UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REQUEST FOR ALTERNATIVE TO THE REQUIREMENTS OF ASME CODE, SECTION XI TO USE A REPAIR AND FLAW EVALUATION METHODOLOGY

ARKANSAS NUCLEAR ONE, UNIT NO. 1

DOCKET NO. 50-313

1.0 INTRODUCTION

Inservice inspection (ISI) of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) Class 1, 2, and 3 components shall be performed in accordance with Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," of the ASME Code and applicable addenda as required by Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.55a(g), except where specific written relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). Section 50.55a(a)(3) states that alternatives to the requirements of paragraph (g) may be used, when authorized by the NRC, if (i) the proposed alternatives would provide an acceptable level of quality and safety or (ii) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Pursuant to 10 CFR 50.55a(g)(4), ASME Code Class 1, 2, and 3 components (including supports) shall meet the requirements, except the design and access provisions and the pre-service examination requirements, set forth in the ASME Code, Section XI, to the extent practical within the limitation of design, geometry, and materials of construction of the components. The regulations require that inservice examination of components and system pressure tests conducted during the first 10-year interval and subsequent intervals comply with the requirements in the latest edition and addenda of Section XI of the ASME Code incorporated by reference in 10 CFR 50.55a(b) 12 months prior to the start of the 120-month interval, subject to the limitations and modifications listed therein.

A system pressure test was performed on the "B" loop of the ANO-1 decay heat removal system during the 1R15 refueling outage. As a result of this test, a pin-hole leak was identified in the casing of the affected decay heat removal/low pressure injection (DHR/LPI) pump. The metal area around this flaw was excavated in an effort to characterize the extent of the flaw and to prepare the casing for a qualified repair in accordance with the requirements of the ASME Code. ANO-1 is currently licensed to the 1992 Edition with portions of the 1993 Addenda as listed in the ANO-1 ISI program for the ASME Code, Section XI. ASME Code, Section XI, Paragraph IWA-4170 requires the repair to be performed in accordance with the original construction code with provisions to use later editions of the construction code or ASME Code, Section III, "Rules for Construction of Nuclear Power Plant Components." During the repair effort, the licensee determined that the repair could not be completely executed in accordance with the requirements of the ASME Code.

By letter dated September 26, 1999 (1CAN099907), Entergy Operations, Inc. (the licensee), requested the NRC staff to review and approve an alternative which would allow the use of a repair and flaw evaluation methodology for the casing flaw on the loop "B" (DHR/LPI) pump for Arkansas Nuclear One, Unit No. 1 (ANO-1). The licensee is seeking approval for this alternative under the provisions of 10 CFR 50.55a(a)(3)(i). This alternative methodology is based on Appendix C of the 1998 Edition of ASME Code, Section XI, which has not been approved for use under the provisions in 10 CFR 50.55a(b) or the licensing basis for ANO-1.

2.0 DISCUSSION

The licensee has evaluated the potential degradation mechanisms that could result in a through-wall leak and discussed their likelihood of occurrence. The evaluation of potential degradation mechanisms included fatigue, erosion-corrosion, cavitation-corrosion, stress corrosion cracking, fabrication-induced flaws, and the effects due to pump vibration. Based on the operation characteristics of the DHR/LPI pump and the material characteristics of the cast stainless steel for the pump casing, the licensee concluded that the flaw was started from a fabrication defect and had grown through-wall via the fatigue degradation mechanism.

