RAIO-0917-55808

September 06, 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 No. 206 (eRAI No. 9057) on the NuScale Design Certification Application

REFERENCE: U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 206 (eRAI No. 9057)," dated September 01, 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 Enclosure to this letter contains NuScale's response to the following RAI Question from NRC eRAI No. 9057:

- 04.05.01-1

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 Darrell Gardner at 980-349-4829 or at dgardner@nuscalepower.com.

Sincerely,

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

Distribution: Gregory Cranston, NRC, OWFN-8G9A
Samuel Lee, NRC, OWFN-8G9A
Bruce Bavol, NRC, OWFN-8G9A

Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9057

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NuScale Response to NRC Request for Additional Information eRAI No. 9057

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

eRAI No.: 9057
Date of RAI Issue: 09/01/2017

NRC Question No.: 04.05.01-1

Title 10 of the Code of Federal Regulations (10 CFR) Part 50, Appendix A, General Design Criterion (GDC) 14 states that, "[t]he reactor coolant pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, or of gross rupture." 10 CFR Part 50, Appendix A, GDC 26 states that, "[t]wo independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded."

In order for the staff to determine whether the NuScale design meets these criteria with regard to pressure-retaining and internal components of its control rod drive (CRD) system, the staff is requesting the following information.

NuScale FSAR Section 4.5.1.3 and your supplemental letter dated June 12, 2017, specifies the use of nickel-chromium based alloy X-750 for the CRD springs with a heat treatment that conforms to the requirements of Aerospace Material Specification (AMS) 5698 or AMS 5699. Operating experience as detailed in Information Notice (IN) No. 82-29, "Control Rod (CRD) Guide Tube Support Pin Failures at Westinghouse PWRs," and B&W Technical Services Group Technical Report S-1473-002, dated December 2013 (ADAMS Accession No. ML15335A285) has shown that some of the heat treatment ranges in the material specifications are susceptible to stress corrosion cracking. IN No. 82-29 specifies that a heat treatment at 2000°F minimum for 1 hour and age hardened at 1300°F minimum for 20 hours minimizes stress corrosion cracking. Therefore, the staff requests that FSAR Section 4.5.1.3 be revised to include the heat treatment (including temperature and time) of this precipitation hardenable alloy based on industry experience to ensure that the material properties of the component are such that it is capable of maintaining its structural integrity and performing its intended function.

NuScale Response:

The Alloy X-750 (UNS N07750) springs in NuScale control rod drive mechanisms (CRDMs) are helical coil type, and are fabricated from Alloy X-750 wire per Aerospace Material Specification (AMS) 5698 and 5699 (Reference 1 and Reference 2). These springs are internal to the CRDM pressure housing and have no pressure-retaining function. Table 1 summarizes the heat treatment conditions allowed by AMS 5698 and 5699. Both AMS specifications require the Alloy X-750 wire to be cold drawn from hot finished wire or rod whose surface must have been prepared for drawing. After cold drawing, all traces of lubricant must be removed.

The RAI cited stress-corrosion cracking (SCC) failures in Alloy X-750 CRD guide tube support pins (Reference 3) and Alloy X-750 clevis bolts (Reference 4) inside Westinghouse-type Pressurized Water Reactors (PWRs). These failed parts were not part of a CRDM. These failures were due to a combination of high tensile stress and a susceptible heat treatment condition (AH), which had a low solution temperature (1800°F) before precipitation heat treatment. Replacement pins and bolts have used improved Alloy X-750 heat treatments conditions (such as HTH) characterized by a higher solution temperature (2000°F). In addition to improved heat treatment, replacement design and manufacturing has also reduced peak tensile stress. Improved SCC performance of replacement Alloy X-750 bolting is due to a combination of improved heat treatment and reduced peak stress.

