

## XI.M17 FLOW-ACCELERATED CORROSION

### Program Description

The program relies on implementation of the Electric Power Research Institute (EPRI) guidelines in the Nuclear Safety Analysis Center (NSAC)-202L-R2 or R3 for an effective flow-accelerated corrosion (FAC) program. The program includes performing (a) an analysis to determine critical locations, (b) limited baseline inspections to determine the extent of thinning at these locations, and (c) follow-up inspections to confirm the predictions, or repairing or replacing components as necessary. NSAC-202L-R2 or R3 provides general guidelines for the FAC program. To provide reasonable assurance that all the aging effects caused by FAC are properly managed, the program includes the use of a predictive code, such as CHECWORKS, that uses the implementation guidance of NSAC-202L-R2 or R3 to satisfy the criteria specified in 10 CFR Part 50, Appendix B, for development of procedures and control of special processes.

### Evaluation and Technical Basis

1. **Scope of Program:** The FAC program, described by the EPRI guidelines in NSAC-202L-R2 or R3, includes procedures or administrative controls to assure that the structural integrity of all carbon steel lines containing high-energy fluids (two-phase as well as single-phase) is maintained. Valve bodies retaining pressure in these high-energy systems are also covered by the program. The FAC program was originally outlined in NUREG-1344 and was further described through the Nuclear Regulatory Commission (NRC) Generic Letter 89-08.
2. **Preventive Actions:** The FAC program is an analysis, inspection, and verification program; no preventive action has been recommended in this program. However, it is noted that monitoring of water chemistry to control pH and dissolved oxygen content, and selection of appropriate piping material, geometry, and hydrodynamic conditions, are effective in reducing FAC.
3. **Parameters Monitored/Inspected:** The aging management program monitors the effects of loss of material due to wall thinning on the intended function of piping and components by measuring wall thickness.
4. **Detection of Aging Effects:** Degradation of piping and components occurs by wall thinning. The inspection program delineated in NSAC-202L-R2 or R3 consists of identification of susceptible locations, as indicated by operating conditions or special considerations. Ultrasonic or radiographic testing is used to detect wall thinning. A representative sample of components is selected based on the most susceptible locations for wall thickness measurements at a frequency in accordance with NSAC 202L guidelines to ensure that degradation is identified and mitigated before the component integrity is challenged. The extent and schedule of the inspections ensure detection of wall thinning before the loss of intended function.
5. **Monitoring and Trending:** CHECWORKS or a similar predictive code is used to predict component degradation in the systems conducive to FAC, as indicated by specific plant data, including material, hydrodynamic, and operating conditions. CHECWORKS is acceptable because it provides a bounding analysis for FAC. The analysis is bounding because in general the predicted wear rates and component thicknesses are conservative when compared to actual field measurements. It is recognized that CHECWORKS is not

always conservative in predicting component thickness; therefore, when measurements show the predictions to be non-conservative, the model must be re-calibrated using the latest field data. CHECWORKS was developed and benchmarked by comparing CHECWORKS predictions against actual measured component thickness measurements obtained from many plants. The inspection schedule developed by the licensee on the basis of the results of such a predictive code provides reasonable assurance that structural integrity will be maintained between inspections. Inspection results are evaluated to determine if additional inspections are needed to ensure that the extent of wall thinning is adequately determined, that intended function will not be lost, and that corrective actions are adequately identified. Previous wear rate predictions due to FAC may change after a power uprate is implemented. Wear rates are updated in CHECWORKS according to power uprate conditions. Subsequent field measurements are used to calibrate or benchmark the predicted wear rates.

