From:	Edward Helvenston
Sent:	Thursday, January 11, 2024 8:55 AM
To:	Rusty Towell; Lester Towell; Benjamin Beasley; Tim Head; Jordan Robison; Alexander Adams; Brazos Fitch
Cc:	Richard Rivera; Michael Wentzel; Greg Oberson (He/Him); Mohsin Ghazali; Boyce Travis; Alexander Chereskin; Ryann Bass; Michael Balazik
Subject:	ACU MSRR PSAR Section 4.3 Audit Question (Related to Material Degradation)
Attachments:	ACU Audit Question 4.3-20.pdf

Dear Dr. Towell,

Attached is a question the NRC staff has prepared for Abilene Christian University (ACU) related to the ACU Preliminary Safety Analysis Report, primarily Section 4.3, "Vessel." The NRC staff would like to discuss this question within the scope of the ACU construction permit (CP) application review Audit Plan for Chapters 4 and 6 and Section 9.6 (see audit plan dated 3/2/2023, ML23065A055), and I am providing in advance to facilitate discussion during an audit meeting. We will add this email, with the question, to public ADAMS. If you have any questions, please let Richard, Mohsin, or I know.

Thank you,

Ed Helvenston, U.S. NRC
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Division of Advanced Reactors and Non-Power Production and Utilization Facilities (DANU)
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Audit Question 4.3-20

The NRC staff notes that during elevated-temperature nuclear service, thermal aging will occur in which the microstructure of the structural alloy evolves. This microstructural evolution may involve changes in grain size, elements in solution, and precipitates. Precipitate evolution includes the type, location, and size. Thermal aging is dependent on time and temperature. Thermal aging is also applicable to welds. Thermal embrittlement may result from a number of processes that may occur during thermal aging. These may include the formation of hardening phases, accumulation of adverse elements on grain boundaries, segregation of impurities to dislocations, and changes in solid solution.

The staff notes that a number of structures, systems, and components (SSCs) in the Abilene Christian University (ACU) Molten Salt Research Reactor (MSRR) could be impacted by thermal aging. According to the document titled "MSRR Codes and Standards, service conditions and safety classification Version 2" which ACU provided for audit on August 10, 2023, SSCs that comprise the reactor fuel salt boundary including the drain tank are designed to be at 1202°F for 20 years, and the reactor thermal management system (RTMS) is also designed for such conditions. The staff notes that long term exposure of 316H stainless steel (SS) for the conditions described by ACU may precipitate embrittling intermetallics such as σ (W. Ren and L. Lin, "Consideration of Thermal Embrittlement in Alloy 316H for Advanced Non-Light Water Reactor Applications," Proceedings of the ASME 2019 Pressure Vessels & Piping Conference, PVP2019-93431 (2019)).

Thermal embrittlement is not addressed in Section III, Division 5 of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, as stated in Subsubarticle HAA-1130. Nevertheless, the staff notes that this phenomenon should be evaluated if its effects on SSCs would challenge the conformance to relevant design criteria. Moreover, the staff notes that RTMS integrity is an assumption in the maximum hypothetical accident (MHA) scenario described in the MSRR Preliminary Safety Analysis Report (PSAR), Revision 1 (ML23319A094), Chapter 13. Therefore, the staff notes that the RTMS integrity needs to be maintained in order to ensure the MHA remains bounding of all potential events.

It is not clear to the NRC staff if or how thermal embrittlement is accounted for in the analyses or evaluations that ACU has performed to demonstrate conformance with design criteria that relate to the integrity of the RTMS. During audit discussions of material degradation topics including Audit Question 4.3-16 (ML23123A044) on November 9, 2023, ACU indicated that it had not considered whether embrittling intermetallics such as σ could form in the SSCs during the SSCs 20-year design life. Additionally, the information provided for audit by ACU on September 29, 2023, in the document titled "Degradation Mechanisms Table September 29 Revision," does not appear to include sufficient information on this degradation mechanism and how ACU intends to address it. ACU stated verbally during the November 9, 2023, audit discussions that it would evaluate this degradation mechanism and revise that table, if necessary. In order to assess this degradation mechanism, provide the following information to address the following questions:

a. Identify which design criteria address the need to ensure adequate structural and mechanical integrity of the RTMS.
b. Describe how the degradation mechanism discussed above will be mitigated for the MSRR (e.g., testing, design, inspection, surveillance coupons, performance monitoring). Have the results of any analyses or evaluations performed by ACU indicated that certain

component attributes (e.g., wall thickness) should be chosen to ensure that there is sufficient design margin to accommodate the effects of thermal embrittlement? Have the results of any analyses or evaluations performed by ACU indicted that the potential for thermal embrittlement should be considered when ACU establishes plans for in-service inspection or monitoring of SSCs (this may include locations, frequencies, or methodologies)? If yes, what criteria will be used to determine that these analyses or evaluations are appropriate for their intended purpose? If surveillance coupons are utilized, what information will they provide, and what action will ACU take based on that information? Where will the surveillance coupons be located, if applicable? Describe how the surveillance coupons compare to the SSCs, if applicable (e.g., time and temperature profiles, and whether the coupons lead the SSCs).

c. In addition to the considerations for the base metal described in question b., describe how these considerations apply to any affected welds.