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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELAXATION REQUEST FROM "ORDER MODIFYING LICENSES (EFFECTIVE IMMEDIATELY)" (EA-03-009) REGARDING THE EXAMINATION OF REACTOR PRESSURE VESSEL HEAD PENETRATION NOZZLES

FACILITY OPERATING LICENSE NO. DRP-51

ENTERGY OPERATIONS, INC.

ARKANSAS NUCLEAR ONE, UNIT 1

DOCKET NO. 50-313

1.0 INTRODUCTION

"Order Modifying Licenses (Effective Immediately)" (EA-03-009), issued on February 11, 2003 (Accession No. ML030380470), requires specific examinations of the reactor pressure vessel (RPV) head and vessel head penetration (VHP) nozzles of all pressurized water reactor plants. Section IV, Paragraph F, of the Order states that the Director, Office of Nuclear Reactor Regulation, may, in writing, relax or rescind any of the conditions set forth in Section IV, Paragraph C of the Order upon demonstration by the licensee of good cause. Section IV, Paragraph F, of the Order states that a request for relaxation regarding inspection of specific nozzles shall address the following criteria: (1) the proposed alternative(s) for inspection of specific nozzles will provide an acceptable level of quality and safety, or (2) compliance with this Order for specific nozzles would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. In addition, Section IV, Paragraph F, of the Order states that requests for relaxation of the Order associated with specific penetration nozzles will be evaluated by the Nuclear Regulatory Commission (NRC) staff using the procedure for evaluating proposed alternatives to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) in accordance with 50.55a(a)(3) of Title 10 of the *Code of Federal Regulations* (10 CFR).

For Arkansas Nuclear One, Unit 1 (ANO-1) and similar plants determined to have a high susceptibility to primary water stress corrosion cracking (PWSCC), in accordance with Section IV, Paragraphs A and B of the Order, the following inspections are required to be performed every refueling outage in accordance with Section IV, Paragraph C.(1) of the Order:

(a) Bare metal visual examination of 100% of the RPV head surface (including 360° around each RPV head penetration nozzle), AND

ENCLOSURE

(b) Either:

(i) Ultrasonic testing of each RPV head penetration nozzle (i.e., nozzle base material) from two (2) inches above the J-groove weld to the bottom of the nozzle and an assessment to determine if leakage has occurred into the interference fit zone, OR

(ii) Eddy current testing or dye penetrant testing of the wetted surface of each J-Groove weld and RPV head penetration nozzle base material to at least two (2) inches above the J-groove weld.

Footnote 3 of the Order provides specific criteria for examination of repaired VHP nozzles.

By letters dated February 3, 2004 (Accession No. ML040540663), and April 21, 2004, Entergy Operations, Inc. (Entergy or the licensee) requested relaxation to implement an alternative to the requirements of Section IV, Paragraph C.(1)(b)(i), of the Order for all RPV head penetration nozzles at ANO-1. ANO-1 has sixty-eight (68) control rod drive mechanism (CRDM) nozzles and one (1) radiation calibration instrumentation nozzle. The licensee requested approval of the relaxation request by April 20, 2004, in order to support inspection activities during the upcoming spring 2004 refueling outage 1 R18. The ANO-1 RPV head is scheduled for replacement during refueling outage 1R19, scheduled to begin during fall of 2005.

The licensee stated that this request does not apply to eight previously repaired nozzles. As described in Footnote 3 of Section IV.C.(1) of the Order, the six nozzles repaired using the pressure boundary relocation repair technique (nozzle numbers 3, 6, 15,17, 35, and 56) will be ultrasonically examined as specified in Request for Alternative ANO1-R&R-004, which has been previously authorized by the NRC staff. Two nozzles repaired using the weld overlay technique (nozzle numbers 54 and 68) will be examined by performing either an eddy current testing (ECT) or liquid penetrant testing (PT) examination on the weld overlay and the inside diameter (ID) of the nozzle blind zone.

2.0 LICENSEE'S RELAXATION REQUEST FOR RPV HEAD CRDM PENETRATION NOZZLES, ORDER NO. EA-03-009

2.1 Order Requirements for Which Relaxation is Requested

Section IV.C.(1) of Order EA-03-009 requires, in part, that the following inspections be performed every refueling outage for high susceptibility plants similar to ANO-1:

(a) Bare metal visual examination of 100% of the RPV head surface (including 360° around each RPV head penetration nozzle), AND

(b) Either:

(i) Ultrasonic testing of each RPV head penetration nozzle (i.e., nozzle base material) from two (2) inches above the J-groove weld to the bottom of the nozzle and an assessment to determine if leakage has occurred into the interference fit zone, OR

(ii) Eddy current testing or dye penetrant testing of the wetted surface of each J-Groove weld and RPV head penetration nozzle base material to at least two (2) inches above the J-groove weld.

