

**Rulemaking Plan, 10 CFR 50.61
Fracture Toughness Requirements for Protection Against
Pressurized Thermal Shock Events**

REGULATORY ISSUE

The Pressurized Thermal Shock (PTS) Rule (Title 10 of the Code of Federal Regulations, Section 50.61) protects against brittle fracture of pressurized water reactor (PWR) reactor pressure vessels (RPVs) during severe cooldown events. The screening limits in the existing rule were based on a conservative probabilistic fracture mechanics analysis. Several licensees will exceed the screening limits in the current rule before the expiration of their renewed licenses. Plants that exceed the screening limits in the existing version of 10 CFR 50.61 must implement compensatory actions. The compensatory actions would require expenditure of significant resources.

The NRC staff is engaged in a research program to update the technical basis for 10 CFR 50.61. The results to date suggest that the risk of through-wall cracking due to PTS is much lower than was previously calculated; therefore, the screening limits in the existing version of 10 CFR 50.61 may impose unnecessary burden on the licensees. The staff proposes to revise the screening limits to reflect the updated technical basis if the final results support the conclusion that the current limits are unnecessarily conservative. Some risk quantification issues remain to be resolved before it will be known how much generic conservatism may be safely eliminated in a revised rule.

The staff's approach to reevaluating the 10 CFR 50.61 screening limits for RPV material characteristics is described in SECY-00-0140, "Reevaluation of the Pressurized Thermal Shock Rule (10 CFR 50.61) Screening Criterion," dated June 23, 2000, and the subsequent periodic status reports (SECY-01-0045, SECY-01-0185, and SECY-02-0092, dated March 16, 2001, October 5, 2001, and May 30, 2002, respectively).

EXISTING REGULATORY FRAMEWORK

RPVs are made of ferritic steels that are tough at high temperatures but become less tough and more brittle at low temperatures. This change in behavior occurs over a range of temperatures. Different heats of steel undergo the transition over different temperature ranges. A reference transition temperature can be defined to characterize the transition in fracture behavior. After irradiation, a ferritic steel's reference transition temperature increases, which means the shift from brittle behavior to ductile behavior occurs over a higher temperature range. This change in material behavior is referred to as embrittlement. If the shift is sufficiently large, the RPV can transition to predominantly brittle behavior in the lower ranges of permissible reactor coolant system operating temperatures.

Operational events that lead to excessive reactor coolant system cooling can create large thermal transients (thermal shock) on the vessel inside surface. If the thermal shocks occur while the vessel is pressurized, the thermal stress can superimpose on the pressure stress to create pressurized thermal shock. If the stresses are high enough, the material embrittlement is sufficiently high, and preexisting fabrication flaws are sufficiently large and unfavorably located, then cracks can initiate from the flaws and extend suddenly through the RPV wall.

The PTS Rule, 10 CFR 50.61, was established to ensure the integrity of irradiation-embrittled RPVs. The rule limited the maximum permissible level of embrittlement for RPV materials in the region adjacent to the core. By limiting embrittlement, the rule limited the predicted through-wall cracking frequency (TWCF) to a value less than 5×10^{-6} per reactor-year. This low TWCF value for the RPV is consistent with the intent of 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 14, "Reactor Coolant Pressure Boundary," GDC 30 "Quality of Reactor Coolant Pressure Boundary," and GDC 31, "Fracture Prevention of Reactor Coolant Pressure Boundary."

PWR licensees are required to estimate an embrittlement metric for their RPV materials. In 10 CFR 50.61, the embrittlement metric is called the reference temperature for pressurized thermal shock (RT_{PTS}) and is calculated by projecting the amount of change in the reference transition temperature that is expected due to irradiation through the end of the operating license. If a licensee determines that RT_{PTS} for any vessel material will exceed the screening limits before the expiration of the license, then the licensee is required to take action by a date three years before the screening limits would be exceeded. Options that are available to licensees include implementation of compensatory measures defined by the PTS rule, submittal and approval of exemptions from the rule, or cessation of operation.

No currently operating PWR has an RT_{PTS} value that will exceed the 10 CFR 50.61 screening limits before the expiration of its 40-year license, but several plants are close to the limit. Some plants that are close to the limit are predicted to exceed it during the first 20-year license renewal period. Plants that exceed the limit must implement compensatory actions such as flux reduction, plant-specific analyses, or RPV annealing. Alternatively, plants may request an exemption from the requirements of 10 CFR 50.61 or shut down.

