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OFFICE OF NUCLEAR REACTOR REGULATION
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NRC REGULATORY ISSUE SUMMARY 201X-XX REGULATORY REQUIREMENTS FOR APPLICATION OF WELD OVERLAYS AND OTHER MITIGATION TECHNIQUES IN PIPING SYSTEMS APPROVED FOR LEAK-BEFORE-BREAK

ADDRESSEES

All holders of operating licenses for pressurized-water reactors (PWR) under the provision of 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, nuclear power plant construction permits, for a PWR under the provisions of 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

INTENT

The U.S. Nuclear Regulatory Commission (NRC) is issuing this regulatory issue summary (RIS) to remind addressees of the regulatory requirements for application of weld overlays and other mitigation techniques in piping systems approved by the NRC based on leak-before-break (LBB) technology. LBB analyses are performed to demonstrate that the probability of fluid system rupture is extremely low. LBB approvals permit licensees to remove protective hardware such as pipe whip restraints and jet impingement barriers. Weld overlays and other mitigation techniques are being used to mitigate Alloy 82/182 butt welds against primary water stress-corrosion cracking (PWSCC) in PWR power plants. A weld overlay changes the weld geometry of the original weld upon which the LBB analysis was based, thus making the original LBB analysis obsolete.

BACKGROUND

The governing requirement for LBB is General Design Criterion (GDC) 4. GDC 4 requires that structures, systems, and components be designed to accommodate the environmental and dynamic effects of postulated pipe ruptures. In May of 1986, the NRC promulgated a rule that modified GDC 4. Final Rule, Modification of General Design Criterion 4 Requirements for Protection Against Dynamic Effects of Postulated Pipe Ruptures, 51 Fed. Reg. 12,501 (April 11, 1986) became effective on May 12, 1986. The rule was summarized as follows:

> The Commission is modifying General Design Criterion 4 (GDC 4) of Appendix A, 10 CFR Part 50 to allow use of leak-before-break

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> technology for excluding from the design basis the dynamic effects of postulated ruptures in primary coolant loop piping in pressurized water reactors (PWRs). The new technology reflects an engineering advance which allows simultaneously an increase in safety, reduced worker radiation exposures and lower construction and maintenance costs. Implementation will permit the removal of pipe whip restraints and jet impingement barriers as well as other related changes in operating plants, plants under construction and future plant designs. Containment design, emergency core cooling and environmental qualification requirements are not influenced by this modification.

This rule, which became known as the "limited scope rule," added a new sentence to GDC 4: "However, the dynamic effects associated with postulated pipe ruptures of primary coolant loop piping in pressurized water reactors may be excluded from the design basis when analyses demonstrate the probability of rupturing such piping is extremely low under design basis conditions. 51 Fed. Reg. at 12,505.

The October 1987 rule, commonly known as the "Broad-Scope Rule," replaced the last sentence of GDC 4 with "However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping." Final Rule, Modification of General Design Criterion (GDC) 4 Requirements for Protection Against Dynamic Effects of Postulated Pipe Ruptures, 52 Fed. Reg. 41,288 (October 27, 1987) became effective on November 27, 1987.

In promulgating the rule, the Commission discussed the benefits to future plants. *See* 52 Fed. Reg. 41,289 - 41,290. The benefits included improved effectiveness of inservice inspection and enhanced safety based primarily on the how, under the rule, pipe whip restraints and jet impingement barriers could be eliminated from future plant designs

Acceptable technical procedures and criteria for using LBB analysis appear in NUREG-1061, “Report of the U.S. Nuclear Regulatory Commission Piping Review Committee,” Volume 3, “Evaluation of Potential for Pipe Breaks,” issued November 1984 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML093170485). The NRC subsequently incorporated the procedures and criteria of NUREG-1061, Volume 3, in Section 3.6.3, “Leak-Before-Break Evaluation Procedures,” of NUREG-0800, “Standard Review Plan [(SRP)] for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” issued March 1987. Section 3.6.3, “Leak-Before-Break Evaluation Procedures,” of NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Revision 1, was issued in March 2007. It provides review procedures and acceptance criteria for the Staff to evaluate licensees’ LBB submittals and determine whether they satisfy the requirements of GDC 4 for eliminating the dynamic effects of postulated pipe rupture. Licensees conduct a qualitative screening evaluation and quantitative LBB fracture mechanics analyses to support an LBB application to a high-energy piping system in a nuclear power plant. The LBB analyses consist of a quantitative leakage rate analysis coupled with a deterministic fracture mechanics analysis. The SRP specifies quantitative margins to be satisfied by the fracture mechanics and leakage rate analyses.