The licensee has requested relaxation from the requirements of Section IV.C.(1)(b) of the Order for the 61 ANO-1 RPV head penetration nozzles that have not been repaired. Entergy plans to inspect these nozzles using the ultrasonic testing (UT) method in accordance with Section IV.C.(1)(b)(i) of the Order to the maximum extent possible. However, a UT inspection of the ID of the RPV head nozzles at ANO-1 can only be performed from 2 inches above the J-groove weld down to a point approximately 0.516 inch above the bottom of the nozzle. This limitation results from inspection probe design and probe lift-off encountered near the bottom of the nozzle while performing the UT examinations.

The licensee stated that to perform either a PT or ECT inspection of the bottom end of each RPV head nozzle would result in a significant increase in personnel radiation exposure and estimated that the radiation exposure associated with performing the PT or ECT inspection to be approximately 0.16 man-REM per nozzle for a total exposure of 11 man-REM. In addition, Entergy estimates that to perform an examination on the entire wetted surface of each nozzle in accordance with Section IV.C.(b)(1)(ii) of the Order would require additional under-head time for preparation and application resulting in approximately 26.5 to 27 man-REM total exposure. The licensee concluded that RPV head nozzles can be volumetrically inspected in accordance with Section IV.C.(1)(b)(i) of the Order from 2 inches above the weld to the top of the blind zone. However, below this point, Entergy believes that the hardships associated with inspection activities required by the Order are not commensurate with the level of increased safety or reduction in probability of leakage that would be obtained by complying with the Order.

2.2 Licensee's Proposed Alternative Method

2.2.1 UT Examination

The licensee stated that the ID surface of each RPV head penetration nozzle (i.e., nozzle base material) shall be ultrasonically examined from 2 inches above the J-weld to 0.516 inches above the bottom of the nozzle. This 0.516-inch "blind zone" is due to a limitation resulting from inspection probe design. Entergy will perform UT examination of the ANO-1 RPV head nozzles using the time-of-flight diffraction (TOFD) technique. The TOFD technique utilizes one pair of transducers aimed at each other looking in the axial direction of the penetration nozzle tube. One of the transducers sends sound into the inspection volume while the other receives the reflected and diffracted signals as they interact with the material. The TOFD technique is used to detect and characterize planar-type defects within the full volume of the tube. The UT examination procedures and techniques to be utilized at ANO-1 have been satisfactorily demonstrated under the Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) Inspection Demonstration Program. Also, the licensee will perform an assessment to determine if leakage has occurred into the interference fit zone, as currently specified in Section IV.C.(1)(b)(i) of the Order. The licensee defined the term "blind zone" as the length portion of the RPV nozzle tube that cannot be inspected. The term "free-span" was defined as the bottom of weld minus the blind zone, and this area below the weld is accessible for volumetric examination. The term "available propagation length" was defined as the bottom of weld minus the top of the crack tip, and that is the area available for crack growth. Figure 1 below shows the inspection areas of a CRDM nozzle as defined by the licensee.

2.2.2 UT Verification of CRDM Nozzle 26

The licensee used measurement data of the RPV head penetration nozzles obtained during the previous ANO-1 refueling outage to determine actual free-span lengths for the RPV head penetration nozzles. However, the storage data files containing the UT measurements for CRDM Nozzle 26 were found to be corrupted; therefore, its actual free-span lengths could not be determined. Because of this situation, Entergy will perform a UT examination on Nozzle 26 to determine its actual free-span lengths. If the free-span lengths meet the measured minimum free-span lengths for its associated nozzle group (26.2°) (see table below), no further actions will be required. If the free-span lengths fail to meet the lengths, Entergy will perform an augmented examination of the blind zone portion of Nozzle 26 not examined by UT. This examination will consist of either ECT or PT, or a combination of both techniques. If performed, this augmented inspection will be included in the 60-day report required by Section IV.E of the Order.

