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Evaluation of the Indications Found at the H5 Weld Location in the Quad Cities Unit 1 Shroud

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IMPORTANT NOTICE REGARDING
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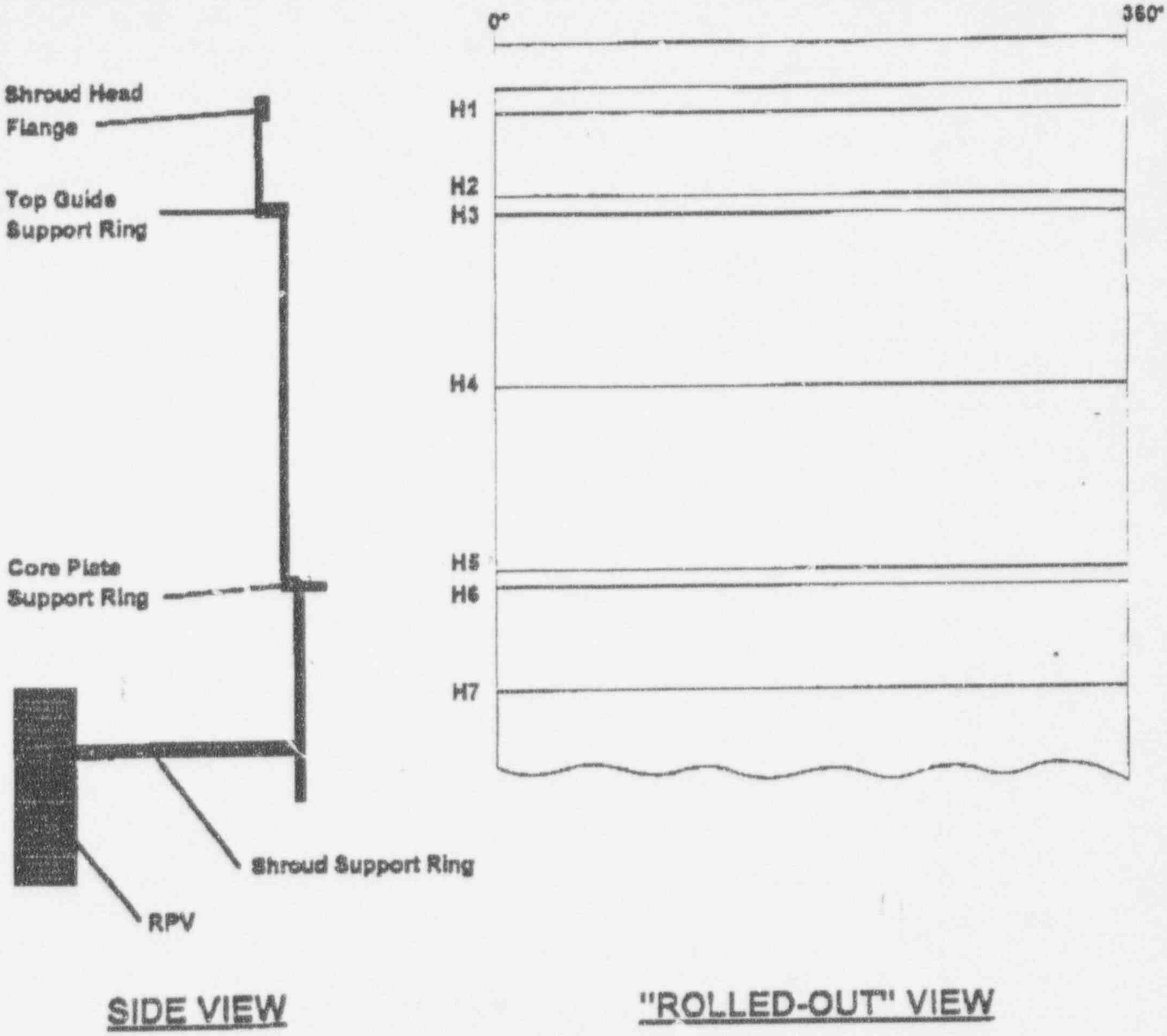
1.0 INTRODUCTION

During the current refueling outage at Quad Cities Unit 1, core shroud inspections were performed in accordance with recommendations given in GE Services Information Letter No. 572, Rev. 1 (SIL 572) [1]. During the initial portion of these inspections, crack indications were visually detected in the vicinity of the H5 weld (see Figure 1). The cracking was located immediately below the H5 weld in the core plate support ring. The indications were predominantly circumferential, and were visible at all accessible locations (approximately 150° of the circumference). Subsequent examination by automated ultrasonic testing (UT) of the indications in all areas of the H5 weld accessible by the UT system confirmed the visual indications to be cracks. Based on the results of automated and manual UT exams and on the results of boat samples taken from the H5 weld location provided by Commonwealth Edison Company (CECo), the probability of detection of flaws deeper than 1.24" on the core plate support ring side of the H5 weld is very high, and no flaws deeper than 1.24" were detected. For this reason, the bounding maximum flaw depth used for the purpose of this structural margin assessment is 1.24" [2].