HOW THE REGULATORY PROBLEM WILL BE ADDRESSED BY RULEMAKING

The current version of 10 CFR 50.61 is based on a probabilistic fracture mechanics (PFM) analysis performed during the 1980s using conservative estimates of material embrittlement and RPV flaw parameters, simplified neutron fluence assumptions, and coarse binning of operational events. The analysis, using the limited computer resources of the time, provided limits that were believed to be adequately safe. The Office of Nuclear Regulatory Research (RES) used the same general approach to revise the technical basis but applied more recent knowledge of fracture mechanics, materials response to irradiation, thermal-hydraulics analysis, and frequencies of (and plant and operator responses to) overcooling transients. The reevaluation employed updated approaches to uncertainty analysis and was executed on contemporary hardware and software platforms.

The updated technical basis is described in NUREG-1806, "Technical Basis for Revision of the Pressurized Thermal Shock (PTS) Screening Limit in the PTS Rule (10CFR50.61): Summary Report," which summarizes several NUREG reports on the same topic. Some risk quantification issues require additional analyses to better quantify plant-to-plant variations and determine how much generic conservatism may be safely eliminated in a revised rule. The staff has developed a methodology to perform the additional analyses. These analyses are being performed by RES and NRR will complete its review and acceptance of the final technical basis by November 2006. The staff expects that the results will continue to support relaxation of the screening limits after the remaining issues are resolved.

Options for Rulemaking

Option 1: Retain the current rule. Licensees with RPVs that do not meet the current screening limits may produce and submit plant-specific analyses to demonstrate that an adequately low risk of through-wall cracking is ensured during continued operation. Alternatively, licensees may request exemptions from 10 CFR 50.61 to use plant-specific toughness measurements that are not permitted by the current rule. Absent RPV annealing or approval of an exemption or plant-specific RPV analysis, plants that exceed the screening limits would be required to cease operation.

The advantage of this approach is that no resources need to be expended for rulemaking. The disadvantage is that several plants will prepare submittals or exemption requests to justify continued operation. The submittals will likely vary widely in quality and content, resulting in an inefficient use of staff and licensee resources during the preparation and review of the submittals. A new regulatory guide (RG) could ensure quality submittals and efficient staff reviews, but preparing the RG would offset the savings in staff resources from not proceeding with rulemaking.

Option 2: Amend the existing regulation to permit licensees to voluntarily implement the less restrictive screening limits based on the updated technical basis. The requirements of the current version of the PTS rule would apply to licensees who choose not to implement the less restrictive screening limits.

A rule revision would provide financial benefits to licensees and efficiency benefits to the NRC staff. Licensees that chose to voluntarily implement the less restrictive screening limits would expend resources to revise their analyses consistent with the updated technical basis. However, this expenditure would be much lower than for the alternatives of continued neutron flux reduction, plant-specific analyses, and submission of exemption requests. The NRC staff would benefit from the reduction in the number and variety of plant-specific analyses or exemption requests that would otherwise be submitted by licensees. The staff would prefer to codify and follow a single, standard approach to PTS analysis rather than review an unknown number of special approaches. This option would provide two methods of determining embrittlement. The voluntary portion of the rule would require the new embrittlement correlation. The unchanged portion of the rule would maintain the old embrittlement correlation.

Option 3: Amend the existing regulation to allow licensees to voluntarily implement the less restrictive screening limits based on the updated technical basis and to require the use of the updated embrittlement correlation by all licensees.

This option provides the same benefits as Option 2, with the added advantage of regulatory consistency. The staff prefers to adopt a single embrittlement correlation to model the degradation mechanism. Furthermore, the updated correlation generally, but not uniformly, predicts lower amounts of embrittlement for PWRs than the earlier version of the correlation. With the updated embrittlement correlation, nearly every licensee will remain below the screening

limits of the existing 10 CFR 50.61 through the license renewal period, which will provide relief to many of the plants that would otherwise exceed the screening limits of the current rule. The plants that would exceed the screening limits of the existing 10 CFR 50.61 using the updated embrittlement correlation could elect to apply the voluntary part of the rule. If pending additional analyses of the updated technical basis do not substantially change the results, it appears that all PWRs can be safely operated through 60 years with respect to PTS.

