.
  - Loss of normal AC at the time of reactor trip is analyzed in NRELAP5.
- Loss of EDNS and Loss of normal AC - Power to the control rod drive mechanisms is provided via the nonsafety DC power distribution (EDNS), so this scenario is the same as discussed above, with the addition of the CRAs dropping at the time at which power is lost. For this event, this scenario is non-limiting because of the immediate loss of power to the CRDMs, resulting in the drop of the CRAs.
- Loss of EDSS, EDNS and Loss of normal AC - Power to the MPS is provided by the highly-reliable DC power distribution system (EDSS), so this scenario results in an actuation of RTS and all of the engineered safety features. This scenario is non-limiting because of the immediate reactor trip.

15.4.2.3 Thermal Hydraulic and Subchannel Analyses

15.4.2.3.1 Evaluation Models

The thermal hydraulic analysis of the plant response to an uncontrolled CRA withdrawal is performed using NRELAP5. The NRELAP5 model is based on the design features of a NuScale module. The non-LOCA NRELAP5 model is discussed in Section 15.0.2. The relevant boundary conditions from the NRELAP5 analyses are provided to the downstream subchannel CHF analysis.

The subchannel core CHF analysis is performed using VIPRE-01. VIPRE-01 is a subchannel analysis tool designed for general-purpose thermal-hydraulic analysis under normal operating conditions, operational transients, and events of moderate severity. See Section 15.0.2 for a discussion of the VIPRE-01 code and evaluation model.

15.4.2.3.2 Input Parameters and Initial Conditions

A spectrum of initial conditions is analyzed to find the limiting reactivity insertion due to an uncontrolled CRA withdrawal. Key inputs of the uncontrolled CRA withdrawal evaluation are provided in Table 15.4-4. The following initial conditions and assumptions ensure that the results have sufficient conservatism.

RAI 15.04.02-1, RAI 15.04.02-2

- Initial power level: 25 percent, 50 percent, 75 percent, and 102 percent of nominal power are analyzed in the uncontrolled CRA withdrawal evaluation. The power level for the limiting MCHFR and RCS pressure cases is 75 percent and 102 percent of nominal power, respectively.

RAI 15.04.02-1, RAI 15.04.02-2

- Reactivity insertion rate: The positive reactivity inserted by the CRA withdrawal is modeled as a constant reactivity addition beginning at the transient initiation. The uncontrolled CRA withdrawal evaluation considers reactivity addition rates up to 21 pcm/s. This value corresponds to the maximum CRA withdrawal rate of 15 in./min.

  – The reactivity insertion rate for the limiting MCHFR case is 1.00.9 pcm/s.

  – The reactivity insertion rate for the limiting RCS pressure case is 15.2 pcm/s.

- Time in cycle: The BOC core conditions are implemented in the limiting uncontrolled CRA withdrawal cases. The least negative reactivity coefficients occur at the BOC, and provide the least amount of feedback to mitigate the power increase due to an uncontrolled CRA withdrawal.
- The turbine bypass system is not credited in this analysis to minimize heat removal by the secondary side.
- Conservative scram characteristics are used, including a maximum time delay, holding the most reactive rod out of the core, and using a bounding control rod drop rate.
- Allowances for instrument inaccuracy are accounted for in the analytical limits of mitigating systems in accordance with the guidance provided in Regulatory Guide (RG) 1.105.

The results from the thermal hydraulic evaluation are used as input to the subchannel analysis to determine the MCHFR for this event. The subchannel evaluation model is discussed in Section 15.0.2.

15.4.2.3.3 Results

The sequence of events for a limiting uncontrolled CRA withdrawal with respect to MCHFR is provided in Table 15.4-3. Figure 15.4-6 through Figure 15.4-11 show the transient behavior of key parameters for an uncontrolled CRA withdrawal.