Since the subsequent repair had not been fully successful in removing the entire flaw in accordance with the code of record, the licensee conducted a flaw evaluation of the repaired pump casing in accordance with Appendix C of the 1998 Edition of the ASME Code, Section XI. The licensee used a finite element model (FEM) to calculate the maximum stress at the crack location due to a pressure of 250 psig for the static load and the maximum stress due to a thermal shock (a step function) of 210 °F for the cyclic load. To use Appendix C, "Evaluation of Flaws in Austenitic Piping" in their flaw evaluation, the licensee applied the stresses from the FEM analyses to another location nearby at the pump bore region having about the same stresses as the crack location (for the crack location and the simulated location, see Figure 1). The resulting allowable flaw depth for a conservatively assumed 360 degree flaw using a $3S_m$ of 60 ksi (allowable stress for Class 1 piping), the Z-factor for gas tungsten arc welds (GTAW), and a safety factor of 3.0, is 91.4 percent of the pump wall thickness (0.914T). This allowable flaw depth far exceeds the current repaired crack configuration of 0.715T. The fatigue crack growth for 480 cycles is only 0.0043 inch, and therefore can be neglected in calculating the predicted crack depth at the end of 480 cycles. A similar flaw evaluation was performed in accordance with Appendix C to address the presence of an axial flaw. The resulting flaw length for a flaw with a depth of 0.914T is 4.4 inches, again, far exceeding the linear indication of 0.75 inch left in the repaired casing.

As a complement to the flaw evaluation, the licensee proposed to conduct additional VT-2 visual inspections of the DHR/LPI pump casing during the quarterly surveillance tests for a complete fuel cycle. If leakage is not identified for a cycle, the licensee will perform a pressure test and VT-2 visual inspection once per period as specified in the ANO-1 ISI program.

3.0 EVALUATION

The staff agrees with the licensee's conclusion that the flaw was originated from a fabrication defect and had grown through-wall by a degradation mechanism of thermal fatigue. This is supported by the licensee's qualitative evaluation of various potential degradation mechanisms and the physical evidence from the licensee's examination of the flaw location from inside and outside of the pump casing. These examinations included liquid penetrant testing, visual examinations, and radiography to the extent possible.

Appendix C is for austenitic piping, but the geometry of the portion of pump casing containing the flaw is not representative of piping. As a result, in the subsequent flaw evaluation, the licensee applied the stresses at the crack location obtained from FEM analyses to a close-by location at the pump bore region which resembles a piping segment having a similar stress profile as the crack location. The licensee did not justify their claim that this approach is bounding. The staff believes that in either linear elastic fracture mechanics (LEFM) or elastic plastic fracture mechanics (EPFM), the component geometry surrounding the crack tip area greatly affects the calculated applied stress intensity factor K (LEFM) or applied J (EPFM). In this evaluation, the crack location in the pump casing corner has an effective thickness of $\sqrt{2}$T, but the bore section, where Appendix C was applied, only has a thickness of 1.0T. Hence, a flaw in the bore section tends to produce a larger K or J. Further, Appendix C using Z factors is somewhat equivalent to the EPFM approach. Based on the above, the staff concludes that the licensee's approach is bounding. The licensee's remaining flaw evaluation was performed in accordance with Appendix C. The licensee was prudent to recognize that the crack was not located in a pipe shape area and used a safety factor of 3.0 instead of 2.77. Since the results from the bounding analysis indicate that the predicted crack depth of 0.715T at the end of 480 heatup/cooldown cycles is less than the allowable crack depth of 0.914T assuming a very conservative 360 degree flaw configuration, the staff accepts the alternative methodology.

To complement the alternative methodology, the licensee proposed to conduct additional VT-2 visual inspections during the quarterly surveillance tests for a complete fuel cycle. The staff determined that these additional inspections, six times in the next fuel cycle, are adequate for detecting any indications due to faulty repair or unanticipated degradation mechanisms. After this cycle, the DHR/LPI pump could be inspected in accordance with the original ANO-1 ISI program.

4.0 CONCLUSION

The staff has completed its review of the licensee's submittal and has concluded that the alternative methodology for the flaw evaluation is acceptable, and that the DHR/LPI pump can be operated with the repaired pump casing until the end of the license. The staff's decision is based on (1) the licensee's evaluation which was determined to be consistent with Appendix C, (2) the demonstration that the licensee's flaw evaluation on a surrogate location is bounding, (3) the predicted flaw depth at the end of 480 heatup/cooldown cycles is less than the allowable crack depth, and (4) the licensee's proposal to conduct quarterly VT-2 visual examinations of the DHR/LPI pump casing during the current fuel cycle. The NRC staff has previously approved evaluations conducted in accordance with Appendix C for various components containing flaws. On the basis of the preceding evaluation, the staff concludes that the proposed alternative provides an acceptable level of quality and safety and, therefore, the licensee's proposed alternative is authorized pursuant to 10 CFR 50.55a(a)(3)(i).