The purpose of this report is to evaluate the indications found near the H5 weld from a structural standpoint. Limit load calculations are performed consistent with the previous Screening Criteria generated for the Quad Cities Unit 1 shroud [3], and structural margins are determined taking into account appropriate crack growth values and ASME Code, Section XI [4] safety factors.



NOTE: NOT TO SCALE

FIGURE 1: QUAD CITIES UNIT 1 SHROUD HORIZONTAL WELD CONFIGURATION

2.0 TECHNICAL APPROACH

The Reference 3 report documents screening criteria developed for the Quad Cities Unit 1 shroud based on limit load and linear elastic fracture mechanics (LEFM) techniques. The purpose of that report was to develop criteria that allowed indications discovered during visual inspection to be screened for further evaluation. Since the criteria were based on visual examinations, all flaws were conservatively assumed to be through-wall and allowable flaw lengths were calculated using limit load and LEFM techniques.

This evaluation determines allowable flaw depth, since UT examination has confirmed that the cracking is not through-wall. The cracking was assumed to be 360° around the circumference of the shroud for the purposes of this evaluation, since the indications discovered were seen at all accessible locations. Similar calculations to those included in the Reference 3 report were performed for a fully circumferential, part through-wall crack. Crack growth estimates were combined with the resulting allowable flaw size to determine structural margin. The results are described in detail in the sections that follow.

2.1 Allowable Flaw Size

The Reference 3 analysis conservatively included LEFM effects for welds H4 and H5 due to potential fluence effects. The fluence estimated for the H5 weld is low (3×10^{16} n/cm^2) [5]. Since the irradiation level is low, the fracture toughness is comparable to that of unirradiated material where ductile behavior governs. This is supported by studies performed by EPRI [6] where the impact of fluence in the amount accumulated by the H5 weld is negligible. Therefore, limit load calculations which use ASME Code, Section XI safety factors are the appropriate technique for evaluating structural margins for this location.

The limit load approach used here is depicted in Figure 2, as obtained from a net section collapse formulation [4,7]. The neutral axis shown in Figure 2 is determined by equilibrating the force resulting from the applied membrane stress, P_m, in the uncracked cross section with the force resulting from a stress equal to the flow stress in the remaining ligament (uncracked region) at the crack cross section.

For the case where $\alpha = 180°$ (i.e., 360° flaw), the following equations apply:

$$\beta = \frac{\pi(1-d/t-P_m/\sigma_f)}{2-d/t}$$

$$P_b' = \frac{2\sigma_f}{\pi}(2-d/t)\sin\beta$$

where:

- t = shroud thickness, inches
- d = crack depth, inches
- α = half crack angle
- β = angle that defines location of neutral axis
- P_m = applied membrane stress, psi
- P_b' = failure bending stress, psi
- σ_f = flow stress of the material = $3S_m$

From Reference 3, the faulted load condition was determined to be limiting. The faulted load condition conservatively includes loading from both a design basis earthquake (DBE) and a main steam line break. For this load case, the membrane stress, P_m, was previously determined to be 0.278 ksi and the bending stress, P_b, was determined to be 2.337 ksi. These stresses are the result of deadweight, seismic and pressure loads. Per Section XI of the ASME Code, a safety factor of 1.4 for the faulted condition was applied to these stresses in the allowable flaw size calculations. The value of S_m at 550°F for the 304 stainless steel shroud material is 16,900 psi. Trial and error solution of the equations given above using these values is shown in Table 1.

The results of Table 1 show that a crack depth of 96% (i.e., a/t = 0.96) of the shroud thickness can be tolerated while still maintaining all ASME Code structural margins. The Quad Cities Unit 1 shroud has a 2 inch wall thickness, and the H5 weld is backed by a 1" fillet weld, as shown in Figure 3. The location of the observed cracking is also shown in Figure 3. The minimum thickness through which the crack must traverse before reaching through-wall is therefore 3 inches. Therefore, the allowable flaw depth in this region, based on limit load analysis, is 2.88" (i.e., 3" x 0.96).