RAI 15.04.02-1, RAI 15.04.02-2

The withdrawal of the regulating bank results in a reactivity insertion that increases reactor power. The power increase leads to a rise in RCS temperature, pressurizer level, and RCS pressure. Feedback from the rising fuel and moderator temperatures partially counteracts the reactivity insertion, slowing the power increase. For uncontrolled CRA withdrawal cases with higher reactivity insertion rates, the MPS trips the reactor on high hot leg temperature or high power rate. These cases are non-limiting because the reactor is tripped before the maximum amount of reactivity can be inserted. The limiting combination of reactivity insertion and reactivity feedback produces the maximum possible power increase prior to trip. The power increase in the limiting MCHFR case is terminated by a reactor trip after a signal delay. The high hot leg temperature limit, the high pressurizer pressure limit, and high power limit are all reached during the reactor trip delay time. The MPS trips the reactor and actuates the DHRS during this event. The most limiting MCHFR occurs at the time of the power peak. The MCHFR remains above the design limit, and no fuel centerline melting is predicted for the uncontrolled CRA withdrawal.

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The uncontrolled CRA withdrawal at power cases that result in a reactor trip, actuate DHRS, and maintain stable core cooling.

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The normal leakage related radiological consequences of this event are bounded by the design basis accident analyses presented in Section 15.0.3.

15.4.2.5 Conclusions

The two applicable acceptance criteria for this AOO are met for the limiting uncontrolled CRA withdrawal cases. These acceptance criteria, followed by how the NuScale Power Plant design meets them are listed below.

1) The thermal margin limits departure from nucleate boiling ratio for pressurized water reactors as specified in SRP Section 4.4, subsection II.1, are met.

    - The MCHFR for the limiting uncontrolled CRA withdrawal is 1.316, which is above the design limit. Therefore, this criterion is met.

2) Fuel centerline temperatures as specified in SRP Section 4.2, subsection II.A.2(a) and (b), do not exceed the melting point.

    - As discussed in Reference 15.4-1, a steady-state linear heat generation rate (LHGR) protection limit can be applied to an uncontrolled CRA withdrawal at power event to ensure that the fuel centerline temperatures do not exceed the melting point. The LHGR for the limiting CRA withdrawal is 8.44, which is below the limit.

RAI 15.04.02-1, RAI 15.04.02-2

The evaluation of an uncontrolled CRA withdrawal ~~from a subcritical or low power startup condition~~at power demonstrates that the RCS pressure does not exceed the RPV design limit. The limiting peak RCS pressure for this event is 2160 psia.

RAI 15.04.02-1, RAI 15.04.02-2

Table 15.4-3: Sequence of Events (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)

Event	Time [s]
CRA bank begins to withdraw	0
High hot leg temperature limit reached	~~72~~178
High ~~reactor power~~pressurizer pressure limit reached	~~78~~184
High ~~pressurizer pressure~~reactor power limit reached	~~78~~186
Reactor trip actuated	~~80~~186
Maximum RCS pressure occurs	~~89~~191
DHRS valves fully open	~~110~~217

RAI 15.04.02-1, RAI 15.04.02-2

Table 15.4-4: Key Inputs for Limiting MCHFR Case (15.4.2 Uncontrolled CRA Withdrawal at Power)

Parameter	Nominal	Bias
Initial power	160 MW	~~+2~~Analyzed 75%
RCS Flowrate	See Table 15.0-6 for range	~~1178.2~~1056.7 lbm/s (low[1])
RCS Pressure	1850 psia	~~Nominal~~ -70 psia
Pressurizer Level	60%	~~Nominal~~ -8%
MTC	0.0 pcm/°F	Most positive
FTC	-1.40 pcm/°F	Least negative

[1] RCS flow rate is near the minimum for 75% power.

RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-6: Withdrawn CRA Reactivity Insertion
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)

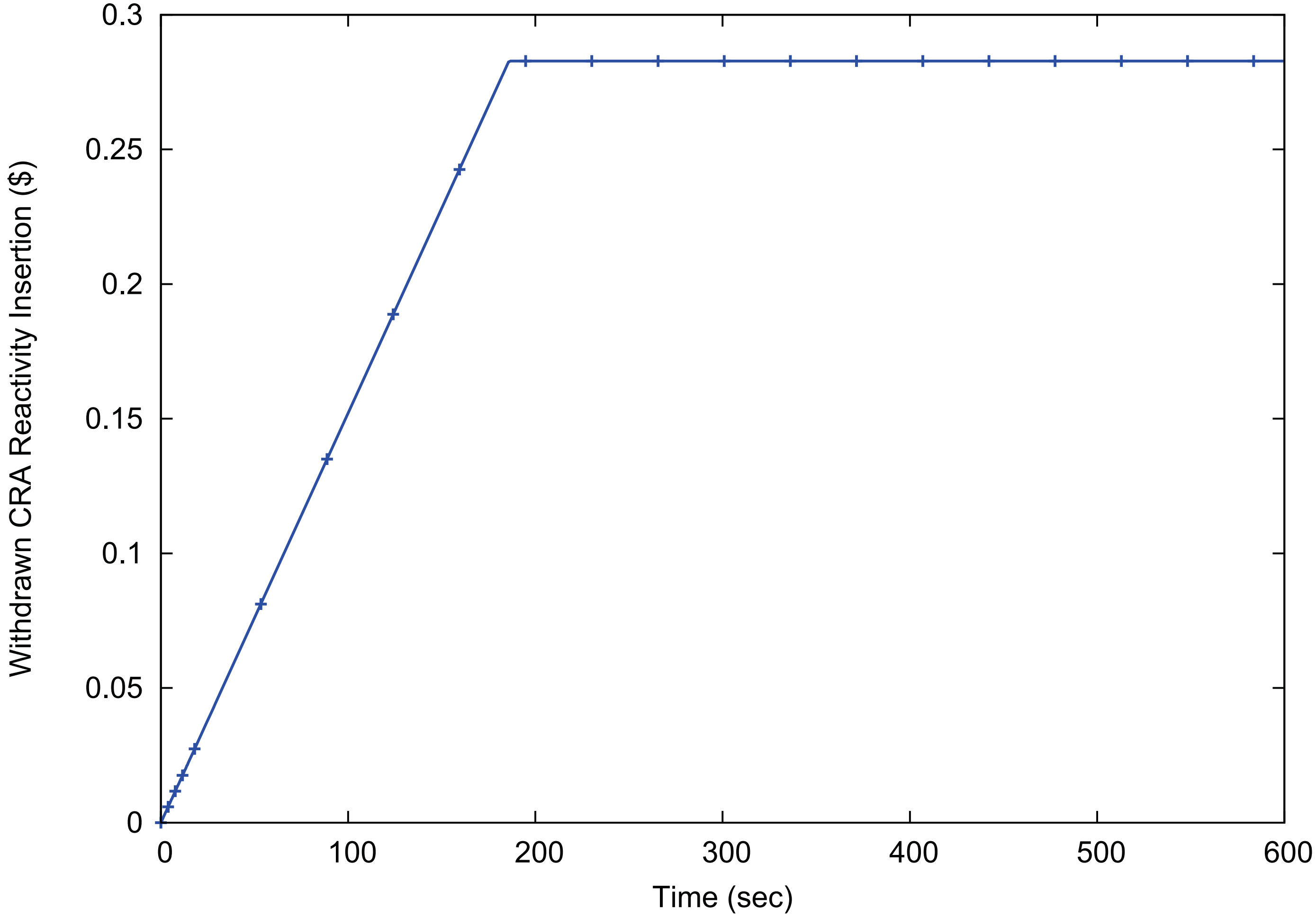