The disadvantage of this approach is that every PWR would be required to recalculate its material embrittlement metric using the updated embrittlement correlation, which would be a backfit. A documented evaluation would need to be prepared in accordance with 10 CFR 50.109(a)(4) to justify an exemption from the requirements to perform a backfit analysis.

Option 4: Amend the existing regulation to require all licensees to implement the less restrictive screening limits associated with the updated technical basis and to use the updated embrittlement correlation.

This option provides the same benefits as Options 2 and 3, but because many plants do not require additional margin with respect to PTS, the application of the updated technical basis to these plants is unnecessary and an uneconomic use of resources for both the staff and those licensees. As does Option 3, this option would also require a backfit analysis.

RECOMMENDATION

The staff recommends that 10 CFR 50.61 be revised in accordance with Option 3. This option will permit several plants to continue operating through at least a first license renewal period, maintains safety, and maintains regulatory consistency with the updated embrittlement correlation.

NUCLEAR SAFETY CONSIDERATIONS

The revised rule will be developed from a technical basis that employs probabilistic fracture mechanics analysis to determine the TWCF in an RPV due to PTS events. The staff described its plans for the PTS reanalysis effort in SECY-00-0140 and provided updates in SECYs 01-0045, 01-0185, and 02-0092. In a memorandum dated June 17, 2002, the Commission stated that if the results of the analyses showed the TWCF to be very low, expenditure of resources to investigate uncertainties in post-RPV failure accident progression would probably not be warranted. However, in accordance with GDC 31, uncertainties with respect to fluence, stresses, materials, and flaws are being evaluated in the updated technical basis. The results of the reanalysis documented by RES in NUREG-1806 indicate that the TWCF is very low, so the staff did not investigate the margins between TWCF, PTS-induced core damage frequency (CDF), and PTS-induced large early release frequency (LERF). Instead, as a conservative and facilitating assumption, the staff recommended that the PTS risk criteria be based on the following logic: PTS-induced LERF is bounded by PTS-induced CDF; PTS-induced CDF is bounded by PTS-induced TWCF; therefore, by limiting the TWCF to less

than 1×10^{-6} per reactor-year, PTS-induced LERF is also limited to less than 1×10^{-6} per reactor-year. The unquantified margin between TWCF and LERF is a retained conservatism in the technical basis. The updated technical basis will continue to ensure that GDCs 14, 30, and 31 are met.

The proposed rule would reduce unnecessary margin. It would allow some plants to reduce or eliminate flux suppression measures, increase licensed reactor power, increase reactor coolant system heatup and cooldown rates, and extend licensed operating periods. These changes in plant design and operation could have the effect of increasing risk. However, the new technical basis information will be used to provide assurance that the increases are limited by the revised rule so that no plant will exceed the TWCF of 1×10^{-6} per reactor-year, which is consistent with Commission guidance on LERF.

ALTERNATIVE EMBRITTLEMENT CORRELATIONS

The American Society for Testing and Materials (ASTM), an international standards body, has approved and published a consensus standard (E-900, "Standard Guide for Predicting Radiation-Induced Transition Temperature Shift in Reactor Vessel Materials") that contains a different embrittlement correlation than the embrittlement correlation currently being proposed for inclusion in the revision to Regulatory Guide 1.99 and the PTS Rule revision. However, there is little difference in computed TWCF between any of the potential correlations that may be used in a revised rule. The correlation in the updated technical basis was developed by the NRC's Office of Nuclear Regulatory Research (RES) and has been more recently calibrated to available data. Because the consensus standard has not been calibrated to recently acquired relevant data, it is currently not a practical candidate for application in the technical basis, because it does not represent the broad range of conditions necessary to justify a revision to the regulations. The RES staff plans to work with ASTM towards a common embrittlement correlation, consistent with the intent of the National Technology Transfer and Advancement Act of 1995 (NTTAA).