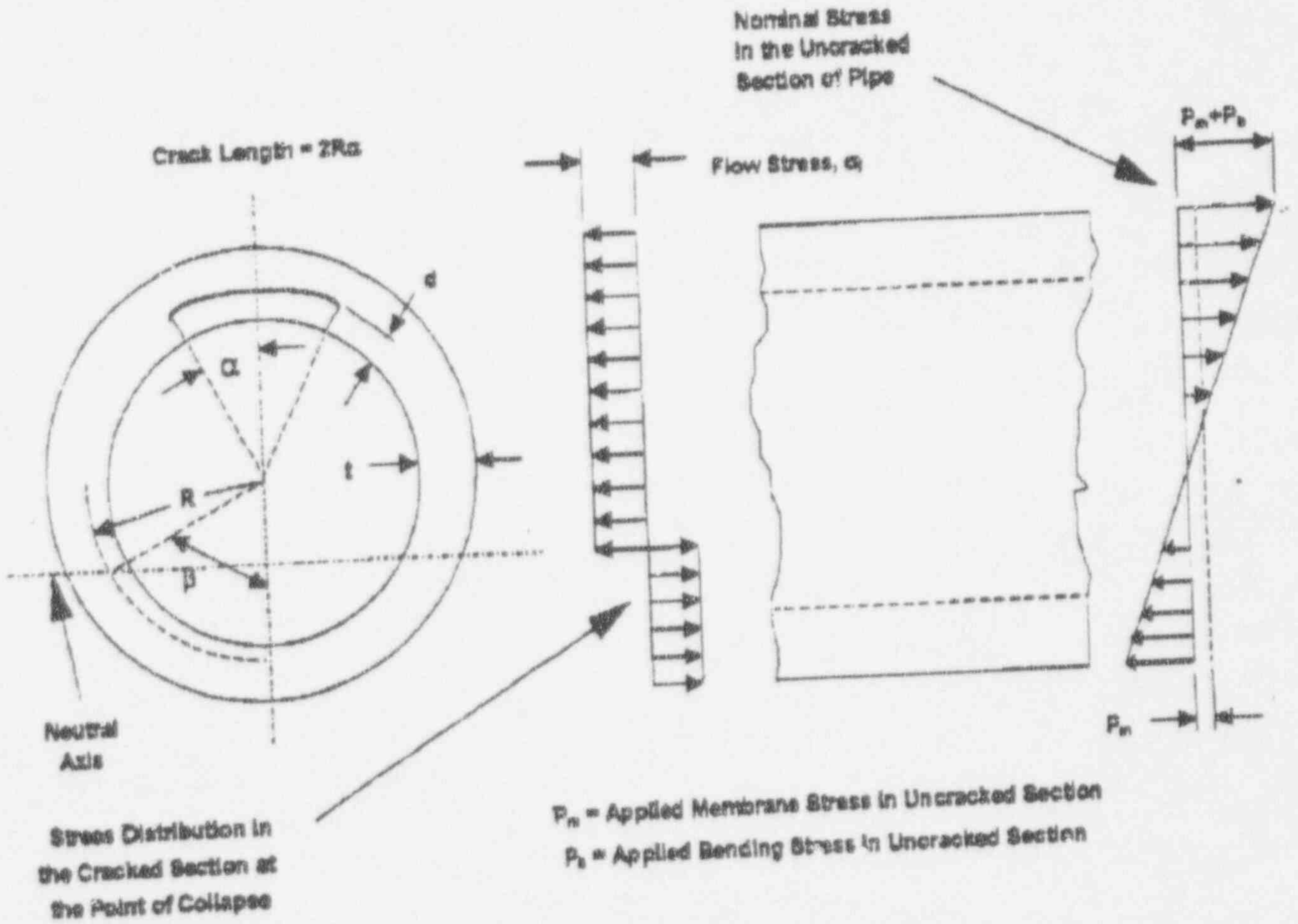


FIGURE 2: LIMIT LOAD METHODOLOGY

TABLE 1: LIMIT LOAD EVALUATION FOR WELD H5

Case #2: The neutral axis is located such that $\alpha + \beta > \pi$ (this is checked below)

$$\beta = \frac{(1 - d/t - P_m{*}SF/\sigma_f)\pi}{2 - d/t}$$ (from References 4 and 7)

$P_b' = (2{*}\sigma_f/\pi) * (2 - d/t) \sin\beta$

Given:

