Appendices for Response to Request for Additional Information 2

RAI 2 Appendix A: Degradation Management Program

Degradation Management Program (DMP) Description

The DMP will be used in the development of the detailed design and the operating license application and will include the articles described below.

Scope Definition

At a minimum, the DMP will include all safety related components in the MSRR. Additionally, ACU will identify SSCs whose failure could adversely affect safety or plant operations, including potentially non-safety related SSCs whose failure is deemed safety-significant. Identified SSCs will be included in the scope of the DMP.

Degradation Mechanism Assessment (DMA)

Potential active degradation mechanisms of the SSCs within the scope of the DMP shall be identified and evaluated. The DMA will consider the following:

- Design characteristics, such as material, geometry, component types, and other attributes related to the system configuration
- Fabrication processes, such as cold work, welding, and heat treatment
- Design margins relevant to each degradation mechanism, such as fatigue, brittle fracture, creep, and creep fatigue
- Operating, transient, and environmental conditions, such as temperatures, pressures, quality of primary and secondary salts, service environments, and neutron dose.
- Applicable industry service experience
- Applicable existing research experience
- Results of any research or testing conducted specifically to support the MSRR
- Relevant examination results
- Impact of any repairs on the system
- Examination, maintenance, repair, and replacement recommendations by SSC vendors
- Relevant compounding effects of synergistic degradation phenomena

The criteria used to identify and evaluate the effect of relevant degradation mechanisms for each SSC will be specified in the DMP and reported in the operating license application.

Plant and SSC Safety Basis and Relative Consequences

The DMP shall qualitatively consider the overall plant risk, safety basis, and the relative risk associated with each SSC. The MSRR's safety objectives are derived from regulatory limits on radiological consequences of licensing basis events. The DMP shall use information from the MSRR event analyses to identify which SSCs are included in the program and the relevant performance features needed to support the safety of the plant.

Identification and Evaluation of Mitigation Strategies

The DMP shall identify mitigation strategies, relevant to the degradation mechanism, to ensure safe and reliable SSC function throughout the operating life. The strategies will maintain conservatism while recognizing and managing uncertainties due to experimental data limitations.

Mitigation strategies will be selected for specific components to address degradation mechanisms relevant to that component. Available data on degradation mechanisms will be leveraged to assess degradation and inform selected appropriate mitigation strategies. In developing strategies, the lack of data (or the uncertainty of data) is relevant and will be considered in the selection of mitigation strategies. The uncertainty due to lack of relevant data may be mitigated with additional margin, design conservatism, monitoring, testing or any combination of strategies to provide reasonable assurance that components will perform their safety function.

These mitigation strategies shall account for all factors that contribute to the likelihood and relative consequences of a failure including, but not limited to:

- Design strategies, including material selection, application of reduction factors, etc.
- Fabrication methods and procedures
- Post fabrication treatment and construction techniques
- Testing
- Operating practices, including technical specifications
- In-service monitoring and NDE
- Maintenance, repair, and replacement strategies

The chosen DMP strategies shall account for possible degradation mechanisms specific to each SSC in the DMP scope. The degradation mechanisms will also consider collective or compounding effects (e.g., embrittlement), as appropriate. The focus of the mitigation strategies, and the DMP overall, is to assure that safety related SSCs will reliably perform their safety function during the service life of the MSRR.

Degradation Management Program Implementation

The DMP will be implemented early in detailed design and used during design and construction to manage potential degradation mechanisms. Documentation of the program and its implementation will include:

- Scope of the included SSCs
- DMA evaluation results for the included SSCs
- Selected strategies for each SSC, including performance parameters
- Documentation of DMP strategies applicable to design and construction
- Identification of any in-service monitoring or NDE required, including any frequency and acceptance criteria

The in-service monitoring and NDE identified as part of the mitigation strategy in the DMP program will be completed as defined by the program. Any SSC that requires in-service NDE as a strategy shall have a baseline NDE performed. The baseline results shall be documented in a permanent archival record. NDE may be performed either on-site or via shop and field examinations.

Performance Monitoring and Degradation Management Program Updates

The affected portions of the DMP shall be re-evaluated during service to incorporate results from any in service monitoring and NDE and any service or industry experience affecting implementation of the program. New information may include the following:

- Changes to plant design, which may introduce (or remove) SSCs within the scope of the DMP, as well as changes in materials, configurations, and stresses. Changes to plant design may change SSC failure consequences.
- Changes to plant procedures, such as operating parameters, system lineups, equipment, and operating modes, may result in different degradation mechanisms or NDE required as determined by DMP update.
- Changes in SSC performance, indicating a potential change in safety basis or relative consequences.
- Results that indicate service-related degradation.
- Industry or research experience, including SSC failure or degradation.

DMP updates may include adjustment of SSC failure consequences based on new information described above.