6. **Acceptance Criteria:** Inspection results are input for a predictive computer code, such as CHECWORKS, to calculate the number of refueling or operating cycles remaining before the component reaches the minimum allowable wall thickness. If calculations indicate that an area will reach the minimum allowed wall thickness before the next scheduled outage, corrective action should be considered.
7. **Corrective Actions:** Prior to service, components for which the acceptance criteria are not satisfied are reevaluated, repaired, or replaced. Long-term corrective actions could include adjusting operating parameters or selecting materials resistant to FAC. When susceptible components are replaced with resistant materials, such as high Cr material, the downstream components should be monitored closely to mitigate any increased wear. 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 (QA) procedures, review and approval processes, and administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B. 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.
9. **Administrative Controls:** Site QA procedures, review and approval processes, and administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B. 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:** Wall-thinning problems in single-phase systems have occurred in feedwater and condensate systems (NRC IE Bulletin No. 87-01; NRC Information Notice [IN] 81-28, IN 92-35, IN 95-11, IN 2006-08) and in two-phase piping in extraction steam lines (NRC IN 89-53, IN 97-84) and moisture separation reheater and feedwater heater drains (NRC IN 89-53, IN 91-18, IN 93-21, IN 97-84). Observed wall thinning may be due to mechanisms other than FAC, which require alternate materials to resolve the issue (Licensee Event Report 50-237/2007-003-00). Operating experience shows that the present program, when properly implemented, is effective in managing FAC in high-energy carbon steel piping and components.

## References

- 10 CFR Part 50, Appendix B, *Quality Assurance Criteria for Nuclear Power Plants*, Office of the Federal Register, National Archives and Records Administration, 2009.
- 10 CFR Part 50.55a, *Codes and Standards*, Office of the Federal Register, National Archives and Records Administration, 2009.
- NRC Generic Letter 89-08, *Erosion/Corrosion-Induced Pipe Wall Thinning*, U.S. Nuclear Regulatory Commission, May 2, 1989.
- NRC IE Bulletin 87-01, *Thinning of Pipe Walls in Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, July 9, 1987.
- NRC Information Notice 89-53, *Rupture of Extraction Steam Line on High Pressure Turbine*, U.S. Nuclear Regulatory Commission, June 13, 1989.
- NRC Information Notice 91-18, *High-Energy Piping Failures Caused by Wall Thinning*, U.S. Nuclear Regulatory Commission, March 12, 1991.
- NRC Information Notice 91-18, Supplement 1, *High-Energy Piping Failures Caused by Wall Thinning*, U.S. Nuclear Regulatory Commission, December 18, 1991.
- NRC Information Notice 92-35, *Higher than Predicted Erosion/Corrosion in Unisolable Reactor Coolant Pressure Boundary Piping inside Containment at a Boiling Water Reactor*, U.S. Nuclear Regulatory Commission, May 6, 1992.
- NRC Information Notice 93-21, *Summary of NRC Staff Observations Compiled during Engineering Audits or Inspections of Licensee Erosion/Corrosion Programs*, U.S. Nuclear Regulatory Commission, March 25, 1993.
- NRC Information Notice 95-11, *Failure of Condensate Piping Because of Erosion/Corrosion at a Flow Straightening Device*, U.S. Nuclear Regulatory Commission, February 24, 1995.
- NRC Information Notice 97-84, *Rupture in Extraction Steam Piping as a Result of Flow-Accelerated Corrosion*, U.S. Nuclear Regulatory Commission, December 11, 1997.
- NRC Information Notice 99-19, *Rupture of the Shell Side of a Feedwater Heater at the Point Beach Nuclear Plant*, U.S. Nuclear Regulatory Commission, June 23, 1999.
- NSAC-202L-R2, *Recommendations for an Effective Flow Accelerated Corrosion Program*, Electric Power Research Institute, Nuclear Safety Analysis Center, Palo Alto, CA, April 8, 1999.
- NSAC-202L-R3, *Recommendations for an Effective Flow Accelerated Corrosion Program*, (1011838), Electric Power Research Institute, Nuclear Safety Analysis Center, Palo Alto, CA, May 2006.
- NUREG-1344, *Erosion/Corrosion-Induced Pipe Wall Thinning in U.S. Nuclear Power Plants*, P. C. Wu, U.S. Nuclear Regulatory Commission, April 1989.

NRC Information Notice 2006-08, *Secondary Piping Rupture at the Mihama Power Station in Japan*, U.S. Nuclear Regulatory Commission, March 16, 2006.

NRC Licensee Event Report 50- 237/2007- 003- 00, *Unit 2 High Pressure Coolant Injection System Declared Inoperable*, U.S. Nuclear Regulatory Commission, September 24, 2007.

NRC Licensee Event Report 1999-003-01, *Manual Reactor Trip due to Heater Drain System Pipe Rupture Caused by Flow Accelerated Corrosion*, U.S. Nuclear Regulatory Commission, May 1, 2000.