P_m =	278	psi (Reference 3)		
P_b =	2,337	psi (Reference 3)		
Safety Factor, SF =	1.4	(for Faulted conditions = limiting per Reference 3)		
$P_m{*}SF$ =	389	psi		
$P_b{*}SF$ =	3,272	psi		
S_m =	16,900	psi (at 550°F for 304 SS)		
$3S_m$ =	50,700	psi = σ_f		
α =	180	° =	3.1416	radians

Thus:

β = (3.1175 - 3.1416 d/t) / (2 - d/t) [Eqn. 1]

P_b' = 32276.6 * (2 - d/t) sinβ [Eqn. 2]

Solving by trial and error:

d/t	β from [Eqn. 1] (radians)	P_b' from [Eqn. 2] (psi)	Difference = $P_b' - P_b{*}SF$	β (°)	α + β > π ?
0.1000	1.4754	61,047	57,775	84.5	YES
0.2000	1.3829	57,075	53,803	79.2	YES
0.3000	1.2794	52,557	49,285	73.3	YES
0.4000	1.1630	47,408	44,136	66.6	YES
0.5000	1.0311	41,534	38,262	59.1	YES
0.6000	0.8804	34,838	31,566	50.4	YES
0.7000	0.7064	27,237	23,965	40.5	YES
0.8000	0.5035	18,688	15,416	28.8	YES
0.9000	0.2637	9,253	5,982	15.1	YES
0.9100	0.2373	8,269	4,998	13.6	YES
0.9200	0.2104	7,280	4,008	12.1	YES
0.9300	0.1830	6,284	3,013	10.5	YES
0.9400	0.1551	5,284	2,013	8.9	YES
0.9500	0.1266	4,280	1,008	7.3	YES
0.9600	0.0976	3,272	1	5.6	YES
0.9601	0.0973	3,262	-9	5.6	YES

