XI.M31 REACTOR VESSEL SURVEILLANCE

Program Description

The Code of Federal Regulations, 10 CFR Part 50, Appendix H, requires that peak neutron fluence at the end of the design life of the vessel will not exceed 10^{17} n/cm^2 (E >1MeV), or that reactor vessel beltline materials be monitored by a surveillance program to meet the American Society for Testing and Materials (ASTM) E 185 Standard. However, the surveillance program in ASTM International Standard Practice E 185-82 is based on plant operation during the current license term, and additional surveillance capsules may be needed for the period of extended operation. Alternatively, an integrated surveillance program for the period of extended operation may be considered for a set of reactors that have similar design and operating features in accordance with 10 CFR Part 50, Appendix H (2009), Paragraph III.C. Additional surveillance capsules may also be needed for the period of extended operation for this alternative.

The objective of the reactor vessel material surveillance program is to provide sufficient material data and dosimetry to (a) monitor irradiation embrittlement at the end of the period of extended operation and (b) determine the need for operating restrictions on the inlet temperature, neutron spectrum, and neutron flux. If surveillance capsules are not withdrawn during the period of extended operation, operating restrictions are to be established to ensure that the plant is operated under the conditions to which the surveillance capsules were exposed.

The program is a condition monitoring program that measures the increase in Charpy V-notch 30 foot-pound (ft-lb) transition temperature and the drop in the upper shelf energy as a function of neutron fluence and irradiation temperature. The data from this surveillance program are used to monitor neutron irradiation embrittlement and are used in the time-limited aging analyses that are described in Section 4.2 of the Standard Review Plan for License Renewal. All capsules in the reactor vessel that are removed and tested must meet the test procedures and reporting requirements of the 1982 edition of ASTM E 185 (ASTM E 185-82), to the extent practicable, for the configuration of the specimens in the capsule. Any changes to the capsule withdrawal schedule, including spare capsules, must be approved by the Nuclear Regulatory Commission (NRC) prior to implementation. Untested capsules placed in storage must be maintained for possible future insertion.

Evaluation and Technical Basis

The Reactor Vessel Surveillance program is plant-specific, depending on matters such as the composition of limiting materials, availability of surveillance capsules, and projected fluence levels. In accordance with 10 CFR Part 50, Appendix H, an applicant submits its proposed withdrawal schedule for approval prior to implementation. Thus, further staff evaluation is required for license renewal.

1. ***Scope of Program:*** The program includes all reactor vessel beltline materials as defined by 10 CFR 50, Appendix G, Section II.F. Materials originally monitored within the scope of the licensee's existing 10 CFR Part 50, Appendix H, materials surveillance program will continue to serve as the basis for the reactor vessel surveillance aging management program unless safety considerations for the term of the renewed license would require the monitoring of additional or alternative materials.

2. ***Preventive Actions:*** The program is a surveillance program; no preventive actions are identified.

3. ***Parameters Monitored/Inspected:*** The program monitors reduction of fracture toughness of reactor vessel beltline materials due to neutron irradiation embrittlement and monitors reactor vessel long term operating conditions (cold leg operating temperature and neutron fluence) that could affect neutron irradiation embrittlement of the reactor vessel. The program uses two parameters to monitor the effects of neutron irradiation: (a) the increase in the Charpy V-notch 30 ft-lb transition temperature and (b) the drop in the Charpy V-notch upper shelf energy. The program uses neutron dosimeters to benchmark neutron fluence calculations. Low melting point elements or eutectic alloys may be used as a check on peak specimen irradiation temperature. Preferably, irradiation temperature will be monitored from cold leg operating temperatures. The Charpy V-notch specimens, neutron dosimeters, and temperature monitors are placed in capsules that are located within the reactor vessel; the capsules are withdrawn periodically to monitor the reduction in fracture toughness due to neutron irradiation.