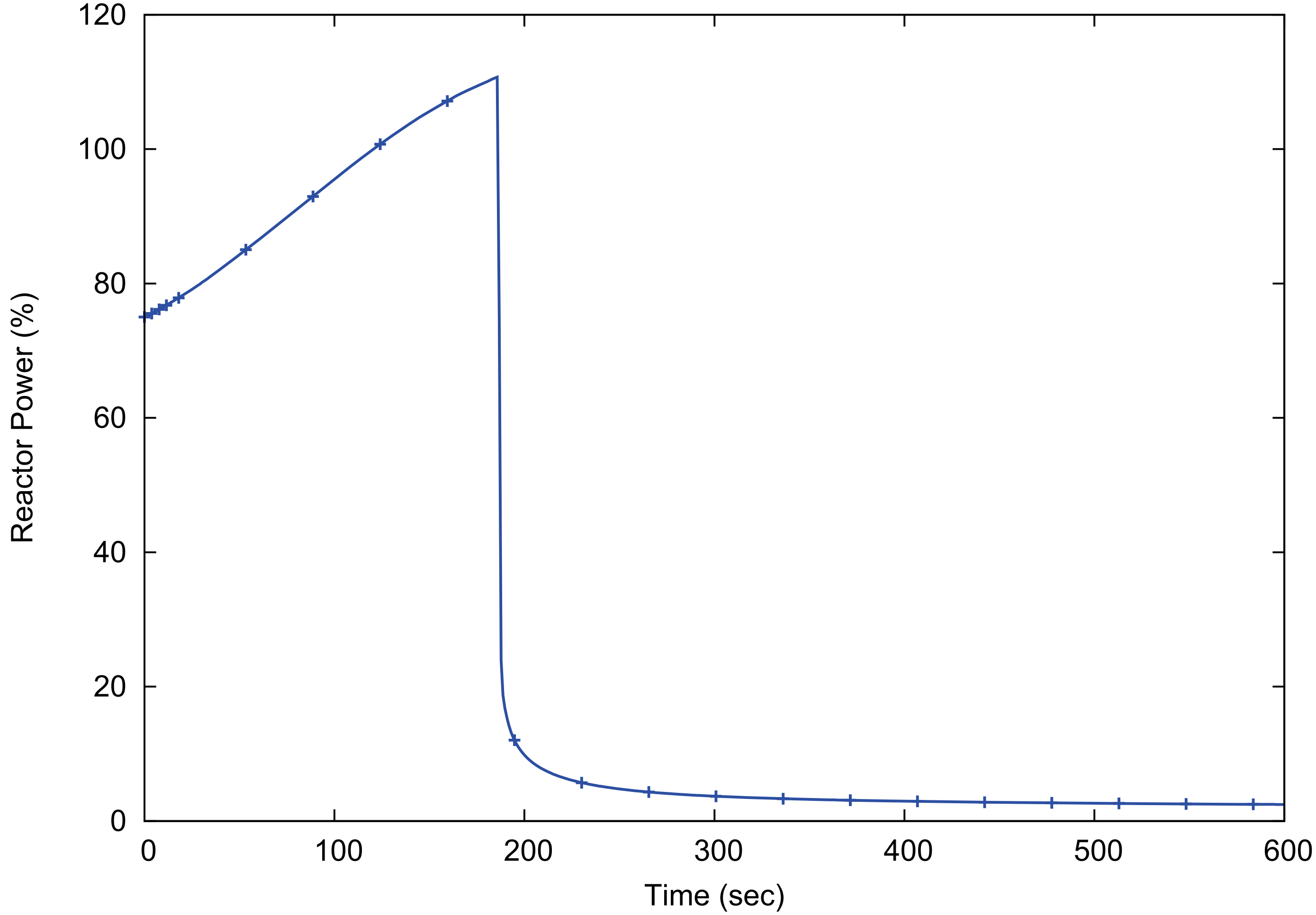
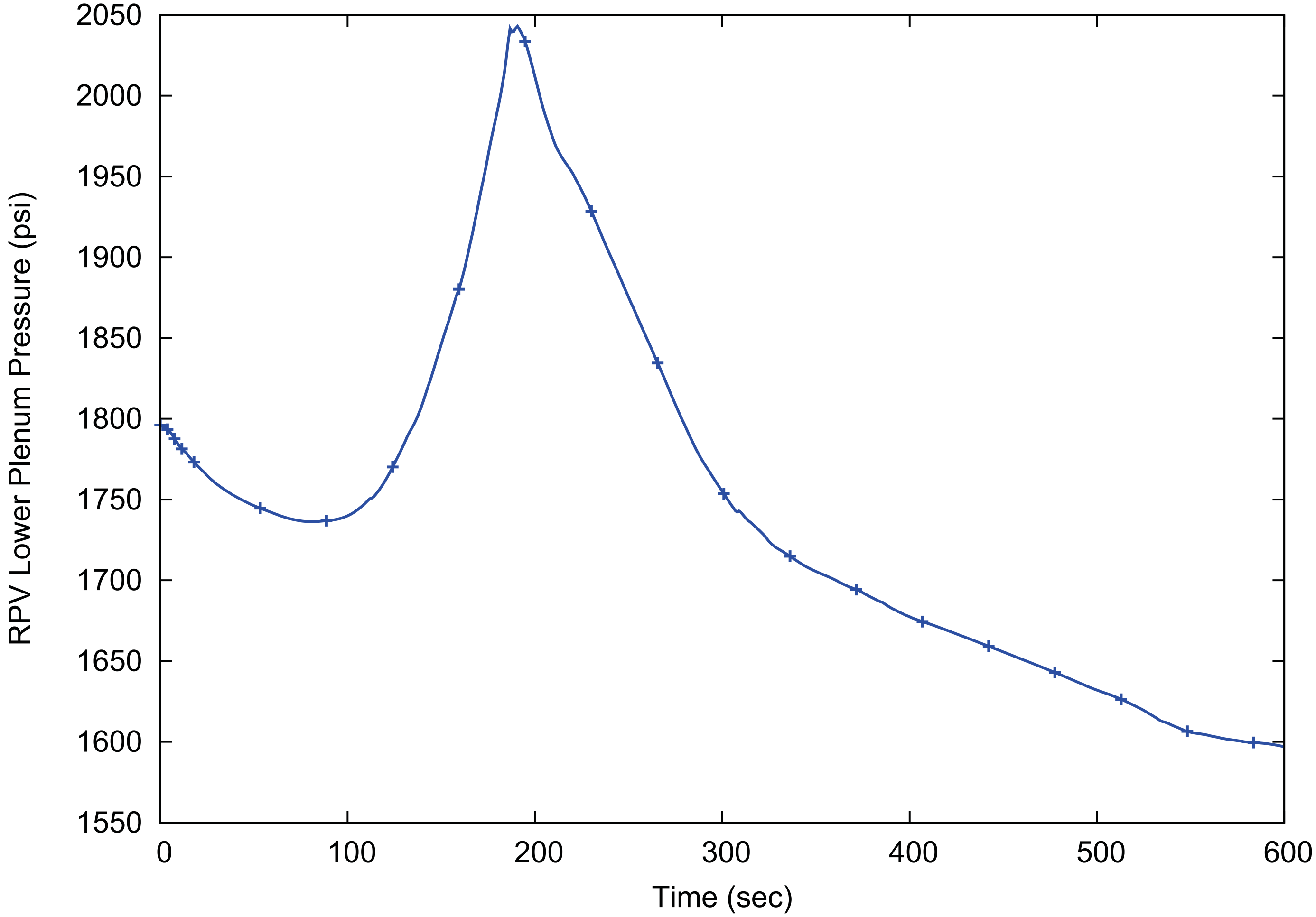