OGC ANALYSIS

The purpose of this rulemaking, as understood by the Office of the General Counsel (OGC), is to modify the existing requirements in 10 CFR 50.61 for evaluating the susceptibility of reactor pressure vessels to pressurized thermal shock (PTS). The staff has identified four options for rulemaking:

- Option 1 Retain the current language of § 50.61 without change.
- Option 2 Revise § 50.61 to provide a voluntary alternative to use (i) a new embrittlement correlation for calculating embrittlement and (ii) new screening limits to determine whether the calculated embrittlement is acceptable without further analysis.
- Option 3 Revise the rule to (i) require all licensees to use the new embrittlement correlation and (ii) provide a voluntary alternative to use the new screening limits to determine whether the calculated embrittlement is acceptable without further analysis.

- Option 4 Revise rule to (i) require all licensees to use the new embrittlement correlation and (ii) require all licensees to use the new screening limits to determine whether the calculated embrittlement is acceptable without further analysis.

Because the staff recommends Option 3, this legal analysis focuses on that option. Based on OGC's understanding of Option 3, we have not identified any bases for legal objection to this rulemaking. However, the area of backfitting merits discussion. The proposed mandatory requirement that all licenses use the new embrittlement correlation constitutes backfitting under 10 CFR 50.109(a)(1). The staff intends to rely on the "defining or redefining the level of adequate protection" exception in § 50.109(a)(4)(iii) as a basis for avoiding preparation of a backfit analysis. OGC believes that invoking this exception is legally supportable. The last time § 50.61 was significantly amended, the Commission concluded that the rulemaking was an adequate protection backfit and that a backfit analysis was; therefore, unnecessary (see 56 FR 22300, 22303 (third column), May 15, 1991). This suggests that the Commission felt that the general topic of PTS was an adequate protection matter. Inasmuch as the embrittlement correlation and the screening limits are key elements of the Commission's PTS requirements, OGC believes it can be reasonably argued that changes to these two elements constitute a redefinition of the level of adequate protection necessary to address PTS events. OGC recommends that the staff evaluate this possible rationale and present the rationale (if it is acceptable) in the backfitting discussion in the statements of consideration (SOC) for the proposed rule.

OGC agrees with the staff's preliminary determination that the proposed rule will require preparation of an environmental assessment since it appears that no categorical exclusions in 10 CFR 51.21(c) apply to the proposed rule.

The determination of whether the proposed rule is a "major rule" (i.e., \$100 million year impact) under the Small Business Regulatory Enforcement Fairness Act (SBREFA) will be made during the development of the regulatory analysis for the proposed rule. If the proposed rule is not a major rule, then the SBREFA-mandated 60-day period for Congressional review before a major rule becomes effective would not be applicable.

In accordance with the National Technology Transfer and Advancement Act (NTTAA) of 1995, P.L. 104-113, the NRC is required to determine whether there are any voluntary consensus codes and standards with respect to methods for evaluating reactor pressure vessel embrittlement and susceptibility to pressurized thermal shock and, if so, whether any applicable code or standard can be endorsed through incorporation by reference into the Commission's regulations as an alternative to NRC-developed requirements (i.e., a "government-unique standard"). The staff has identified the ASTM E-900 standard that contains a method of evaluating reactor pressure vessel embrittlement and susceptibility to pressurized thermal shock, including a different embrittlement correlation. In the rulemaking plan, the staff suggests that the E-900 standard is not a practical alternative to the requirements to be developed in the contemplated rulemaking, because it does not represent the broad range of conditions necessary to justify a revision to the regulations. The OGC supports the staff continuing to work with the ASTM committee, consistent with the intent of the National Technology Transfer and Advancement Act of 1995 (NTTAA).

Finally, in light of the Commission's policy in favor of using performance-based requirements, OGC assumes that the language of the proposed rule under Option 3 would continue the existing rule's performance-based approach to addressing PTS.

In conclusion, we have determined that, at this time, there are no known bases for legal objection to the contemplated rulemaking.

BACKFIT ANALYSIS

Because the updated technical basis would be applied as a voluntary alternative under Option 3, implementation of the updated technical basis is not a backfit as defined by 10 CFR 50.109. However, the proposed revision to 10 CFR 50.61 includes a change to the embrittlement correlation that is used to estimate the material embrittlement metric for neutron fluence. It is proposed that the new correlation be applicable to all parts of the revised rule so that all licensees will be required to calculate the embrittlement metrics for their RPV beltline materials. The imposition of the embrittlement correlation would be considered a backfit. However, the staff intends to rely on the "defining or redefining the level of adequate protection" exception in § 50.109(a)(4)(iii) as a basis for avoiding preparation of a backfit analysis, although an evaluation will need to be prepared to justify use of this exception. As noted in the above OGC analysis, the Commission concluded that the previous rulemaking for PTS was an adequate protection backfit and a backfit analysis was; therefore, unnecessary.