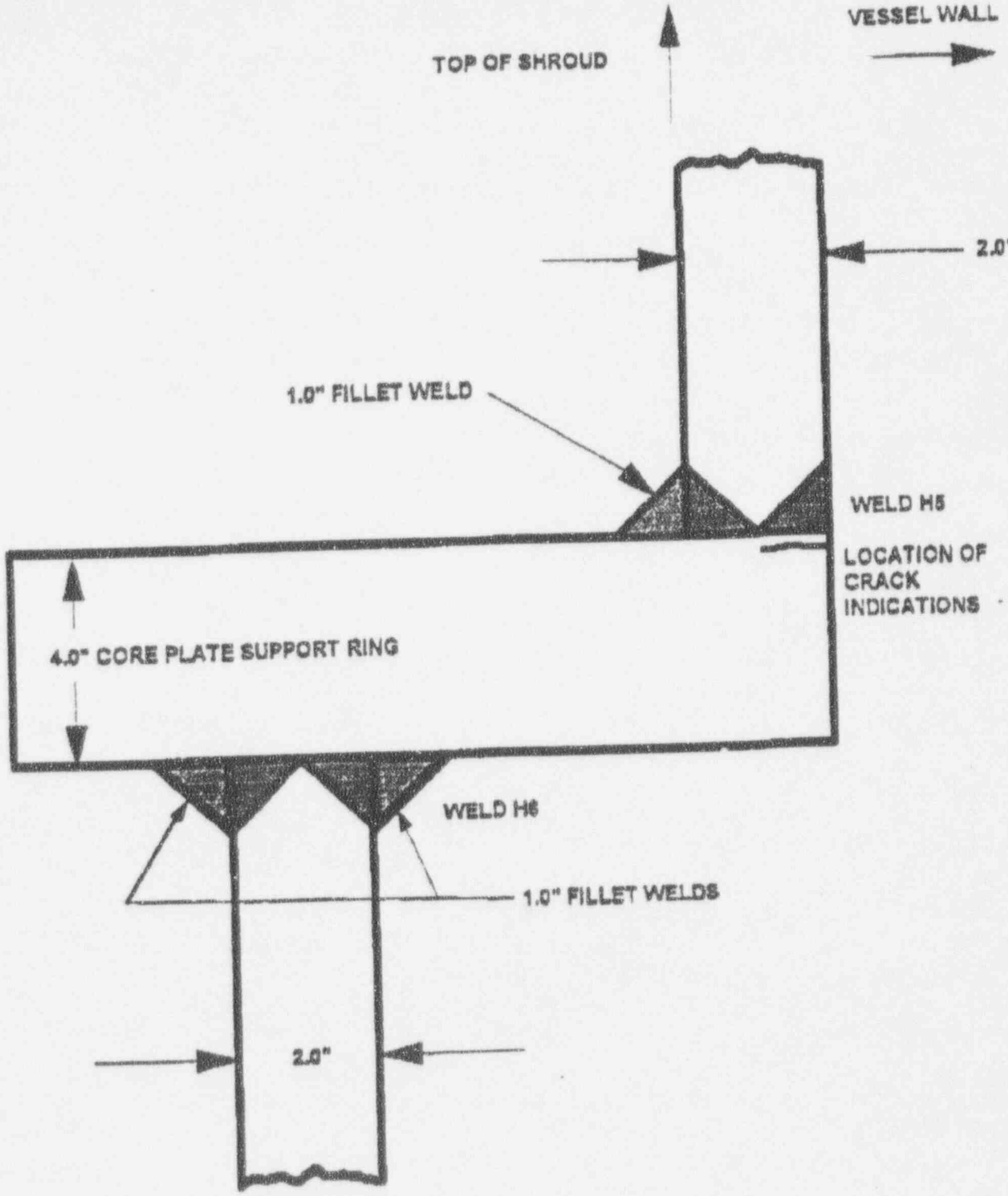


FIGURE 3: H5 WELD DETAILS AND CRACKING LOCATION

2.2 Crack Growth Assessment

Prior analyses [3] have conservatively used a crack growth rate of 5×10^{-5} inch/hour. This was intended to be a bounding value that covered both intergranular stress corrosion cracking (IGSCC) and irradiation assisted stress corrosion cracking (IASCC). More recent predictions made with the GE PLEDGE predictive model where plant-specific water chemistry and other effects were included suggest a crack growth rate of 1.32×10^{-5} inch/hour, as shown in Figure 4. Thus, the 5×10^{-5} inch/hour value based on the IGSCC/IASCC combination is definitely conservative for the H5 weld.

A significant point to be made is that the observed cracking thus far is mainly due to prior operation at relatively high conductivities, including aggressive anions such as sulfates and chlorides. With the increased attention to IGSCC, most boiling water reactor (BWR) plants have dramatically reduced their aggressive anion input, thus assuring that future crack growth rates are much lower than that in the past. Quad Cities Unit 1 currently operates below 0.15 μS/cm conductivity and 5 ppb chloride and sulfate combined. Figure 4 shows the dependence of the predicted growth rate on the conductivity based on the GE predictive model for IGSCC. Figures 5 and 6 show the dependence on sulfate and chloride species [9]. In all cases, the lower sulfate and chloride levels lead to dramatically lower crack growth rates. Additionally, Quad Cities Unit 1 has been operated on hydrogen water chemistry (HWC) since the third quarter of 1990 [8] which will help contribute to reduced crack propagation rates. Thus, any margin assessments based on the two growth rates (5×10^{-5} inch/hour for bounding values and 1.32×10^{-5} inch/hour based on the GE PLEDGE predictive model) are conservative.

Pre-operational testing of BWR internals has demonstrated that high cycle fatigue resulting from flow induced vibration is not a concern for the core shroud. Additionally, low cycle fatigue caused by thermal and/or pressure changes in the core region are negligible since all anticipated changes in these parameters result in relatively low stresses in the core shroud. This is further supported by the fact that no fatigue cracking was observed from boat samples removed from the cracked areas of the Quad Cities 1 shroud, as well as the core shrouds of other BWRs. Therefore, the impact of fatigue on the core shroud is concluded to be negligible, and is not considered to be a further contributor to the crack growth values discussed here.

The use of the automated UT system combined with enhanced manual UT provided crack depths at a number of locations along the circumference. As expected, the crack depths varied along the circumference of the inspected regions. For conservatism, the bounding maximum flaw

depth of 1.24" was used in the limit load evaluation described in this report. Since the evaluation for limit load is based on the total structural area available, the more appropriate value to use is the average depth, not the bounding maximum depth. Therefore, the structural margins shown in the next section are likely to reflect even more conservatism.

2.3 Structural Margin Determination

Since crack indications with a bounding maximum depth of 1.24" were estimated based on UT and boat sample evaluation, a maximum crack depth of 1.24" was conservatively used for evaluating structural margin. Crack growth values corresponding to each of the two crack growth values identified above were added to this maximum flaw depth. Structural margin was assessed by comparing the remaining ligament to the required ligament obtained from the limit load evaluation. The results are shown in Table 2.