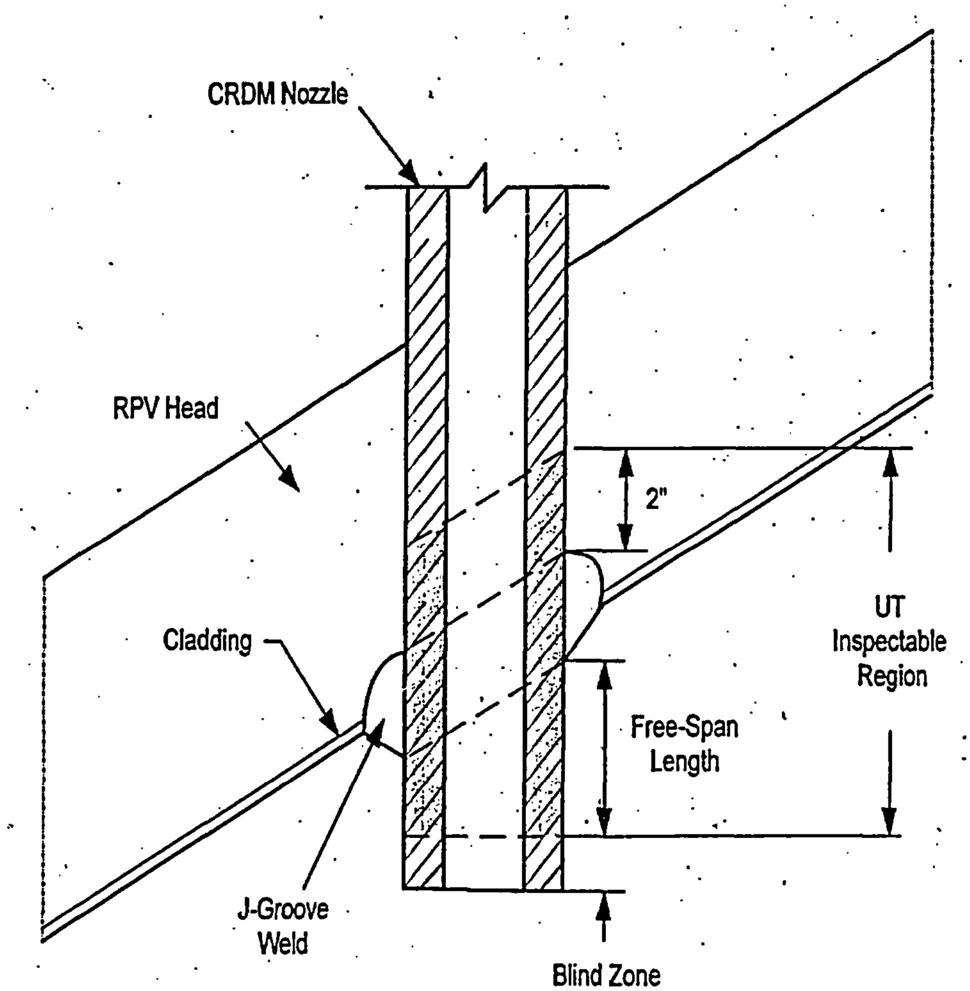

Figure 1

2.2.3 Analysis

For the blind zone portion of each RPV head penetration nozzle not examined by UT as required by the Order, the licensee performed analysis to determine if sufficient free-span lengths (uphill and downhill) exist between the blind zone and the weld to facilitate one (1) operating cycle of crack growth without the crack reaching the weld. The analysis is documented in Engineering Report M-EP-2004-001, Revision 0 which was included as Enclosure 2 to the licensee's February 3, 2004, submittal (Engineering Report M-EP-2004-001 is not included in this Safety Evaluation (SE)). The engineering evaluation included a finite element stress analysis and fracture mechanics evaluations. Four RPV head penetration nozzle locations have been selected for analysis in the engineering evaluation. The selected location groups (RPV head angles) are 0°, 18.2°, 26.2°, and 38.5° with the 0° head angle at the vertical centerline of the RPV head, the 38.5° head angle location being the outermost nozzles, and the other two groups being intermediate locations between the center and outermost locations.

The measured minimum free-span lengths for each nozzle group are documented in Table 1 of Engineering Report M-EP-2004-001 and are summarized in the table below.

Nozzle Group	Nozzle Numbers in the Group	Measured Minimum Free-Span Length @ Downhill Location	Measured Minimum Free-Span Length @ Uphill Location
0^0	1	1.040 inches	1.040 inches
18.2^0	2 thru 21	0.430 inches	1.450 inches
26.2^0	22 thru 37	0.630 inch	2.840 inches
38.5^0	38 thru 69	0.440 inches	3.080 inches

The results of the stress analysis at each location are bounding for nozzles higher on the head (e.g., analysis for 26.2° bounds the intermediate nozzles between 18.2° and 26.2°). The selected nozzle head angle locations provide an adequate representation of residual stress profiles and a proper basis for analysis to bound all RPV head nozzles. The stress analyses and fracture mechanics evaluations performed to address these conditions are summarized below. The analysis indicated that every nozzle, except CRDM Nozzle 26 which was not encompassed within the analysis, has adequate free-span lengths. Actions to be taken for Nozzle 26 are discussed above.

2.2.3.1 Stress Analysis

The licensee performed "finite element" based stress analysis (FEA) on the ANO-1 RPV head nozzle locations in this evaluation. For conservatism, the yield strength used in the analysis for each nozzle head angle location is the highest yield strength of the RPV head penetration nozzles. To ensure that the FEA adequately modeled the as-built configuration of the ANO-1 RPV head nozzles and welds, a detailed review of actual UT examination data from the previous refueling outage was performed.