The NRC Staff previously approved plant-specific LBB analyses for the reactor coolant system (RCS) piping at all PWR facilities and approved plant-specific LBB analyses for some RCS branch piping at a limited number of PWRs. The Staff approved these LBB analyses under GDC 4 using the guidance in NUREG-1061, Volume 3, or SRP Section 3.6.3, Revision 0.

SUMMARY OF ISSUES

When the NRC approved LBB analyses in the 1980s and 1990s for the currently operating fleet of PWRs, RCS butt welds had not exhibited corrosion, and, therefore, the Staff concluded that PWR RCS piping was not susceptible to cracking failure from the effects of corrosion (E. G. Adensam, "Request for Exemption from a Portion of General Design Criterion 4 of Appendix A to 10 CFR Part 50," Agencywide Documents Access and Management System (ADAMS) Accession No. ML013100102, 10, April 23, 1985). Since 2000, PWSCC has occurred in the RCS systems of a number of PWRs.

RIS 2008-25, "Regulatory Approach for Primary Water Stress-Corrosion Cracking of Dissimilar Metal Butt Welds in Pressurized-Water Reactor Primary Coolant System Piping," dated October 22, 2008, discusses PWSCC in Alloy 82/182 RCS piping butt welds. In RIS 2008-25, the NRC Staff discussed the actions taken to address the potential effects of PWSCC. Actions include augmented inspections of piping welds in addition to the inspections that Section XI of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code already requires. These inspections of Alloy 82/182 welds use techniques that industry has qualified for the detection of PWSCC.

The industry has used several methods to mitigate PWSCC, including weld overlays fabricated with Alloy 52 materials. Alloy 52 materials are considered more resistant to PWSCC than Alloy 82/182 materials. Other methods used are mechanical stress improvement and Alloy 52 inlays and onlays.

This following paragraphs review the regulatory requirements for application of weld overlays and other mitigation techniques in piping systems approved for LBB. It discusses changes to the current licensing basis that may occur as a result of mitigating welds.

1. Requirements and Guidance for Leak Before Break

GDC 4, "Environmental and Dynamic Effects Design Bases," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 requires, in part, that nuclear power facilities be protected against the effects of postulated pipe ruptures. GDC 4 also states, in part, that dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.

SRP Section 3.6.3 specifies that the NRC reviewer should evaluate the material susceptibility to corrosion, the potential for high residual stresses, and environmental conditions that could lead to degradation by stress corrosion cracking. This SRP further specifies that the NRC reviewer's evaluation should demonstrate that stress corrosion cracking is not a potential source of pipe rupture. This part of the review is called a screening evaluation.

2. Systems Approved for Leak Before Break

After a review of supporting analyses, the Staff issued approvals to exclude the dynamic effects of postulated pipe ruptures from the design basis for the reactor coolant loop piping for all PWRs and for certain reactor coolant loop branch piping for some PWRs.

3. Prior Approval

GDC 4 provides a clear requirement for prior approval of LBB as a condition to implementing designs that exclude the dynamic effects associated with postulated pipe ruptures. GDC 4 states that “dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.” The Commission reviews and approves the various plant specific evaluations before it authorizes the removal of hardware which mitigates the dynamic effects of postulated high energy pipe ruptures.

4. Applicability of the Broad Scope Revision to GDC 4

Licensees and applicants were not required to make any changes as a result of the revisions to GDC 4. Rather, GDC 4 provided licensees and applicants with an option, not previously available without an exemption, to perform LBB analyses.

5. Leak-Before-Break Approvals

Before it had completed the limited-scope revision to GDC 4, the NRC granted exemptions to GDC 4 to exclude the dynamic effects of postulated pipe ruptures of primary coolant loop piping in some pressurized-water reactors. After the NRC revised GDC 4, it approved the use of LBB analysis on a plant-by-plant basis both before and after issuance of operating licenses. Some of these approvals were for "Pre-GDC" plants designed before the NRC issued the GDC. Non-GDC plants sought and received Commission approval to remove dynamic effects from design bases. For such plants, the CLB would be GDC 4 since LBB would have been approved by the NRC Staff based upon GDC 4.

6. Operating Experience

In 2000, a large accumulation of boric acid deposits observed during a refueling outage at Virgil C. Summer Nuclear Station led to the discovery of cracking in the “A” hot leg pipe-to-reactor-pressure-vessel nozzle Alloy 82/182 butt weld. The weld had a through-wall axial flaw with a small circumferential component and other small part-through-wall axial flaws. Based on destructive examinations of the piping and the weld material that was removed, the licensee determined that PWSCC caused the flaws.