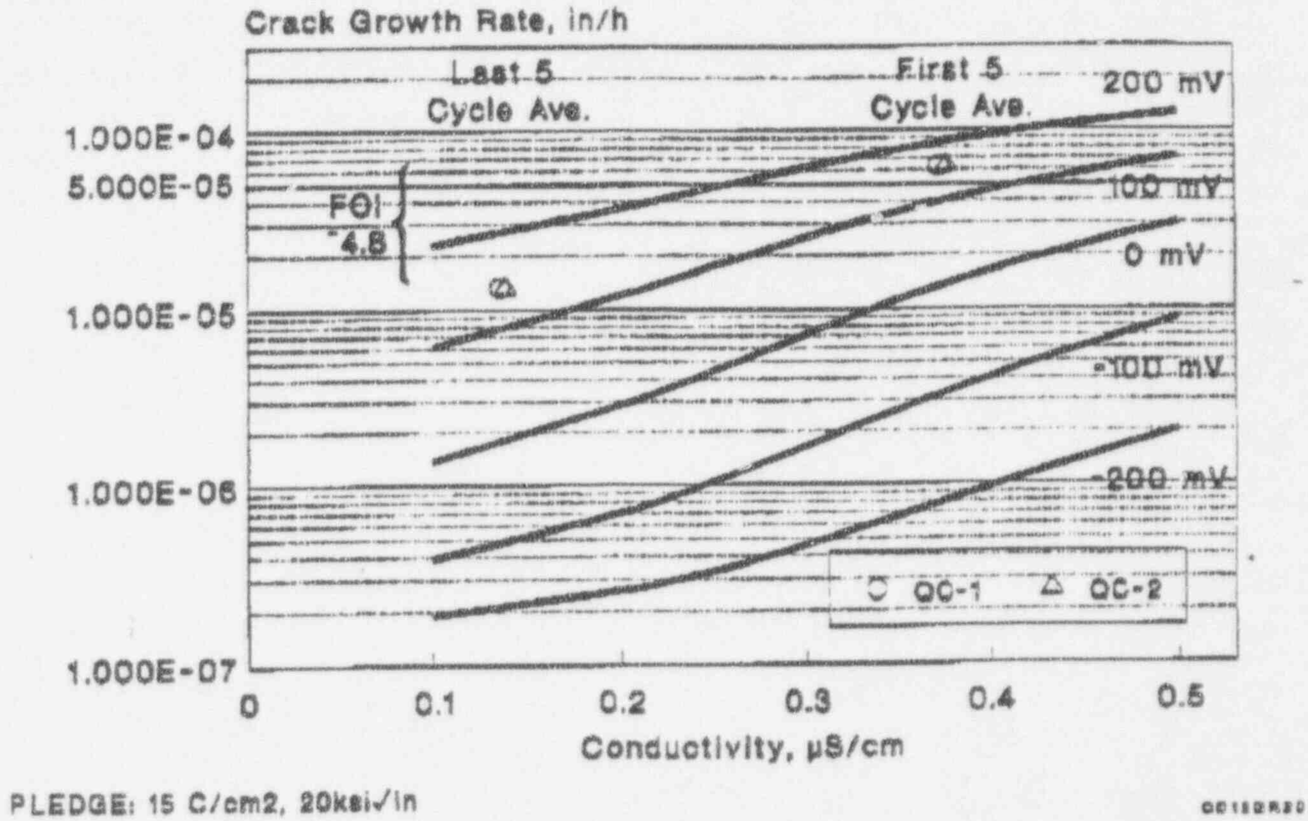


FIGURE 4: PLEDGE MODEL PREDICTION FOR QUAD CITIES 1/2

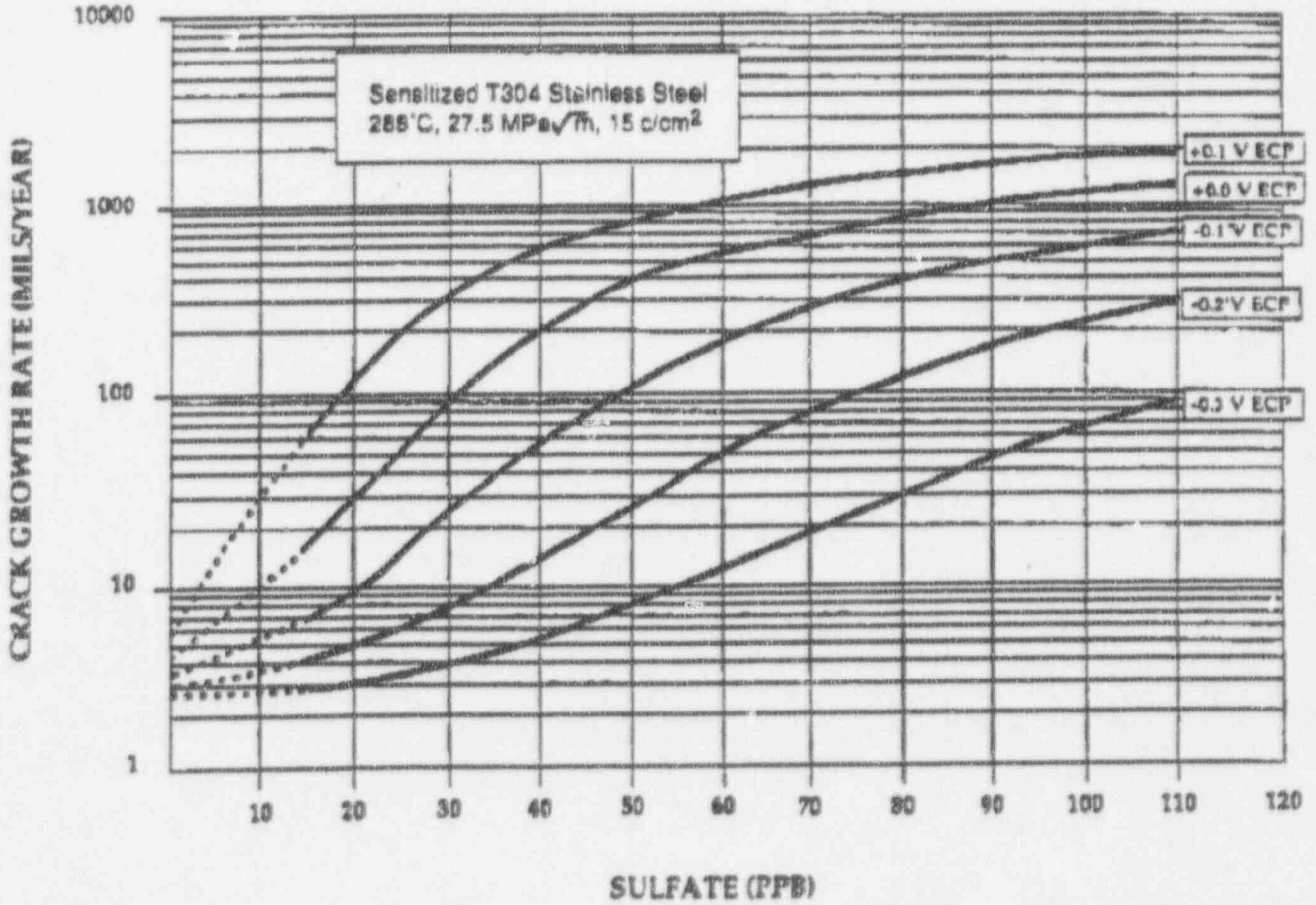


FIGURE 5: CRACK GROWTH RATE AS A FUNCTION OF SULFATE

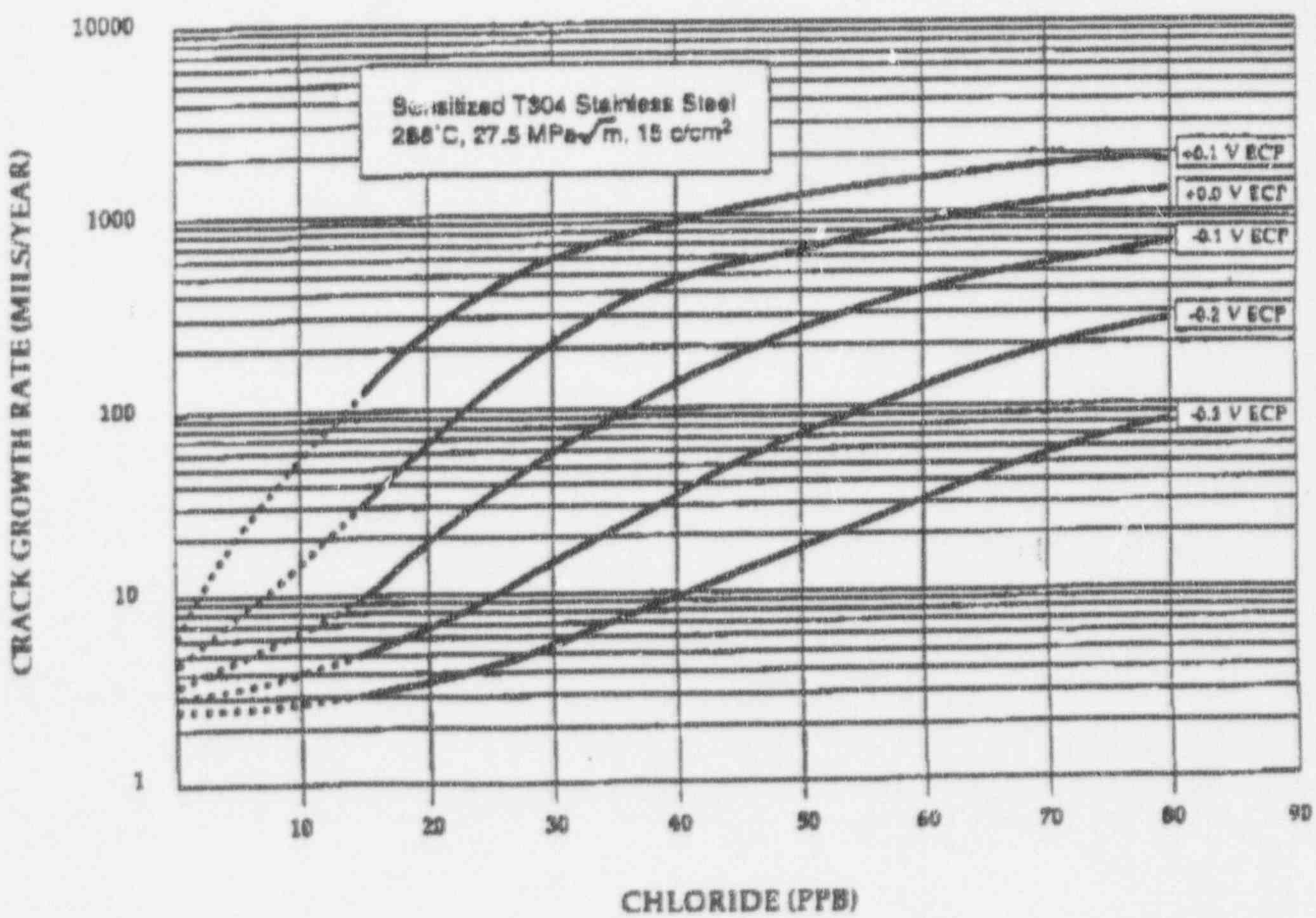


FIGURE 6: CRACK GROWTH RATE AS A FUNCTION OF CHLORIDE

TABLE 2: STRUCTURAL MARGIN RESULTS FOR WELD H5

(Based on a 360°, 1.24" Depth Flaw)

Case	Crack Growth Rate [inch/hour]	Crack Growth Period [months]	Crack Growth[1] [inches]	Final Crack Depth [inches]	Allowable Crack Depth [inches]	Margin Factor[2]	Time Until Allowable Depth is Reached[3] [hours (yrs)]
1	5×10^{-5}	6	0.20	1.44	2.88	13.0	32,800 (4.1)
2	5×10^{-5}	18	0.60	1.84	2.88	9.7	32,800 (4.1)
3	1.32×10^{-6}	6	0.05	1.29	2.88	14.3	124,200 (15.5)