CRDMs are active components that require springs. Several CRDM designs have used Alloy X-750 coil springs fabricated from cold-drawn wire (AMS 5698 and 5699) whose heat treatments are not identical to those for bars used for bolting. Both AMS 5698 and 5699 require solution treatment at 2000 to 2200°F prior to cold drawing and precipitation heat treatment. The higher solution temperature affords a higher SCC resistance than the failed Alloy X-750 bolting in AH condition. The tensile stresses of the failed Alloy X-750 bolting were near or above room temperature yield strength. In contrast, CRDM coil springs are not designed to be stressed beyond elastic limit or creep limit in order to maintain spring functionality.

Alloy X-750 coil springs fabricated from AMS 5698 or 5699 have been used by CRDMs designed by Westinghouse, Combustion-Engineering, and Babcock & Wilcox. To date, no SCC failures have been noted in these springs. The excellent operating experience of Alloy X-750 CRDM coil springs is in contrast to the cited Alloy X-750 bolting SCC. As a result, CRDM springs for advanced PWR designs continue to use AMS 5698 and 5699. Examples besides NuScale are listed below:

• Chapter 4.5.1.3 of AP600 DCD and AP1000 (Reference 5 and Reference 6) states:

"*The springs in the control rod drive mechanism are made from nickel-chromium-iron alloy (Alloy 750), ordered to Aerospace Material Specification (AMS) 5698 or AMS 5699 with* *additional restrictions on prohibited materials. Operating experience has shown that springs made of this material are not subject to stress-corrosion cracking in pressurized water reactor primary water environments."*

• Chapter 4.5.1.3 of APR1400 DCD (Reference 7) states:

"*Springs are made of Alloy X-750. They conform with AMS 5698 or 5699 and are drawn from hot-finished wire or rod that has been previously ground or has had surface preparation to remove scale, seams, or other injurious surface imperfections. The wire is heat treated at about 1,149 °C (2,100 °F) before being reduced to size. The springs fabricated from these materials have no failure experience in Korea."*

The NuScale CRDM design is similar to the design for Westinghouse-type PWRs. According to NuScale CRDM designer, no SCC failures have been noted during operation for such springs which is consistent with statements in AP600 and AP1000 DCD Chapter 4.5. Considering the CRDM operating experience, the SCC failures cited by the RAI are not indicative of SCC susceptibility of Alloy X-750 CRDM springs. NuScale's choice of AMS 5698 and 5699 is consistent with other advanced PWRs. Therefore, there is no technical reason to restrict or modify AMS 5698 and 5699 heat treatments for CRDM springs to avoid SCC.

NuScale has inserted a sentence in FSAR Section 4.5.1.3 to support the choice of AMS 5698 and 5699. This sentence will state that operating experience has indicated no reports of stress-corrosion cracking of Alloy X-750 CRDM springs fabricated from AMS 5698 and AMS 5699.

Table 1. Heat Treatment of AMS 5698 and AMS 5699 (UNS N07750)

Condition	Heat Treatment
AMS 5698G, No. 1 Temper	• Solution treatment at 2000 - 2200°F before being cold drawn to size • Precipitation treatment at 1350°F for 16 hours, air cool
AMS 5699G, Spring Temper	Direct precipitation treatment • Solution treatment at 2000 - 2200°F before being cold drawn to size • Precipitation treatment at 1200°F for 4 hours, air cool
	• Solution anneal + precipitation treatment • Solution treatment at 2000 - 2200°F before being cold drawn to size • Solution anneal at 2100°F for 2 hours, air cool • Precipitation treatment at 1550°F for 24 hours, air cool, reheat to 1300°F for 20 hours, air cool

References:

1. SAE International, AMS 5698, Rev G, "Nickel Alloy, Corrosion and Heat-Resistant, Wire 72Ni - 15.5Cr - 0.95Cb - 2.5Ti - 0.70Al - 7.0Fe No. 1 Temper, Precipitation Hardenable".