The FEA for the analyzed nozzles determined the stress distribution from the bottom of the nozzle to just above the top of the weld at the downhill, uphill, and mid-plane azimuthal locations. The downhill and mid-plane locations are selected for analysis because they represent the shortest distances that a crack has to propagate to reach the nozzle weld region. The uphill location is selected for completeness of the analysis. The results of the FEA are presented in Figures 4 through 17 and Tables 2 through 11 of Engineering Report M-EP-2004-001 (Engineering Report M-EP-2004-001 is not included in this SE). The stress distributions produced by this analysis were used to perform the fracture mechanics evaluations.

2.2.3.2 Fracture Mechanics Evaluation

Safety analyses performed by the MRP have demonstrated that axial cracks in the nozzle tube material do not pose a challenge to the structural integrity of the nozzle. However, axial cracks may lead to pressure boundary leaks above the weld that could produce outside diameter (OD) circumferential cracks and thus create structural integrity concerns.

The analyses performed in the engineering evaluation are designed to determine the behavior of postulated cracks that could exist in the blind zone. Hence, the crack growth region is from the top of the blind zone to the bottom of the weld (see Figure 1). The engineering evaluation included: design review of the RPV head construction, detailed residual stress analysis, selection of representative nozzle locations, utilization of representative fracture mechanics models, and the application of a suitable crack growth law.

Postulated cracks for the analysis included axial ID and OD part through-wall and through-wall cracks. Axial cracks are selected for evaluation in this analysis because of their potential to propagate to the weld region. Axial ID and OD part through-wall crack sizes were larger than twice the smallest crack sizes successfully detected by UT under the EPRI MRP Inspection Demonstration Program. Part through-wall cracks are centered at the top of the blind zone in the analysis. Through-wall cracks are postulated to exist from the top of the blind zone down to a point where the hoop stress is ≤ 10 ksi. The ID and OD part through-wall and through-wall cracks are located along the circumference of each nozzle at the 0° (downhill), 90° (mid-plane), and 180° (uphill) azimuthal locations.

Thirty different cases have been analyzed using crack growth rates from EPRI Report MRP-55, Material Reliability Program - Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick-Wall Alloy 600 Material. In summary, the evaluation results from all cases demonstrate that postulated flaws in the blind zone region will not compromise the weld in one cycle of operation. As previously discussed, CRDM Nozzle 26 will be volumetrically examined to ensure it meets this evaluation. The analysis further demonstrates that a larger margin exists (i.e. longer than one fuel cycle) at all evaluated locations. At several locations that were analyzed, no PWSCC-induced crack growth was observed because the stress distribution at these locations produced stress intensity factors that were below the threshold value for crack propagation by PWSCC. For the limited cases where PWSCC crack growth was predicted, the crack growth in one cycle of operation did not challenge the weld. Results of the fracture mechanics evaluations are documented in Table 14 of Engineering Report M-EP-2004-001 and summarized below.

Nozzle Group	Azimuth Location	Crack Type	Allowed Propagation Dimension (inch) [2]	Allowed Growth/Cycle (inch)[3]
0°	All	ID	0.865 L/0.617 D	0L/0D
		OD	0.865	0
		Thru-wall	1.044	0
18.2°	Downhill	ID	0.255 L/ 0.617 D	0.065 L/0.111 D
		OD	0.255	0.062
		Thru-wall	0.430	0.313
	Uphill	ID	1.275 L/0.617 D	0.032 L / 0.088 D
		OD	1.275	0
		Thru-wall	1.45	0
	Mid-plane	ID	0.96 L/0.617 D	0L/0D
		OD	0.96	0
		Thru-wall	1.135	0
26.2°	Downhill	ID	0.405 L/0.617 D	0.041 L / 0.092 D
		OD	0.405	0
		Thru-wall	0.58	0
	Uphill	ID	2.665 L/0.617 D	0L/0D
		OD	2.665	0
		Thru-wall	2.84	0
	Mid-plane	ID	1.645 L/0.617 D	0L/0D
		OD	1.645	0
		Thru-wall	1.82	0
38.5°	Downhill	ID	0.265 L/0.617 D	0L/0D
		OD	0.265	0.010
		Thru-wall	0.44	0
	Uphill	ID	2.905 L/ 0.617 D	0L/0D
		OD	2.905	0
		Thru-wall	3.08	0
	Mid-plane	ID	1.805 L/0.617 D	0L/0D
		OD	1.805	0
		Thru-wall	1.98	0

[2]L = Length; D = Depth; [3]Both L and D dimensions are given for surface cracks on the ID. The limiting condition is reached when the postulated crack becomes through-wall and the upper tip reaches the bottom of the weld. The allowable propagation length of the surface-connected crack, L, is equal to the actual (measured) free-span length minus 0.175 inch, which is the distance the crack extends into the free-span at the minimum detectable crack size.