Figure 15.4-7: Reactor Power
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



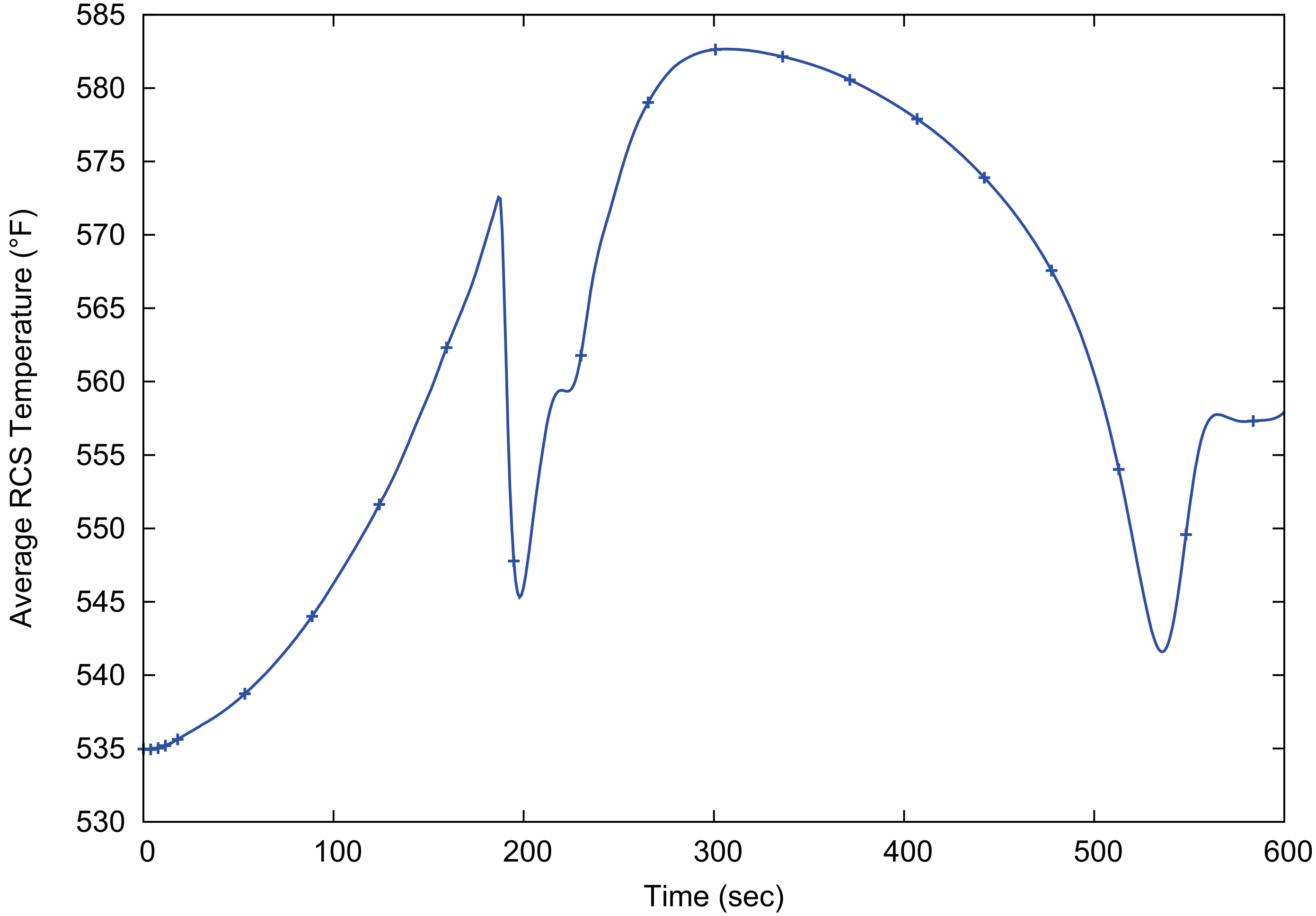
RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-8: RCS Pressure for Limiting MCHFR Case
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