In September 2005, the Electric Power Research Institute Materials Reliability Program issued MRP-139, “Materials Reliability Program: Primary System Piping Butt Weld Inspection and Evaluation Guideline,” that all PWR plants agreed to implement. MRP-139 provides industry guidance for the inspections of butt welds in PWR primary systems and includes volumetric inspection techniques that the industry has qualified for the detection of PWSCC. These inspections augment inspections of these locations required by Section XI of the ASME Boiler and Pressure Vessel Code. Under this program, butt welds susceptible to PWSCC receive a baseline examination and periodic examinations and are not permitted to be inspected on a

sampling basis. The frequency of the examination is based on the factors related to the likelihood of PWSCC occurring at the weld, such as temperature. The requirement to perform frequent weld examinations has motivated the industry to mitigate the pressurizer nozzle welds, which are the welds most susceptible to PWSCC, and many other susceptible welds.

The volumetric examinations carried out under MRP-139 revealed a number of welds with indications attributable to PWSCC. However, they did not identify any deep circumferentially oriented indications. PWR licensees are addressing the potential for PWSCC to occur in Alloy 82/182 butt welds through a program of inspecting and mitigating welds. The Staff has not identified any violations of the Commission's regulations with respect to LBB analyses for unmitigated welds.

7. Mitigation of Primary Water Stress-Corrosion Cracking

The industry has used several methods to mitigate PWSCC, including weld overlays fabricated with Alloy 52 materials. Alloy 52 materials are considered more PWSCC-resistant than Alloy 82/182 materials. Other methods that industry has used include mechanical stress improvement and Alloy 52 inlays and onlays. The Staff considers that mitigation by these techniques, if properly applied, is adequate to address the screening evaluation of SRP Section 3.6.3.

The ASME Code, Sections III or XI, does not contain rules for installing weld overlays, inlays and onlays. The NRC Staff has not, as of the date of this RIS, approved any ASME Code Cases for application of weld overlays, inlays or onlays in Regulatory Guide 1.147, Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1. Licensees may install mechanical stress improvement without NRC approval since it does not affect the Code design or inspection requirements. To apply weld overlays, inlays, or onlays in ASME Code systems, licensees obtain NRC Staff approval of the mitigation as an alternative to the existing ASME Code pressure boundary design and inspection requirements pursuant to 10 CFR 50.55a(a)(3)(i).

Obtaining NRC Staff approval of the weld overlay as an alternative to ASME Code requirements is separate from and does not also imply NRC approval of the requirements of LBB. Mechanical stress improvement and Alloy 52 inlays and onlays would not substantially change the weld geometry or the original design-basis assumptions of the weld and, therefore, likely would not invalidate the original LBB analyses submitted to the NRC for approval.

8. Leak-Before-Break Analyses of Weld Overlays

LBB analyses consist of a leakage rate calculation and a fracture mechanics calculation. The leakage calculation determines the size (arc length) of a postulated, idealized through-wall crack that would leak at a specified flow rate based on the capability of the applicable leakage detection systems multiplied by a margin of 10. The fracture mechanics calculation ensures that the largest crack that satisfies the fracture mechanics acceptance criteria in SRP Section 3.6.3 is at least two times larger than the leakage size crack. LBB analysis applies only to an entire piping system or a portion thereof that can be analyzed. Portions of the piping system that can be analyzed are typically segments located between anchor points. An LBB analysis examines or calculates the leakage and fracture mechanics margins at critical locations in the analyzed segment, and the analysis summary typically includes the margins for the location(s) in each piping system with the lowest margins. Critical locations would generally include the locations that have the least favorable combination of stress and material properties

for base metal, weldments, nozzles, and safe ends relative to the leakage and fracture mechanics margins.

A weld overlay changes the weld geometry of the original weld upon which the LBB analysis was based, thus making the original LBB analysis obsolete. Recalculation of the piping and nozzle stresses would be needed if the addition of weld overlays substantially changes the deadweight loading or the flexibility of the piping system. Updating the LBB analysis entails calculation of the leakage and fracture mechanics margins for the piping system to ensure that the modified piping system satisfies the licensee's design (i.e. GDC 4).

Thus far, licensees have not demonstrated that it is feasible to determine by inspection (i.e., without performing the leakage and fracture mechanics calculations) whether the piping system modified by overlaid welds will continue to satisfy the plants' design and LBB analyses. For example, licensees have not shown that even if in the original LBB analysis the weld overlay location had higher fracture mechanics and leakage margins than the margins of the limiting location, the original analysis could still be applied based solely on inspection.

9. NRC Review and Approval of Leak-Before-Break Analyses of Weld Overlays

If a licensee decides to apply a weld overlay to mitigate a weld and if the weld is part of a piping system approved for LBB, the weld overlay will make the original LBB analysis obsolete. The licensee will have to revise the LBB analysis. Applying the criteria of 10 CFR 50.59, “Changes, Tests, and Experiments,” to the weld overlay situation may result in the determination that a license amendment is required. The NRC Staff would then review and approve or deny the LBB analyses for weld overlays.