2.2.3.3 Additional Analyses

The fracture mechanics evaluations described above assess the potential for postulated cracks to propagate from the top of the blind zone to the weld in less than one cycle of plant operation, assuming either an ID or OD crack with an initial length of approximately 2 times the smallest detectable length, or a through-wall crack from the top of the blind zone down to a point where the hoop stress is ≤ 10 ksi. Because the blind zone is significantly longer than the smallest detectable length, this approach did not consider ID or OD cracks that extend down to the bottom of the nozzle. This is appropriate if the hoop stress at the bottom of the postulated flaw is compressive or if the hoop stress is a low tensile stress (< 10 ksi), as these hoop stresses will not propagate PWSCC. For the through-wall cracks, in all cases, the hoop stress rapidly decreases below the blind zone such that none of the postulated though-wall cracks extend to the bottom of the nozzle.

The potential for postulated cracks to propagate from the bottom of the blind zone to the weld was also evaluated. In general, the stress analysis indicates that the magnitude of the hoop stress distribution from the top of the blind zone to the bottom of the nozzle along both the ID and OD surfaces decreases steadily and becomes compressive. The extent or height of the compression zone for each nozzle group and azimuthal location is presented in Table 13 of the Engineering Report M-EP-2004-001 and is summarized below (Engineering Report M-EP-2004-001 is not included in this SE).

Nozzle Group	Azimuthal Location	Compression Zone Height	Maximum Hoop Stress Where No Compression Zone Exists
0°	All	0.56 inch	N/A
18.2°	Downhill	0.4 inch	N/A
	Uphill	0.8 inch	N/A
	Mid-plane	0.9 inch	N/A
26.2°	Downhill	0.357 inch	N/A
	Uphill	0.953 inch	N/A
	Mid-plane	0.875 inch	N/A
38.5°	Downhill	0.5 inch	N/A
	Uphill	1.0 inch	N/A
	Mid-plane	0	10.954 ksi

The height of the compression zone is measured from the bottom of the nozzle. Within the compression zone regions, no PWSCC-assisted crack growth is possible. For those nozzle groups with a tensile stress below 10 ksi, the possibility for PWSCC crack initiation is extremely low. Based on these stress profiles, only the 38.5° mid-plane location warrants additional analysis for crack growth below the postulated cracks discussed above. A hoop stress of 10.954 ksi exists along the ID surface at the bottom of the 38.5° nozzle at the mid-plane location. Because of this higher stress value, this nozzle location was selected for additional analysis by fracture mechanics. An ID surface crack was postulated near the bottom of the nozzle. The analysis showed that it would not propagate from PWSCC. However, the model for the surface crack is based on cracks that are remote from the edge of the plate. Because of this, a through-wall edge crack at the bottom of the nozzle was also evaluated. Based on this analysis, postulated cracks at the bottom of the 38.5° nozzle (mid-plane) do not propagate into the weld in less than one cycle of plant operation. Furthermore, the analysis results indicate that the postulated cracks in the region do not reach the weld in 2 years of operation.

2.2.3.4 Analysis Conclusions

Fracture mechanics evaluations were performed at the downhill, uphill, and mid-plane locations of the 0°, 18.2°, 26.2°, and 38.5° RPV head nozzles to assess the potential for postulated cracks to grow from the blind zone to the nozzle weld in less than one cycle of plant operation. Additional analyses were performed to assess the potential for postulated cracks to grow from along the bottom of the 38.5° nozzle at the mid-plane location to the weld in one cycle of operation.

The evaluations indicate that a crack in the blind zone of a nozzle will not grow into the weld of the nozzle within one cycle of operation. See Table 1 below which identifies the nozzle locations bounded by these evaluations.

This analysis incorporates a crack-growth formula different from that described in Footnote 1 of the Order, as provided in EPRI Report MRP-55. Entergy is aware that the NRC staff has not yet completed a final assessment regarding the acceptability of the EPRI report. If the NRC staff finds that the crack-growth formula in MRP-55 is unacceptable, Entergy shall revise its analysis that justifies relaxation of the Order within 30 days after the NRC informs Entergy of an NRC-approved crack-growth formula. If Entergy's revised analysis shows that the crack growth acceptance criteria are exceeded prior to the end of Operating Cycle 19 (following the upcoming refueling outage), Entergy will, within 72 hours, submit to the NRC written justification for continued operation. If the revised analysis shows that the crack growth acceptance criteria are exceeded during the subsequent operating cycle, Entergy shall, within 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack growth acceptance criteria are not exceeded during either Operating Cycle 19 or the subsequent operating cycle, Entergy shall, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack-growth analyses performed for Operating Cycle 19 and future cycles for RPV head penetrations will be based on an NRC-acceptable crack growth rate formula.