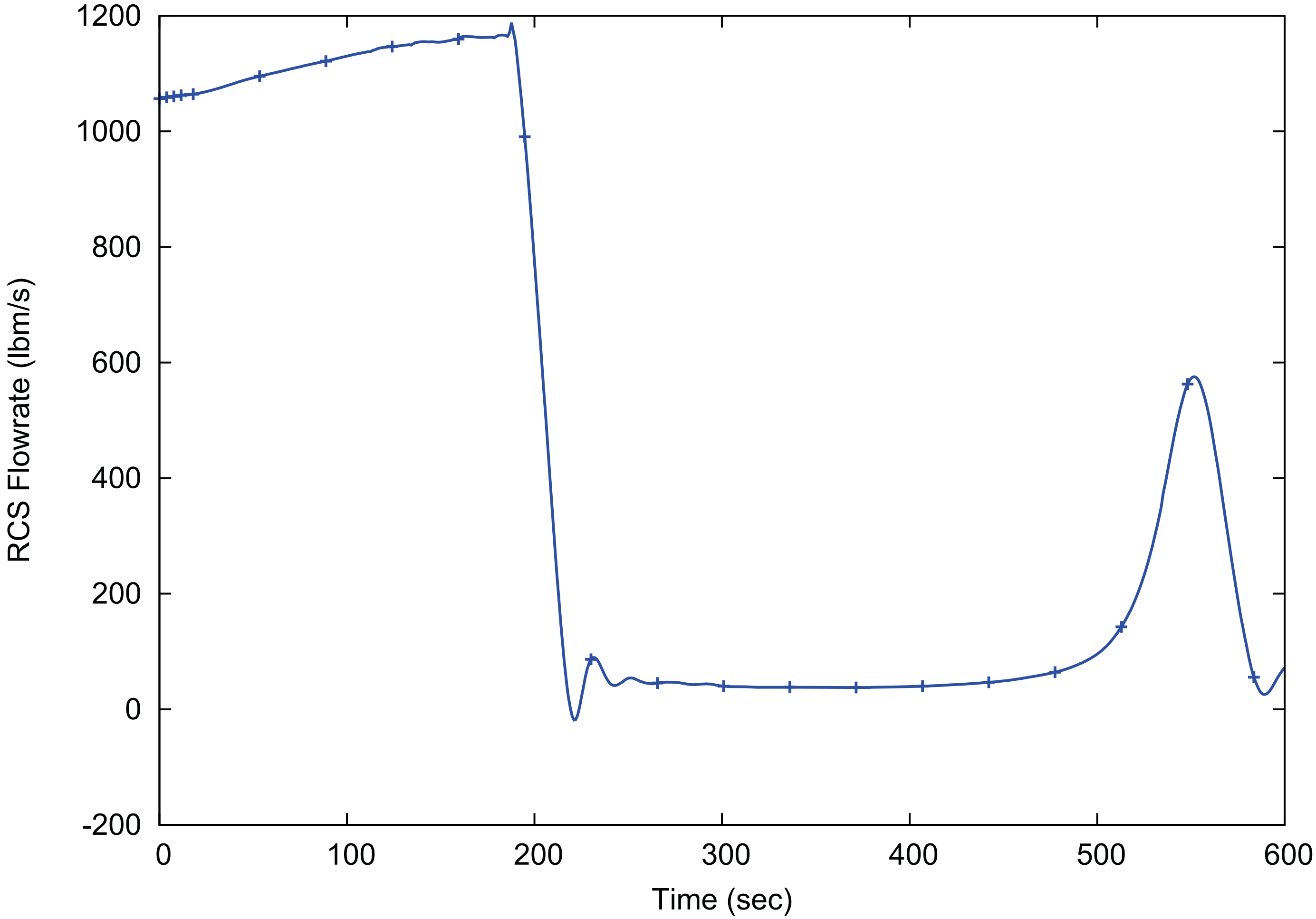
RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-9: Average RCS Temperature
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