SUPPORTING DOCUMENTS NEEDED

An environmental assessment or, as appropriate, a determination of no environmental impact statement, will be prepared as part of this rulemaking. If the rule contains reporting or record keeping requirements, an Office of Management and Budget (OMB) clearance package will be prepared for submission to the OMB. A regulatory analysis will also be prepared.

PUBLIC/INDUSTRY PARTICIPATION

RES held a series of public meetings to review progress on the development of the updated technical basis for PTS. An industry Issue Task Group within the Electric Power Research Institute Materials Reliability Program follows RPV issues for PWR. The task group consists of licensees and vendor representatives, EPRI project managers, consultants, and a Nuclear Energy Institute (NEI) representative. There were no NRC representatives on the EPRI task group. Participants in the EPRI-sponsored task group attended many of the RES meetings. Representatives of the task group have reviewed the available NRC technical basis documents. Task group representatives also actively participated in a review of the inputs to, and the methodology for, developing the updated technical basis. In separate meetings, NEI has periodically briefed NRC management on the industry's positions. The industry endorsed previous versions of the technical basis and the proposed risk metrics and goals and strongly supports staff efforts to revise 10 CFR 50.61. The industry has not reviewed the most recent technical basis documentation. The public release of the technical basis documents is scheduled for May 2006. RES will also make available to the public any revisions to the technical basis documents as a result of the remaining analyses as soon as those documents become available.

The staff will seek public comment by publishing the proposed rule in the *Federal Register* for a 60-day public comment period.

EDO OR COMMISSION ISSUANCE

Because of the significance of the proposed changes and stakeholder interest in this rulemaking effort, the staff recommends that the Commission issue the proposed and final rule.

RESOURCES

For NRR, approximately 2.9 FTE and \$50K are needed for this rulemaking during the FY 2006 - FY 2008 time frame. Of this amount, 1.1 FTE is budgeted for FY 2006 and 1.1 FTE and \$25K is budgeted for FY 2007. The remaining resources of 0.7 FTE and \$25K for FY 2008 will be addressed during the FY 2008 PBPM process. For RES, 2 FTE and \$310K is needed during the FY 2006 - FY 2008 time frame. Of this amount, 0.5 FTE and \$200K is budgeted for FY 2006, 1.0 FTE and \$75K is budgeted for FY 2007, and 0.5 FTE and \$35K will be addressed during the FY 2008 PBPM process. For ADM, 0.1 FTE is budgeted each year for FY 2006 - FY 2008.

Working Group:

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COORDINATION

The Office of the General Counsel has reviewed this Commission paper and has no legal objection.

The Office of the Chief Financial Officer has reviewed this Commission paper for resource implications and has no objection.

SCHEDULE

The schedule below provides anticipated dates for key rulemaking milestones. Upon approval of this rulemaking plan, the staff intends to move forward with rulemaking activities to achieve the milestones. However, as noted previously, there is some potential that the results of required additional analyses will indicate that a beneficial degree of relaxation of the screening limits cannot be justified by the current generic approach, in which case rulemaking activities would be terminated. The dates for all actions that are scheduled after the date indicated for resolution of the outstanding technical basis issues should not be tracked as staff commitments until it has been determined that these technical issues have been successfully resolved.

Actions	Timeframe
Issue draft NUREG documents for public comment	May 2006
RES issues draft revised technical basis documents	September 2006
Resolve remaining outstanding technical issues	November 2006
RES documents revised technical basis	November 2006
ACRS and CRGR briefing on proposed rule	January 2007
Proposed rule to EDO	February 2007
Proposed rule to Commission	March 2007
Publish proposed rule	April 2007
Hold public meeting	May 2007
End of public comment period for proposed rule	June 2007
ACRS and CRGR briefing on final rule	November 2007
Final rule to EDO	December 2007
Final rule to Commission	January 2008