3.0 STAFF EVALUATION

By letter dated February 3, 2004, the licensee requested relaxation to implement an alternative to the requirements of Section IV.C.(1)(b)(i), of the Order for all RPV head penetration nozzles at ANO-1. ANO-1 has 68 CRDM nozzles and 1 radiation calibration instrumentation nozzle. The licensee stated that this request did not apply to 8 previously repaired nozzles because 6 of those 8 nozzles were repaired using the pressure boundary relocation repair technique (nozzle numbers 3, 6, 15,17, 35, and 56) and 2 nozzles were repaired using the weld overlay technique (nozzle numbers 54 and 68). This leaves 61 nozzles for which the licensee is requesting relaxation from the requirements of Section IV.C.(1)(b) of the Order.

The NRC staff reviewed the information submitted by the licensee in support of its request for relaxation of the Order. The staff's review of the request was based on Criterion (2) of Paragraph F of Section IV of the Order, which states:

> Compliance with this Order for specific nozzles would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Within the context of the licensee's proposed alternative examination of the RPV penetration nozzles, the licensee has demonstrated the hardship that would result from implementing examinations to the bottom end of the 60 CRDM nozzles and one radiation calibration instrument nozzle. The hardship identified by the licensee includes the nozzle configuration, limitation of the UT probe used for nozzle examination, and radiation exposure to perform UT examination in accordance with the Order. This evaluation focuses on the issue of whether there is a compensating increase in the level of quality and safety, such that these nozzles should be inspected despite this hardship.

The licensee performed an engineering evaluation that included a FEA of the 60 CRDM nozzles and one radiation calibration instrument nozzle and a fracture mechanics-based crack growth analysis for PWSCC. Thirty analysis cases were performed. These analyses are performed for four nozzles groups (the nozzles were chosen at four head angles; 0^0, 18.2^0, 26.2^0, and 38.5^0) in the reactor vessel head to account for the varied geometries of the nozzle penetration. In this manner the analysis provides a bounding evaluation for the 60 CRDM nozzles and one radiation calibration instrument nozzle in the reactor vessel head. Although Section XI of the ASME Code does not provide guidelines for characterizing postulated flaws for applications similar to the ANO-1 RPV nozzle blind zones, it is reasonable to assume existence of the largest flaw that could exist in the blind zone consistent with engineering principles.

The licensee used the following approach in order to evaluate the integrity of the nozzles for one operating cycle:

As stated above, 30 analyses cases representing 4 RPV head penetration nozzle locations were selected for analysis in the engineering evaluation by the licensee. The selected location groups were 0°, 18.2°, 26.2°, and 38.5° with the 0° head angle at the vertical centerline of the RPV head, the 38.5° head angle location being the outermost nozzles, and the other 2 groups being intermediate locations between the center and outermost locations. After the location groups were identified, the licensee determined the measured minimum free span length for each nozzle group using data from previously performed UT examinations on ANO-1 RPV nozzles. For one nozzle (nozzle 26) the UT data was corrupted and, therefore, the licensee committed to perform UT examination to establish the measured free-span length to be used in the engineering analysis. The staff finds this approach acceptable because the selected nozzle groups account for the varied geometries of the nozzle penetration and thus the analysis provides a bounding evaluation for the 60 CRDM nozzles and one radiation calibration instrument nozzle in the reactor vessel head.

The licensee performed FEA to determine stress distribution from the bottom of the nozzle to just above the top of the weld at the downhill, uphill, and mid-plane azimuthal locations. The downhill and mid-plane locations were selected for the analysis because they represent the shortest distance that a crack has to propagate to reach the nozzle region. The stress distributions produced by FEA were used as input to the fracture mechanics evaluations. The staff evaluated the information regarding the FEA modeling performed by the licensee. The licensee's FEA model considered materials and welding processes by simulating melting and solidification of individual welding passes through a combination of thermal and structural models. Heat treatment history has also been considered. This method of calculating residual stresses is consistent with the industry practice and is acceptable to the staff. In summary, the use of resulting stresses from the FEA model as input to the licensee's fracture mechanics evaluation is acceptable.

The fracture mechanics analyses were performed to determine the impact of not examining the blind zone and evaluated three possible cases: a part through-wall axial crack initiated from the ID, a part through-wall axial crack initiated from the OD, and a through-wall axial crack.

For part through-wall cracks the initial crack depth was obtained from the EPRI Topical Report (TR)-103696, "PWSCC of Alloy 600 Materials in PWR Primary System Penetrations." The initial crack depth was determined to be 11.0% of wall thickness deep for an ID axial crack and 16% of wall thickness deep for an OD axial crack. The crack length is based on the detected length of 4 mm (0.157 inch) from EPRI TR-103696. In the deterministic fracture mechanics analyses that the licensee performed, the part through-wall crack lengths are more than doubled to 0.35 inch and the crack center is located at the top of the blind zone. Thus, the crack spans both the blind zone and the region that can be inspected. The postulated crack sizes and depths are two times the detectable limits with one-half (0.175 inch) of the flaw length being located in the area that can be examined. This provides for a conservative evaluation because it places the crack tip 0.175 inch closer to the weld where the hoop stresses are higher and assumes that 0.175 inch of the region that can be examined is already cracked, reducing the remaining area for crack propagation.