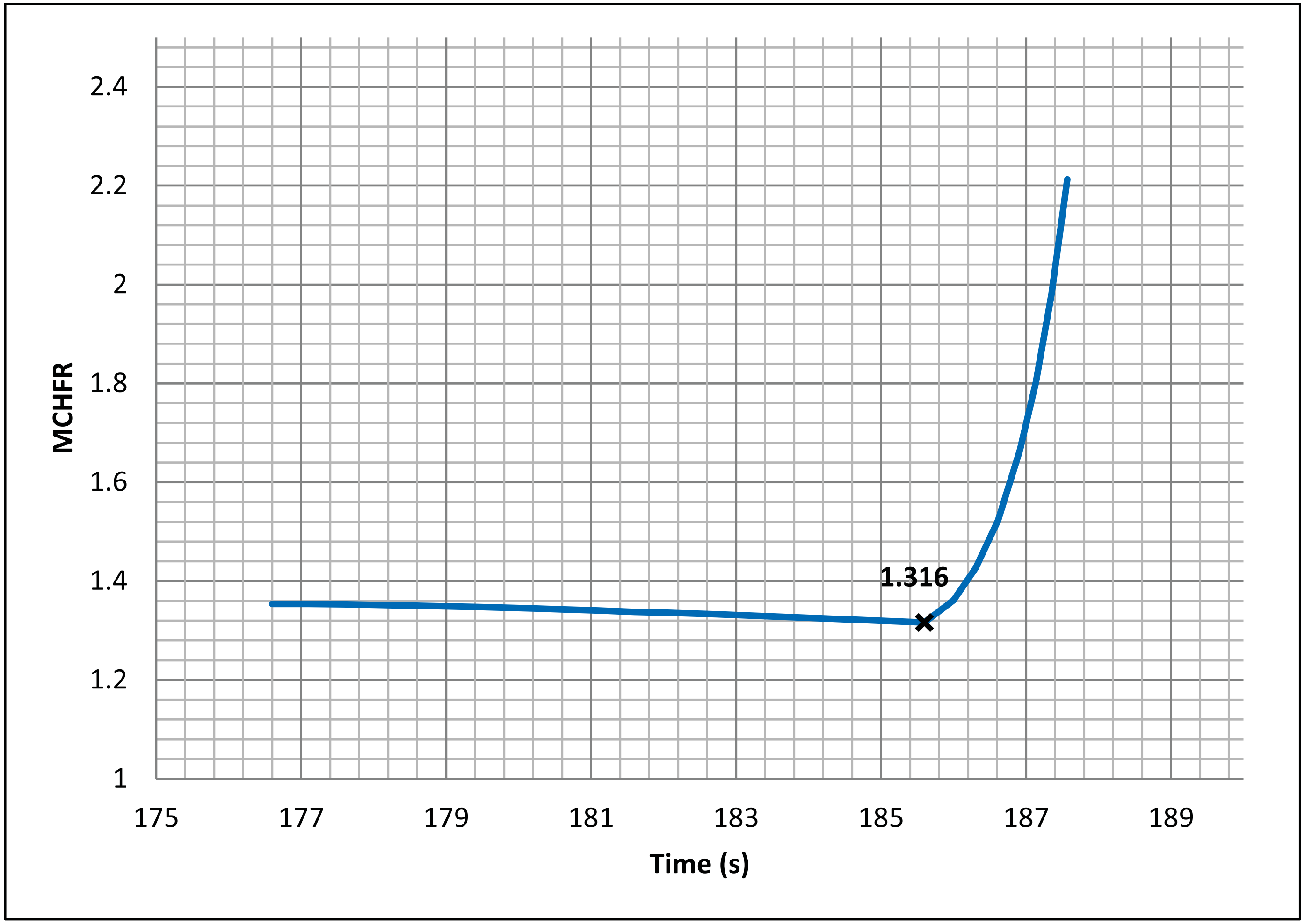
RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-10: RCS Flow
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-11: ~~CHFR~~Critical Heat Flux Ratio
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)



RAI 15.04.02-1, RAI 15.04.02-2

Figure 15.4-12: RCS Pressure for Maximum Pressure Case
(15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)