The LBB method of evaluating the leakage at weld overlay locations would be a departure from the original LBB analysis methodology reviewed and approved by the NRC. The LBB leakage analysis accounts for the resistance to leakage provided by the surface of the postulated idealized through-wall crack. The nature of the crack surface is called the crack morphology and the Staff reviews and approves the crack morphology parameter as part of the LBB review. The LBB leakage crack for a weld overlay has different crack morphologies from the morphology used in the original analysis. Although this change in crack morphology results in a change in input parameters, the change is also a change in methodology. .

10. Existing Weld Overlays in Leak-Before-Break-Approved Systems

To date, the NRC has not taken any enforcement action specific to weld overlays.

Some licensees may have already applied weld overlays to piping systems that the NRC Staff approved for LBB. Such licensees must follow applicable requirements in 10 CFR 50.55a to apply the weld overlay and in 10 CFR 50.59 to determine if the weld overlay would have constituted a change in the plant's design requiring a license amendment.

Licensees that have already applied weld overlays in LBB-approved piping systems should assure that all appropriate regulations were followed. If a licensee identifies a potential problem related to consideration of the impact of a weld overlay on the plant's design and LBB analyses, then the licensee should take prompt corrective action. Corrective actions might include reassessing a previous 10 CFR 50.59 evaluation for weld overlays and performing an operability determination. Further, corrective actions include updating the LBB analysis and, if required by 10 CFR 50.59, submitting a license amendment to the NRC in a timely manner.

License conditions may apply to LBB analysis. In such cases, licensees are responsible for ensuring that a weld overlay would not violate any license conditions or for seeking necessary regulatory approvals.

11. Future Application of Weld Overlays in Leak-Before-Break-Approved Systems

Some licensees may decide to apply a weld overlay in an upcoming outage to address inspection results or a potential PWSCC flaw in a pipe weld. In the absence of NRC approved Code requirements for weld overlays, the NRC Staff must review and approve weld overlays as an alternative to the requirements of the ASME Code. Licensees are reminded that a weld overlay in a piping system approved for LBB affects the design basis of the plant and may require submitting of an amendment to the NRC.

Licensees are expected to make appropriate plans to avoid placing plants in nonconformance with the plants licensing bases as a consequence of weld overlays done during outages. Such plans may include submitting a license amendment to the NRC with sufficient time to allow the agency to complete the licensing action before plant startup.

BACKFIT DISCUSSION

This RIS reminds addressees of existing regulatory requirements in 10 CFR Part 50 (including requirements in the ASME Boiler and Pressure Vessel Code which have been incorporated by reference and mandated under § 50.55a) for the application of weld overlays and other PWSCC mitigation techniques in piping systems approved for LBB. This RIS does not require any licensee to take any action or written response beyond what is required in 10 CFR Part 50, and any applicable technical specifications, license conditions and exemption terms.

As described in Section 10 above, a licensee may have already installed weld overlays to mitigate welds in piping systems approved for LBB without considering whether the use of such overlays changes the LBB analysis approved by the NRC and described (or should have been described) in the FSAR as required by 10 CFR 50.71(e). Any change to the approved LBB analysis must be evaluated under 10 CFR 50.59 to determine if the change requires prior NRC review and approval via a license amendment (or be the basis for a licensee request under 10 CFR 50.55a(a)(3) for NRC approval of an alternative to applicable ASME requirements). In addition, the licensee must perform an operability determination if it has not previously considered whether the use of such weld overlays would change a previously-approved LBB analysis. To the extent that a licensee believes that these actions, if now imposed by plant-specific order or other legally-binding requirement, constitutes backfitting as defined in 10 CFR 50.109(a)(1), the NRC Staff believes that that these actions would constitute a compliance backfit under 10 CFR 50.109(a)(4)(i). As discussed above, consideration of the effect of such weld overlays is required by § 50.71(e) and § 50.59. Consequently, the NRC Staff did not perform a backfit analysis for this RIS.

FEDERAL REGISTER NOTIFICATION

This RIS is informational and does not represent a departure from current regulatory requirements. A notice of opportunity for public comment was not required and was not published in the Federal Register, however a public meeting was held on _____ to discuss a draft of the RIS.

CONGRESSIONAL REVIEW ACT

The NRC has determined that this RIS is not a rule as designated by the Congressional Review Act (5 U.S.C. Sections 801–808) and, therefore, is not subject to the Act.

PAPERWORK REDUCTION ACT STATEMENT

This RIS does not contain any new or amended information collection requirements subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.).

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

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