RAI 2 Appendix B: Salt Environment Compatibility Testing

Corrosion Rate Experiments

Multiple series of tests will be conducted to support corrosion estimations in the MSRR. These tests are designed to identify expected corrosion rates at a variety of reactor conditions. These tests will be done on unstressed as well as stressed (U-Bend) samples, with and without welding. The categories of tests to be done are listed below.

Sample Categories

1. Static Purified FLiBe, 650 °C (45 Tests Total, in glovebox)
   - Goal: Establish baseline for static corrosion of 316H in FLiBe based systems
   - 3 materials tested (Base Metal 316H, Welded 316H, 316H + Graphite)
   - 5 exposure times tested (50 h, 200 h, 500 h, 1000 h, 2000h)
   - 3 (triplicate) samples per test

2. Static Purified FLiBe + Added Beryllium, 650 °C (18 Tests Total, in glovebox)
   - Goal: Observe how Beryllium addition changes corrosion rates of 316H in FLiBe
   - 3 materials tested (Base Metal 316H, Welded 316H, 316H + Graphite)
   - 3 exposure times tested (500 h, 1000 h, 2000h)
   - 2 (duplicate) samples per test

3. Static Purified FLiBe + Added UF4, 650 °C (6 Tests Total, in glovebox)
   - Goal: Observe how fuel addition changes corrosion rates of 316H in FLiBe
   - 1 material tested (Base Metal 316H)
   - 3 exposure times tested (500 h, 1000 h, 2000h)
   - 2 (duplicate) samples per test

4. Static Purified FLiBe + Controlled O2 Content, 650 °C (12 Tests Total, in glovebox)
   - Goal: Observe how oxygen addition changes corrosion rates of 316H in FLiBe
   - 2 materials tested (Base Metal 316H, Welded 316H)
   - 3 exposure times tested (500 h, 1000 h, 2000h)
   - 2 (duplicate) samples per test

5. Static Purified FLiBe + Added Beryllium and Controlled O2 Content, 650 °C (12 Tests Total, in glovebox)
   - Goal: Observe coupled oxygen and beryllium effects on corrosion of 316H in FLiBe
   - 2 materials tested (Base Metal 316H, Welded 316H)
   - 3 exposure times tested (500 h, 1000 h, 2000h)
   - 2 (duplicate) samples per test Page 38 of 41

6. Static Purified FLiBe Accident Scenario, 750 °C (4 Tests Total, in glovebox)
   - Goal: Observe effects on corrosion rates of 316H in FLiBe at elevated temperatures
   - 2 materials tested (Base Metal 316H, Welded 316H)
   - 2 exposure times tested (4 h, 24 h)

7. Static U-Bend Purified FLiBe, 650 °C (18 Tests Total, in glovebox)
   - Goal: Establish baseline for U-Bend corrosion of 316H in FLiBe based systems
   - 2 materials tested (Base Metal 316H, Welded 316H)
   - 3 exposure times tested (500 h, 1000 h, 2000h)
   - 3 (triplicate) samples per test

8. Static U-Bend Purified FLiBe + Controlled O2 Content, 650 °C (18 Tests Total, in glovebox)
   - Goal: Observe how oxygen addition changes U-Bend corrosion rates of 316H in FLiBe
   - 2 materials tested (Base Metal 316H, Welded 316H)
   - 3 exposure times tested (500 h, 1000 h, 2000h)
   - 3 (triplicate) samples per test

<u>Sample Preparation</u>

The steel samples will be placed inside an unsealed Ni-container, containing a known volume of test salt. The samples will be electrically isolated from the Ni-container. This experimental setup will be done inside a negative pressure, inert glovebox, with controlled oxygen and moisture below 1 ppm. The samples will then be subjected to the test conditions. Following this, the steel samples will be removed and sent to the analysis site, while the salt remains at the test site. U-Bend samples will be prepared according to ASTM standard G30-22.

<u>Sample Analysis</u>

The samples will be characterized for the mode and extent of corrosion after a given test duration. This data will provide information on the effect of time on corrosion rate under tested salt conditions. Plots of corrosion rate (in terms of depth of corrosion penetration), as measured by the visible attack as well as energy-dispersive x-ray spectroscopy data on active element depletion, will be plotted against test time to determine the corrosion rate. Data fitting will be used to determine the corrosion reaction kinetics under each tested condition. Although the extent of corrosion will depend on the salt purity or its redox potential, we expect the corrosion rate to follow a parabolic shape due to depletion of impurities as well as the dependence of active alloying elements on their diffusion in stainless steel. This data will also be used as input to the material research coupon extraction schedule for the MSRR. Welded samples in these tests will provide data on the corrosion rate in the weld area as well as on the heat-affected zone near the welded area.

The samples must be removed from the salt in a way that does not destroy the corrosion history to ensure an accurate analysis. They must also be completely decontaminated of both uranium and beryllium content for analysis. A procedure for verifying untampered results will be developed.

Salt samples before and after the test will also be collected and preserved in sealed glass containers for chemical analysis, including analysis for cation concentrations in the salt from corrosion of the sample.