UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
OFFICE OF NEW REACTORS
WASHINGTON, DC 20555-0001

NRC REGULATORY ISSUE SUMMARY 2014-XX
INFORMATION ON LICENSING APPLICATIONS FOR FRACTURE TOUGHNESS REQUIREMENTS FOR FERRITIC REACTOR COOLANT PRESSURE BOUNDARY COMPONENTS

ADDRESSEES

All holders of and applicants for an operating license or construction permit for a nuclear power reactor under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

All holders of and applicants for a power reactor combined license, standard design approval, or manufacturing license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Reactors." All applicants for a standard design certification, including such applicants after initial issuance of a design certification rule.

INTENT

The U.S. Nuclear Regulatory Commission (NRC) is issuing this regulatory issue summary (RIS) to provide guidance to addressees on the scope and detail of information that should be provided in reactor vessel fracture toughness and associated pressure-temperature (P-T) limits licensing applications to facilitate staff review. This RIS requires no action or written response on the part of addressees.

BACKGROUND INFORMATION

The fracture toughness of reactor vessel materials may decrease with time in the presence of sufficient neutron irradiation. Therefore, NRC regulations require monitoring of reactor vessel material fracture toughness during plant operation. Reactor vessel material toughness is monitored using P-T limits and Charpy upper shelf energy. P-T limits define the pressure and temperature operating conditions that must be maintained to ensure adequate margins of safety exist on material fracture toughness. Charpy upper shelf energy is a measure of the average energy absorbed by materials at a temperature that is above the upper end of the temperature transition region where materials lose significant fracture toughness.

10 CFR Part 50 Appendix G, "Fracture Toughness Requirements," Section I, "Introduction and Scope," states the following:

> *This appendix specifies fracture toughness requirements for ferritic materials of pressure-retaining components of the reactor coolant pressure boundary of light water nuclear power reactors to provide adequate margins of safety during any condition of normal operation, including anticipated operational occurrences and system hydrostatic tests, to which the pressure boundary may be subjected over its service lifetime.*

Generic Letter 96-03[1], "Relocation of the Pressure Temperature Limit Curves and Low Temperature Overpressure Protection System Limits," January 31, 1996, advises licensees that they may request a license amendment to relocate the P-T limit curves from their plant technical specifications (TS) to a pressure temperature limits report (PTLR) or a similar document, and states the following:

> *The methodology used to determine the P-T and [low temperature overpressure protection] LTOP system limit parameters must comply with the specific requirements of Appendices G and H to Part 50 of Title 10 of the Code of Federal Regulations (10 CFR), be documented in an NRC-approved topical report or in a plant-specific submittal, and be incorporated by reference into the TS. Subsequent changes in the methodology must be approved by a license amendment; 10 CFR 50.59 does not apply.*

In particular, 10 CFR Part 50, Appendix G specifies minimum Charpy upper-shelf energy for reactor vessel beltline materials and P-T limits and minimum temperature requirements for the reactor vessel.

Ferritic materials of pressure-retaining components of the reactor coolant pressure boundary (RCPB) include the following:

(1) reactor vessel forgings (e.g., shells, nozzles, and flanges)
(2) plates and welds from which the reactor vessel was manufactured
(3) ferritic materials in reactor coolant system piping, pumps, valves, and other pressure vessels

Of particular interest is the reactor vessel beltline, which is defined in 10 CFR Part 50, Appendix G as the region of the reactor vessel that "directly surrounds the effective height of the active core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron radiation damage to be considered in the selection of the most limiting material with regard to radiation damage." The beltline region experiences increased embrittlement over the operating period of the reactor vessel as a result of accumulated neutron radiation from the core.

10 CFR Part 50, Appendix H, "Reactor Vessel Material Surveillance Program Requirements," provides the requirements to monitor changes in the fracture toughness properties of ferritic materials in the reactor vessel beltline resulting from the exposure to neutron irradiation and the thermal environment. Appendix H to 10 CFR Part 50 states that *no* material surveillance program is required for reactor vessels for which it can be conservatively demonstrated by analytical methods that the peak neutron fluence at the end of operating period will not exceed 1 x 10^{17} neutrons/centimeter (n/cm^2) with energy greater than one million electron volts (E > 1 MeV). Appendix G to 10 CFR Part 50 states, "To demonstrate compliance with the fracture toughness requirements of section IV of this appendix, ferritic materials must be tested in accordance with the ASME Code and, for the beltline materials, the test requirements of appendix H of this part." Therefore, the fracture toughness requirements of 10 CFR Part 50 Appendix G for the reactor vessel beltline are applicable to the reactor vessel materials with projected neutron fluence values greater than 1 x 10^{17} n/cm^2 (E > 1 MeV) at the end of the operating period.

[1] Agencywide Documents Access and Management Systems (ADAMS) at Accession No. ML031110004.

Changes in the fracture toughness properties of ferritic reactor vessel materials have been demonstrated to occur at neutron fluence levels as low as $1x10^{17}$ n/cm^2 (E > 1 MeV). This threshold neutron fluence level is based on the surveillance program criteria set forth in 10 CFR Part 50 Appendix H. During operation, the physical region of the reactor vessel with fluence that exceeds this level can expand as a result of several factors, including power uprates, increased operating periods due to license renewal, modified fuel design, neutron fluence methodology updates, and fuel placement within the core. The result is that changes in fracture toughness properties resulting from neutron embrittlement may occur in materials where the effects of radiation damage may not have been considered previously when developing the P-T limits for the vessel. In particular, this may be true for reactor vessel nozzle materials when the nozzles are positioned immediately above or below the active core height.