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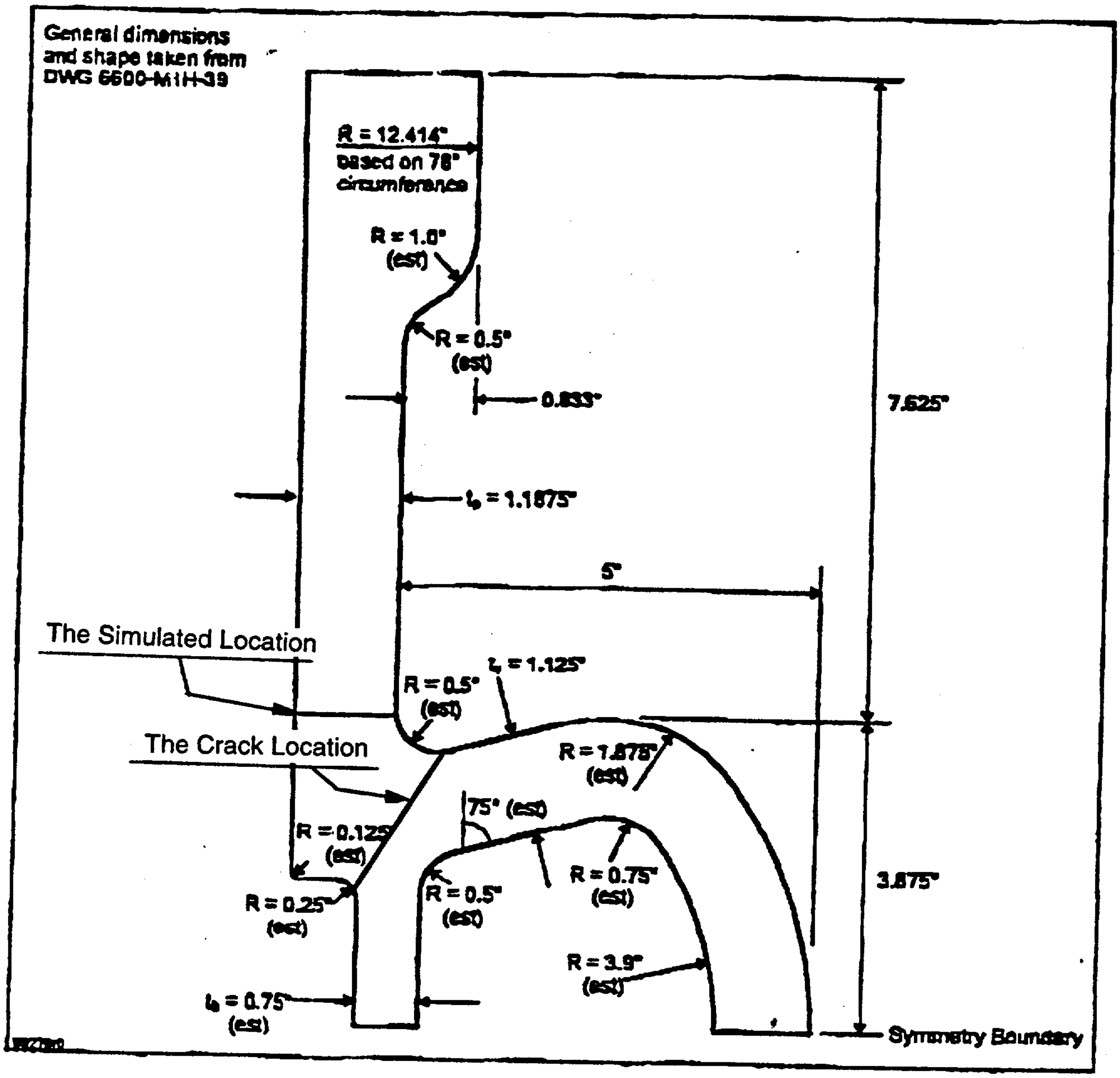

Figure 1. Geometry