In addition to evaluating the part through-wall cracks, the licensee conservatively evaluated a through-wall axial crack. The through-wall axial crack is postulated to exist from the top of the blind zone down to a point where the hoop stress is ≤ 10 ksi. This is a very conservative assumption. It is almost impossible for a crack to initiate on the surface and propagate through-wall while being totally contained within the blind zone, because the length of a part through-wall crack would propagate into the region that can be inspected long before its depth reaches a through-wall condition.

To assess the consequence of having flaws in the blind zone, the licensee assumed three initial flaw geometries in its fracture mechanics evaluation: an ID elliptical surface flaw 0.06787 inch deep and 0.35 inch long, an OD elliptical surface flaw 0.09872 inch deep and 0.35 inch long, and a through-wall flaw of length from the top of the blind zone to a point of hoop stress less than 10 ksi. Because the crack face of the assumed through-wall flaw is several times larger than that for an assumed ID or OD flaw, the through-wall flaw geometry is a very conservative assumption. In all thirty cases the analysis showed that the postulated flaw in the blind zone will not challenge the weld in one cycle of operation. The licensee's results of the crack growth analysis are shown in Table 1 of this SE. The NRC staff finds the crack growth results acceptable because the licensee has used conservative assumptions to demonstrate that the postulated flaw will not affect the integrity of the weld for one cycle of operation.

For applied stress intensity factor (K) calculations for ID and OD flaws, the licensee used an influence-function approach based on extensive FEA for thick cylinders with ID and OD surface flaws by S. R. Mettu, et al., (1992). For applied K calculations for through-wall flaws, the licensee used another influence-function approach based on extensive FEA for thick cylinders with through-wall flaws by Christine C. France, et al., (1997). Using formulas for thick cylinders is appropriate because, for this application, the radius to thickness (R/t) ratio for the 60 CRDM nozzles and one radiation calibration instrument nozzle is within the acceptable range.

The aforementioned crack growth analysis used the approach described in Footnote 1 of the Order, with the exception of the crack growth rate (CGR) formula, as the criteria to set the necessary height of the surface examination. Therefore, the coverage addressed by this request provides reasonable assurance of structural integrity of the component. However, this analysis incorporates a CGR formula different from that described in Footnote 1 of the Order, as provided in the EPRI Report, "Material Reliability Program (MRP) Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick Wall Alloy 600 Material (MRP-55), Revision 1." The NRC staff has completed a preliminary review of the crack growth formula but has not yet made a final assessment regarding the acceptability of the report. If the NRC staff finds that the crack growth formula in industry report MRP-55 is unacceptable, the licensee shall revise its analysis that justifies relaxation of the Order within 30 days after the NRC informs the licensee of an NRC-approved crack growth formula. If the licensee's revised analysis shows that the crack growth acceptance criteria are exceeded prior to the end of the current operating cycle, this relaxation is rescinded and the licensee shall, within 72 hours, submit to the NRC written justification for continued operation. If the revised analysis shows that the crack growth acceptance criteria are exceeded during the subsequent operating cycle, the licensee shall, within 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack growth acceptance criteria are not exceeded during either the current operating cycle or the subsequent operating cycle, the licensee shall, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack growth analyses performed for this and future cycles for RPV head penetrations must be based on an acceptable CGR formula. As stated in Section 2.2.3.4 of this Safety Evaluation the licensee has committed to comply with the conditions stated above.

Based on the results from the crack growth analysis, there is reasonable assurance of structural integrity for the uninspected portions of the nozzles. Therefore, performance of UT to the bottom of the 60 CRDM nozzles and one radiation calibration instrument nozzle would result in hardship without a compensating increase in the level of quality and safety.

The staff finds that the licensee's proposed alternative examination of the 60 CRDM RPV head penetration nozzles and one radiation calibration instrument nozzle using UT from 2 inches above the J-groove weld down to a point approximately 0.516 inch above the bottom of the nozzle provide reasonable assurance of structural integrity of the RPV head, VHP nozzles, and welds. Further inspection of the 60 CRDM nozzles and one radiation calibration instrument nozzle in accordance with Section IV.C.(1)(b)(i) of Order EA-03-009 would result in hardship without a compensating increase in the level of quality and safety. Therefore, pursuant to Section IV, Paragraph F, of Order EA-03-009, good cause has been shown for relaxation of the Order, and the staff authorizes, for one operating cycle commencing with the startup from the Spring 2004 refueling outage, the proposed alternative inspection for the 60 CRDM head penetration nozzles and one radiation calibration instrument nozzle at ANO-1, subject to the following condition:

