Reactor Vessel Integrity

The Reactor Vessel (RV) integrity is ensured for the following reasons:

- The RV will be designed and fabricated to the high standards of quality required by the ASME Boiler and pressure Vessel Code and the pertinent Code cases.
- The RV will be fabricated from material of controlled and demonstrated quality.
- The RV will be subjected to extensive preservice inspection and testing to ensure that the vessel will not fail because of material or fabrication deficiencies.
- The RV will operate under conditions, procedures, and protective devices that ensure that the vessel design conditions will not be exceeded during normal reactor operation, maintenance, testing, and anticipated transients.
- The RV will be subjected to periodic inspection to demonstrate that its high initial quality of the RV has not deteriorated significantly under service conditions (ASME Section XI inservice inspection (ISI)).
- The RV will be subjected to surveillance to account for neutron irradiation damages so that the operating limitation may be adjusted (Reactor vessel surveillance capsule program).
- The fracture toughness of the RV and RCPB materials will be sufficient to ensure that when stressed under operation, maintenance, testing, and postulated accident conditions, they will behave in a nonbrittle manner and will minimize the probability of rapidly propagating fracture (pressure-temperature limits, pressurized thermal shock).

Brief discussion on reactor vessel surveillance capsule program, pressure-temperature limits, pressurized thermal shock, and upper shelf energy follows (Section XI ISI not discussed here):

Reactor Vessel Material Surveillance Capsule Program (RVSP)

Appendix H, "Reactor Vessel Material Surveillance Program Requirements," to 10 CFR Part 50 presents the requirements for a material surveillance program to monitor the changes in fracture toughness properties of materials in the RV beltline region resulting from exposure to neutron irradiation and the thermal environment. These requirements include conformance with ASTM E-185, "Standard Recommended Practices for Surveillance Tests for Nuclear Reactor Vessels." The staff reviewed the RV materials to determine that they meet the relevant requirements for Appendix H as they relate to determining and monitoring fracture toughness.

The RVSP is an operational program, as discussed in SECY-05-0197. The COL applicant must describe the program and its implementation in sufficient scope and level of detail for the staff to make a reasonable assurance finding on its acceptability. The COL application must also describe the method for calculating neutron fluence for the reactor vessel beltline and the surveillance capsules. In addition, RG 1.206 lists some of the topics that should be addressed in the description of the RVSP.

Some of this information must be reviewed and approved prior to issuing the COL to make sure that an appropriate and effective RSVP is in place. However, COL holder must provide the remaining items that may not be readily available to them at the time of COL application. Complete RVSP must be reviewed and approved by the staff prior to fuel loading.

Pressure-Temperature Limits

Pressure-Temperature (P-T) limits are required as a means of protecting the reactor vessel during startup and shut down to minimize the possibility of fast fracture. The methods outlined in Appendix G of Section XI of the ASME Code are employed in the analysis of protection against nonductile failure. Beltline material properties degrade with radiation exposure, and this degradation is measured in terms of the adjusted reference temperature (ART), which includes a reference nil ductility temperature shifts, initial RT_{NDT}, and margin.

The issue of P-T limits may be addressed in three different ways:

- Option 1: DCD discusses the generation methodology using 10 CFR 50, Appendix G and combined operating license applicant (COLA) provides a bounding P-T limits. COL holder will update the P-T limits using plant-specific P-T limits using actual vessel material properties. COL holder must amend the technical specification (TS) as well. Significant staff resources needed for review and approval of each COLA's P-T limits and review of COL holder's submittal.

- Option 2: DCD provides a generic P-T limits using 10 CFR 50, Appendix G. COL applicants use the generic P-T limits during the licensing process. COL applicants may use the generic P-T limits in the technical specification. However, each COL holder must update the P-T limits using plant-specific materials along with a request for license amendment. Significant staff resources needed to review and approve the P-T limits, its impact on low temperature over pressurization protections system (LTOP), and the license amendment.

- Option 3: DCD develops a generic pressure temperature limit report (PTLR) using 10 CFR 50, Appendix G and GL 96-03. NRC reviews and approves the PTLR. COL applicant(s) confirm the use of the PTLR. COL holder(s) submit the updated P-T limits and LTOPs for information only as long as the methodology of PTLR remains the same. No license amendment needed. NRC staff need not review and approve the updated P-T limits. This is most efficient process for the applicant and the staff.

Pressurized Thermal Shock

PTS events are potential transients in a pressurized-water RV that can cause severe overcooling of the vessel wall, followed by immediate repressurization. The thermal stresses, caused when the inside surface of the RV cools rapidly, combined with the high-pressure stresses, will increase the potential for fracture if a flaw is present in a low-toughness material. The materials most susceptible to PTS are the materials in the RV beltline where neutron radiation gradually embrittles the material over time.

10 CFR 50.61(b) requires for each PWR for which an operating license has been issued, the licensee shall have projected values of RT_{PTS}, accepted by the NRC, for each RV beltline material for the end of life (EOL) fluence. The RT_{PTS} values are normally projected using the bounding projected fluence and RV materials in the Design Certification Document (DCD). COL applicant must confirm the RT_{PTS} values referring the DCD.

Within one year of acceptance of the assembled RV, the COL holder will provide RT_{PTS} evaluation using the plant-specific RV material for NRC's review and approval.

Upper Shelf Energy

Reactor vessel beltline materials must have Charpy upper-shelf energy, in the transverse direction for base material and along the weld for weld material according to the ASME Code, of no less than 75 ft-

lb initially and must maintain Charpy upper-shelf energy throughout the life of the vessel of no less than 50 ft-lbs (68 J), unless demonstrated otherwise and approved by the NRC staff.

Fluence Projection

RG 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence," which is based on GDC 14, 30, and 31, describes methods and practices acceptable to the staff regarding calculational techniques and statistical practices using the dosimetry measurements. In addition, the results of the dosimetry are used to benchmark and validate calculational methods for estimating vessel irradiation.

The applicant is expected to submit the fluence calculation methodology for the NRC staff's review and approval.