Determination of the P-T limits for a plant in accordance with the requirements of 10 CFR Part 50 Appendix G considers several factors, including the initial properties and composition of the vessel materials, the accumulated neutron fluence for each material (and hence the neutron embrittlement of the material), and the stress levels applied to the materials resulting from operating loads and structural discontinuities, such as nozzles. The inclusion of stress levels from structural discontinuities makes consideration of only the limiting material for a particular reactor vessel (generally considered to be the vessel shell material with the highest reference temperature) in the determination of the P-T limits insufficient. This is because the effects of structural discontinuities for a material with a lower reference temperature (such as a nozzle with a lower neutron fluence) may result in lower allowable P-T limits than those for the vessel shell material limiting material with a higher reference temperature. Thus, the development of P-T limits for the reactor coolant pressure boundary must consider not only the vessel shell material with the highest reference temperature but also other vessel materials with structural discontinuities.

Vessel materials with stress discontinuities and a lower reference temperature are unlikely to provide the lowest allowable P-T limits for a vessel except early in the plant operating life or in cases with limited differences in the reference temperatures for the vessel shell materials and the materials with stress discontinuities (for example where the vessel shell materials have low levels of neutron embrittlement). Nevertheless, addressees must still be able to demonstrate that the P-T limits in license amendment requests and PTLRs developed for the plant do, in fact, bound all ferritic components of the reactor coolant pressure boundary as required by section I of 10 CFR Part 50, Appendix G. In addition, this demonstration would need to consider the effects of any replaced ferritic reactor coolant pressure boundary components on the adequacy of the P-T limits.

During recent license amendment submittals by licensees pertaining to P-T limits, the NRC staff requested additional information from the applicants due to a lack of sufficient demonstration that all ferritic materials of the reactor coolant pressure boundary were addressed. These requests for additional information are consistent with NRC's NUREG-0800, "Standard Review Plan," guidelines, as specified in Section 5.3.2, "Pressure-Temperature Limits, Upper-Shelf Energy, and Pressurized Thermal Shock." To date, licensee responses to NRC requests for additional information have indicated that revised P-T limits have bounded all ferritic materials of the reactor vessel and reactor coolant system for the approved P-T limits periods[2]. Such responses are consistent with licensees' understanding that has been communicated to NRC in

[2] An example request, as summarized in a safety evaluation for P-T limits for the Seabrook Station, Unit No. 1, may be found in ADAMS at Accession No. ML120820510.

the past (e.g., refer to page 5-8 of EPRI Report No. NP-5172-SR, Revision 1, "Primer: Fracture Mechanics in the Nuclear Power Industry," May 1991[3]).

SUMMARY OF ISSUE

Some recent licensee submittals pertaining to reactor vessel P-T limits have lacked sufficient demonstration that all ferritic materials of the reactor coolant pressure boundary were addressed in accordance with the requirements of 10 CFR Part 50 Appendix G. Specifically, some submittals regarding P-T limits provided technical bases analyzing only the reactor vessel material with the highest reference temperature without supporting details to demonstrate that the resulting P-T limits were bounding for all ferritic components of the reactor coolant pressure boundary. In determining P-T limits, reactor vessel materials with the highest reference temperature may not always be limiting because the consideration of stress levels from structural discontinuities (such as nozzles) may be more limiting. All addressees should ensure that P-T limits (including NRC-approved PTLRs) sufficiently address all ferritic materials of pressure-retaining components of the reactor coolant pressure boundary, including the impact of structural discontinuities, and address the impact of neutron fluence accumulation in accordance with the requirements of 10 CFR Part 50 Appendix G. Specifically, all ferritic components within the entire RCPB must be considered in the development of P-T limits, and the effects of neutron radiation must be considered for any materials that are predicted to experience an end-of-license neutron fluence exposure greater than $1x10^{17}$ n/cm^2 (E > 1 MeV).

BACKFITTING AND ISSUE FINALITY

This RIS clarifies what information addressees should submit in applications concerning reactor vessel fracture toughness and associated pressure-temperature limits. This RIS requires no action or written response. The RIS does not contain a new or changed NRC staff position or an interpretation of the applicable regulations that would constitute backfitting as defined in 10 CFR 50.109, or represent an inconsistency with applicable issue finality provisions in 10 CFR Part 52. Therefore, the NRC did not prepare a backfit analysis for this RIS or further address the issue finality criteria in Part 52.

FEDERAL REGISTER NOTIFICATION

[Discussion to be provided in final RIS.]

CONGRESSIONAL REVIEW ACT

[Discussion to be provided in final RIS.]

PAPERWORK REDUCTION ACT STATEMENT

This RIS does not contain new or amended information collection requirements that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). Existing requirements were approved by the Office of Management and Budget, approval number 3150-0011.

[3] Publicly available for download at https://www.epri.com.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

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Please direct any questions about this matter to the technical contacts listed below.

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