X.M1 FATIGUE MONITORING

Program Description

Fatigue usage factor is a computed mechanical parameter suitable for gauging fatigue damage in components subjected to fluctuating stresses. Crack initiation is assumed to have started in a structural component when the fatigue usage factor at a point of the component reaches the value of 1, the design limit on fatigue. In order not to exceed the design limit on fatigue usage, the aging management program (AMP) monitors and tracks the number of critical thermal and pressure transients for the selected components. The program also verifies that the severity of the monitored transients are bounded by the design transient definition for which they are classified.

The AMP addresses the effects of the reactor coolant environment on component fatigue life (to determine an environmentally-adjusted cumulative usage factor, or CUF_{en}) by assessing the impact of the reactor coolant environment on a set of sample critical components for the plant. Examples of critical components are identified in NUREG/CR-6260. Environmental effects on fatigue for these critical components may be evaluated using one of the following sets of formulae:

- Carbon and Low Alloy Steels
  - Those provided in NUREG/CR-6583, using the applicable ASME Section III fatigue design curve
  - Those provided in Appendix A of NUREG/CR-6909, using either the applicable ASME Section III fatigue design curve or the fatigue design curve for carbon and low alloy steel provided in NUREG/CR-6909 (Figures A.1 and A.2, respectively, and Table A.1)
  - A staff approved alternative

- Austenitic Stainless Steels
  - Those provided in NUREG/CR-5704, using the applicable ASME Section III fatigue design curve
  - Those provided in NUREG/CR-6909, using the fatigue design curve for austenitic stainless steel provided in NUREG/CR-6909 (Figure A.3 and Table A.2)
  - A staff approved alternative

- Nickel Alloys
  - Those provided in NUREG/CR-6909, using the fatigue design curve for austenitic stainless steel provided in NUREG/CR-6909 (Figure A.3 and Table A.2)
  - A staff approved alternative

Any one option may be used for calculating the CUF_{en} for each material.

Evaluation and Technical Basis

1. ***Scope of Program:*** The scope includes those components that have been identified to have a fatigue TLAA. The program monitors and tracks the number of critical thermal and pressure transients for the selected components. The program ensures the fatigue usage remaining within the allowable limit, thus minimizing fatigue cracking of metal components caused by anticipated cyclic strains in the material.

   For purposes of monitoring and tracking, applicants should include, for a set of sample reactor coolant system components, fatigue usage calculations that consider the effects of the reactor water environment. This sample set should include the locations identified in NUREG/CR-6260 and additional plant-specific component locations in the reactor coolant pressure boundary if they may be more limiting than those considered in NUREG/CR-6260.

2. ***Preventive Actions:*** The program prevents the fatigue TLAAs from becoming invalid by assuring that the fatigue usage resulting from actual operational transients does not exceed the Code design limit of 1.0, including environmental effects where applicable. This could be caused by the numbers of actual plant transients exceeding the numbers used in the fatigue analyses or by the actual transient severity exceeding the bounds of the design transient definitions. However, in either of these cases, if the analysis is revised to account for the increased number or severity of transients such that the CUF value remains below 1.0, the program remains effective.

3. ***Parameters Monitored/Inspected:*** The program monitors all plant design transients that cause cyclic strains, which are significant contributors to the fatigue usage factor. The number of occurrences of the plant transients that cause significant fatigue usage for each component is to be monitored. Alternatively, more detailed monitoring of local pressure and thermal conditions may be performed to allow the actual fatigue usage for the specified critical locations to be calculated.

4. ***Detection of Aging Effects:*** The program provides for updates of the fatigue usage calculations on an as-needed basis if an allowable cycle limit is approached, or in a case where a transient definition has been changed, unanticipated new thermal events are discovered, or the geometry of components have been modified.

5. ***Monitoring and Trending:*** Trending is assessed to ensure that the fatigue usage factor remains below the design limit during the period of extended operation, thus minimizing fatigue cracking of metal components caused by anticipated cyclic strains in the material.

6. ***Acceptance Criteria:*** The acceptance criterion is maintaining the cumulative fatigue usage below the design limit through the period of extended operation, with consideration of the reactor water environmental fatigue effects described in the program description and scope of program.

7. ***Corrective Actions:*** The program provides for corrective actions to prevent the usage factor from exceeding the design code limit during the period of extended operation. Acceptable corrective actions include repair of the component, replacement of the component, and a more rigorous analysis of the component to demonstrate that the design code limit will not be exceeded during the period of extended operation. Scope expansion includes consideration of other locations with the highest expected cumulative usage factors when considering environmental effects. As discussed in the Appendix for GALL, the staff

finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the corrective actions.

8. ***Confirmation Process:*** Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the requirements of Appendix B to 10 CFR Part 50. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process and administrative controls.

9. ***Administrative Controls:*** As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the administrative controls.

10. ***Operating Experience:*** The program reviews industry experience relevant to fatigue cracking. Applicable operating experience relevant to fatigue cracking is to be considered in selecting the locations for monitoring. As discussed in NRC Regulatory Issue Summary 2008-30, the use of certain simplified analysis methodology to demonstrate compliance with the ASME Code fatigue acceptance criteria could be nonconservative; therefore, a confirmatory analysis is recommended.

References

NRC Regulatory Issue Summary 2008-30, *Fatigue Analysis of Nuclear Power Plant Components*, U.S. Nuclear Regulatory Commission, December 16, 2008.

NUREG/CR-5704, *Effects of LWR Coolant Environments on Fatigue Design Curves of Austenitic Stainless Steels,* U.S. Nuclear Regulatory Commission, April 1999.

NUREG/CR-6260, *Application of NUREG/CR-5999 Interim Fatigue Curves to Selected Nuclear Power Plant Components,* U.S. Nuclear Regulatory Commission, March 1995.

NUREG/CR-6583, *Effects of LWR Coolant Environments on Fatigue Design Curves of Carbon and Low–Alloy Steels*, U.S. Nuclear Regulatory Commission, March 1998.

NUREG/CR-6909, *Effects of LWR Coolant Environments on the Fatigue Life of Reactor Materials,* U.S. Nuclear Regulatory Commission, February 2007.