2. SAE International, AMS 5699, Rev G, “Nickel Alloy, Corrosion and Heat-Resistant, Wire 72Ni - 15.5Cr - 0.95Cb - 2.5Ti - 0.70Al - 7.0Fe Spring Temper, Precipitation Hardenable”.
3. Nuclear Regulatory Commission, Information Notice No. 82-29: Control Rod Drive (CRD) Guide Tube Support Pin Failures at Westinghouse PWRs.
4. Babcock & Wilcox Company, B&W Technical Services Group Technical Report S-1473-002, dated December 2013 (ADAMS Accession No. ML15335A285).
5. Westinghouse Electric Company Ltd., AP600 Design Control Document Tier 2, Chapter 4.5 Reactor Materials (ADAMS Accession ML003691285).
6. Westinghouse Electric Company Ltd., AP1000 Design Control Document Tier 2, Chapter 4.5 Reactor Materials (ADAMS Accession ML11171A447).
7. Korea Hydro & Nuclear Power Company Ltd, APR1400 Design Control Document Tier 2, Chapter 4 Reactor (ADAMS Accession ML15006A043).

Impact on DCA:

FSAR Section 4.5.1.3 been revised as described in the response above and as shown in the markup provided in this response.

4.5.1.3 Other Materials

The use of martensitic stainless steel is limited to Type 410 with a minimum tempering temperature of 1050°F to prevent temper embrittlement and stress-corrosion cracking.

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Nickel-chromium based alloy X-750 is used for the CRDM springs and cobalt-based alloys Haynes 25 and Stellite 6 are used for wear-resistant parts as identified in Table 4.5-1. These materials have been used in existing pressurized water reactor (PWR) CRDMs for the same function with satisfactory performance. The material of the rod drive expansion plug and pins associated with gripper components is Haynes 25. Stellite 6 material is limited to hardfacing of the CRDM gripper latch arm tips. To minimize the possibility of stress-corrosion cracking failures, the CRDM springs and wear-resistant parts are procured in the same heat treatment condition as previously used in the industry. Alloy X-750 spring material and heat treatment conform to the requirements of AMS 5698 or AMS 5699. There have been no operating experience reports of stress-corrosion cracking of Alloy X-750 CRDM springs fabricated from AMS 5698 and AMS 5699. For Alloy X-750, the cobalt impurity is maintained as low as possible and does not exceed 1%. To minimize cobalt intrusion into the reactor coolant, low-cobalt or cobalt-free alloys may be used for wear-resistant CRDM parts if their wear and corrosion resistance are qualified by testing.

4.5.1.4 Material Cleaning and Cleanliness Control

Cleaning of CRDMs complies with the ASME NQA-1 requirements (Reference 4.5-2). The final surface cleanness meets the requirements for "Class B" of Subpart 2.1.

Handling, storage, and shipping of CRDMs comply with ASME NQA-1-2008, Part 1, Requirement 13. Packaging, shipment, handling, and storage of CRDMs meet the requirements of "Level B" of ASME NQA-1a-2009, Part II, Subpart 2.2 (Reference 4.5-2).

4.5.2 Reactor Internals and Core Support Structure Materials

RAI 04.05.02-2

Figures 3.9-1 through 3.9-4~~5~~ show the reactor vessel internals (RVI) subassemblies with components that comprise the RVI. The RVI consist of core support assembly, lower riser assembly, upper riser assembly, flow diverter, and pressurizer spray nozzles. The RVI do not contain any cast austenitic stainless steel (CASS) components.

4.5.2.1 Materials Specifications

Table 4.5-2 lists the RVI materials and associated specifications, including the material grade, class, or type as applicable. The portions of the RVI performing a core support function are classified as Quality Group B and are designed and fabricated as Class CS in accordance with ASME BPV Code, Section III, Subsection NG. The materials for core support structures and threaded structural fasteners conform to the requirements of ASME BPV Code, Section III, Subsubarticle NG-2120, and the applicable requirements of ASME BPV Code, Section II, Part D, Tables 2A, 2B, and 4. The remaining portions of the