4. ***Detection of Aging Effects:*** Reactor vessel beltline materials will be monitored by a surveillance program in which surveillance capsules are withdrawn from the reactor vessel and tested in accordance with ASTM E 185-82. This ASTM standard describes the methods used to monitor irradiation embrittlement (described in Element 3, above), selection of materials, and the withdrawal schedule for capsules. However, the surveillance program in ASTM E 185 is based on plant operation during the current license term, and additional surveillance capsules may be needed for the period of extended operation. Alternatively, an integrated surveillance program for the period of extended operation may be considered for a set of reactors that have similar design and operating features in accordance with 10 CFR Part 50, Appendix H, Paragraph III.C. Additional surveillance capsules may also be needed for the period of extended operation for this alternative.

   The plant-specific or integrated surveillance program shall have at least one capsule with a projected neutron fluence equal to or exceeding the 60-year peak reactor vessel wall neutron fluence prior to the end of the period of extended operation. The program withdraws one capsule at an outage in which the capsule receives a neutron fluence of between one and two times the peak reactor vessel wall neutron fluence at the end of the period of extended operation and tests the capsule in accordance with the requirements of ASTM E 185-82.

   It is recommended that the program retain additional capsules within the reactor vessel to support additional testing if, for example, the data from the required surveillance capsule turn out to be invalid or in preparation for operation beyond 60 years. If the projected neutron fluence for these additional capsules is expected to be excessive if left in the reactor vessel, the program may propose to withdraw and place one or more untested capsules in storage for future reinsertion and/or testing.

   If a plant has ample capsules remaining for future use, all pulled and tested samples or capsules placed in storage with reactor vessel neutron fluence less than 50% of the projected neutron fluence at the end of the period of extended operation may be discarded. Pulled and tested samples, unless discarded before August 31, 2000, and capsules with a neutron fluence greater than 50% of the projected reactor vessel neutron fluence at the end of the period of extended operation are placed in storage (these specimens and capsules

are saved for future reconstitution and reinsertion use) unless the applicant has gained NRC approval to discard the pulled and tested samples or capsules.

If an applicant does not have ample capsules remaining for future use, all pulled and tested capsules, unless discarded before August 31, 2000, are placed in storage. (These specimens are saved for future reconstitution use, in case the surveillance program is reestablished.)

Plant-specific and fleet operating experience should be considered in determining the withdrawal schedule for all capsules; the withdrawal schedule shall be submitted as part of a license renewal application for NRC review and approval in accordance with 10 CFR Part 50, Appendix H.

If all surveillance capsules have been removed, a licensee may seek membership in an integrated surveillance program unless the integrated surveillance program does not have surveillance material representative of its limiting beltline materials or the program can propose one of the following:

(a) An Active Surveillance Program with Reinstituted Specimens

This program consists of (1) capsules from a surveillance program described above, (2) reconstitution of specimen from tested capsules, (3) capsules made from any available archival materials, or (4) some combination of the three previous options. This program could be a plant-specific program or an integrated surveillance program.

(b) An Alternative Neutron Monitoring Program

Programs without in-vessel capsules use alternative dosimetry to monitor neutron fluence during the period of extended operation.

If all surveillance capsules have been removed, operating restrictions are established to ensure that the plant is operated under conditions to which the surveillance capsules were exposed. The exposure conditions of the reactor vessel are monitored to ensure that they continue to be consistent with those used to project the effects of embrittlement to the end of license. If the reactor vessel exposure conditions (neutron flux, spectrum, irradiation temperature, etc.) are altered, then the basis for the projection to 60 or more years is reviewed and, if deemed appropriate, modifications are made to the Reactor Vessel Surveillance program. Any changes to the Reactor Vessel Surveillance program must be submitted for NRC review and approval in accordance with 10 CFR Part 50, Appendix H.

5. ***Monitoring and Trending:*** The program provides reactor vessel material fracture toughness data for the time limited aging analyses (TLAAs) on neutron irradiation embrittlement (e.g., upper-shelf energy, pressurized thermal shock and pressure-temperature limits evaluations, etc.) for 60 years. The program is designed to periodically remove and test capsules for monitoring and trending purposes. Refer to the Standard Review Plan for License Renewal, Section 4.2, for the NRC acceptance criteria and review procedures for reviewing TLAAs for neutron irradiation embrittlement.