> If the NRC staff finds that the crack-growth formula in MRP-55 is unacceptable, Entergy shall revise its analysis that justifies relaxation of the Order within 30 days after the NRC

informs Entergy of an NRC-approved crack-growth formula. If Entergy's revised analysis shows that the crack growth acceptance criteria are exceeded prior to the end of the operating cycle which follows the current refueling outage, this relaxation is rescinded and Entergy will, within 72 hours, submit to the NRC written justification for continued operation. If the revised analysis shows that the crack growth acceptance criteria are exceeded during the subsequent operating cycle, Entergy shall, within 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack growth acceptance criteria are not exceeded during either the upcoming operating cycle or the subsequent operating cycle, Entergy shall, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack-growth analyses performed for the upcoming operating cycle and future cycles for RPV head penetrations will be based on an NRC-acceptable crack growth rate formula.

4.0 CONCLUSION

The staff concludes that the licensee's proposed alternative examination of the 60 CRDM RPV head penetration nozzles and one radiation calibration instrument nozzle using UT from 2 inches above the J-groove weld down to a point approximately 0.516 inch above the bottom of the nozzle provide reasonable assurance of structural integrity of the RPV head, VHP nozzles, and welds. Further inspection of the 60 CRDM nozzles and one radiation calibration instrument nozzle in accordance with Section IV.C.(1)(b)(i) of Order EA-03-009 would result in hardship without a compensating increase in the level of quality and safety. Therefore, pursuant to Section IV, Paragraph F, of Order EA-03-009, good cause has been shown for relaxation of the Order, and the staff authorizes, for one operating cycle commencing with the startup from the Spring 2004 refueling outage, the proposed alternative inspection for the 60 CRDM head penetration nozzles and one radiation calibration instrument nozzle at ANO-1, subject to the following condition:

> If the NRC staff finds that the crack-growth formula in MRP-55 is unacceptable, Entergy shall revise its analysis that justifies relaxation of the Order within 30 days after the NRC informs Entergy of an NRC-approved crack-growth formula. If Entergy's revised analysis shows that the crack growth acceptance criteria are exceeded prior to the end of the operating cycle which follows the current refueling outage, this relaxation is rescinded and Entergy will, within 72 hours, submit to the NRC written justification for continued operation. If the revised analysis shows that the crack growth acceptance criteria are exceeded during the subsequent operating cycle, Entergy shall, within 30 days, submit the revised analysis for NRC review. If the revised analysis shows that the crack growth acceptance criteria are not exceeded during either the upcoming operating cycle or the subsequent operating cycle, Entergy shall, within 30 days, submit a letter to the NRC confirming that its analysis has been revised. Any future crack-growth analyses performed for the upcoming operating cycle and future cycles for RPV head penetrations will be based on an NRC-acceptable crack growth rate formula.

Principal Contributor: G. Georgiev

Date: April 29, 2004

TABLE 1 Results of Crack Growth Analysis

Nozzle Location	Nozzle Azimuth Location	Axial Crack Evaluated	Crack Evaluation Results
0°	All	ID Part through-wall	No PWSCC growth
		OD Part through-wall	No PWSCC growth
		Through-wall	No PWSCC growth
18.2°	Downhill	ID Part through-wall	Greater than 1 Cycle to reach weld
		OD Part through-wall	Greater than 1 Cycle to reach weld
		Through-wall	Greater than 1 Cycle to reach weld
	Uphill	ID Part through-wall	No PWSCC growth
		OD Part through-wall	No PWSCC growth
		Through-wall	No PWSCC growth
	Mid-plane	ID Part through-wall	No PWSCC growth
		OD Part through-wall	No PWSCC growth
		Through-wall	No PWSCC growth
26.2°	Downhill	ID Part through-wall	Greater than 1 Cycle to reach weld
		OD Part through-wall	No PWSCC growth
		Through-wall	Greater than 1 Cycle to reach weld
	Uphill	ID Part through-wall	No PWSCC growth
		OD Part through-wall	No PWSCC growth
		Through-wall	No PWSCC growth
	Mid-plane	ID Part through-wall	No PWSCC growth
		OD Part through-wall	No PWSCC growth
		Through-wall	No PWSCC growth
38.5°	Downhill	ID Part through-wall	No PWSCC growth
		OD Part through-wall	Greater than 1 Cycle to reach weld
		Through-wall	No PWSCC growth
	Uphill	ID Part through-wall	No PWSCC growth
		OD Part through-wall	No PWSCC growth
		Through-wall	No PWSCC growth
	Mid-plane	ID Part through-wall	No PWSCC growth
		OD Part through-wall	No PWSCC growth
		Through-wall	No PWSCC growth