The TLAAs are projected in accordance with NRC Regulatory Guide (RG) 1.99, Rev. 2, “Radiation Embrittlement of Reactor Vessel Materials,” and the pressurized thermal shock

rules (10 CFR 50.61 or 10 CFR 50.61a). When using NRC RG 1.99, Rev. 2, or equivalent provisions in 10 CFR 50.61, a licensee has a choice of the following:

(a) Neutron Embrittlement Using Chemistry Tables and Upper Shelf Energy Figures

An applicant may use the tables and figures in NRC RG 1.99, Rev. 2, to project the extent of reactor vessel neutron embrittlement for the period of extended operation based on material chemistry and neutron fluence. This is described as Regulatory Position 1 in NRC RG 1.99, Rev. 2.

(b) Neutron Embrittlement Using Surveillance Data

When two or more credible surveillance data sets are available, the extent of reactor vessel neutron embrittlement for the period of extended operation may be projected according to Regulatory Position 2 in NRC RG 1.99, Rev. 2, based on best fit of the surveillance data. The credible data could be collected during the current and extended operating term. A plant-specific program or an integrated surveillance program during the period of extended operation provides for the collection of additional data.

A program that determines embrittlement by using NRC RG 1.99, Rev. 2, tables and figures (item [a]) uses the applicable limitations in Regulatory Position 1.3 of NRC RG 1.99, Rev. 2. The limits are based on material properties, temperature, material chemistry, and neutron fluence.

The program that determines embrittlement by using surveillance data (item [b]) defines the applicable bounds of the data, such as cold leg operating temperature and neutron fluence. These bounds are specific for the referenced surveillance data. For example, the plant-specific data could be collected within a smaller temperature range than that in NRC RG 1.99, Rev. 2.

The reactor vessel monitoring program provides that if future plant operations exceed these limitations or bounds, such as operating at a lower cold leg temperature or higher fluence, the impact of plant operation changes on the extent of reactor vessel embrittlement is evaluated and the NRC is notified.

6. ***Acceptance Criteria:*** The data are used for reactor vessel embrittlement projections to comply with 10 CFR Part 50, Appendix G, requirements and 10 CFR 50.61 or 10 CFR 50.61a limits through the period of extended operation.

7. ***Corrective Actions:*** There are no acceptance criteria that apply to the surveillance data, but the results of surveillance capsule testing will be incorporated into site operating limitations. The data will be used for reactor vessel embrittlement projections to comply with 10 CFR Part 50, Appendix G, requirements and 10 CFR 50.61 or 10 CFR 50.61a limits through the period of extended operation.

   If a capsule is not withdrawn as scheduled, the NRC is notified and a revised withdrawal schedule is submitted to the NRC.

   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 corrective actions.

8. ***Confirmation Process:*** 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 confirmation process, and administrative controls.

9. ***Administrative Controls:*** The administrative controls for this program provide for a formal review and approval of corrective actions. The administrative controls for this program are implemented through the site's QA program in accordance with the requirements of 10 CFR Part 50, Appendix B.

10. ***Operating Experience:*** The existing reactor vessel material surveillance program provides sufficient material data and dosimetry to (a) monitor irradiation embrittlement at the end of the period of extended operation and (b) determine the need for operating restrictions on the inlet temperature, neutron fluence, and neutron flux.

References

10 CFR Part 50, Appendix G, *Fracture Toughness Requirements,* Office of the Federal Register, National Archives and Records Administration, 2009.

10 CFR Part 50, Appendix H, *Reactor Vessel Material Surveillance Program Requirements*, Office of the Federal Register, National Archives and Records Administration, 2009.

10 CFR 50.61, *Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events*, Office of the Federal Register, National Archives and Records Administration, January 4, 2010.

10 CFR 50.61a, *Alternate Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events*, Office of the Federal Register, National Archives and Records Administration, January 4, 2010.

ASTM E 185-82, *Standard Practice for Conducting Surveillance Tests of Light-Water Cooled Nuclear Power Reactor Vessels,* American Society for Testing Materials, Philadelphia, PA. (Versions of ASTM E 185 to be used for the various aspects of the reactor vessel surveillance program are as specified in 10 CFR Part 50, Appendix H.)

NRC Regulatory Guide 1.99, Rev. 2, *Radiation Embrittlement of Reactor Vessel Materials*, U.S. Nuclear Regulatory Commission, May 1988.