4	1.32×10^{-5}	18	0.16	1.40	2.88	13.3	124,200 (15.5)

NOTE: (1) Crack growth is determined for each crack growth period assuming 8,000 hours per year (≈91% availability).

(2) The margin factor is calculated by dividing the remaining ligament by the required ligament, as follows (for case #1, thickness = 3"):

Margin Factor = Remaining Ligament/Required Ligament
= (3.0-1.44)/(3.0-2.88)
= 13.0

(3) The time until the allowable crack depth is reached is determined by dividing the minimum existing ligament by the crack growth rate, as follows (for case #1):

Time = Minimum Existing Ligament/Crack Growth Rate
= (Allow. Depth-Current Maximum Depth)/Crack Growth Rate
= $(2.88-1.24)/5 \times 10^{-5}$
= 32,800 hours
or 32,800/8,000 = 4.1 years

3.0 CONCLUSIONS

This evaluation provides a structural margin assessment of the indications found near the H5 weld in the Quad Cities Unit 1 shroud. Limit load techniques and ASME Code, Section XI safety factors were used to demonstrate adequate structural margin for the next 18-month fuel cycle of operation assuming a 360°, 1.24-inch deep flaw at the H5 weld location. The structural margin results are summarized in Table 2. A list of all of the conservative assumptions used in the evaluation is provided in Table 3.

The results of Table 2 demonstrate, based on limit load techniques, that approximately a factor of ten is available in terms of required area for a 18-month fuel cycle of operation with a bounding maximum flaw depth of 1.24" in the H5 weld of the Quad Cities Unit 1 shroud.

TABLE 3: CONSERVATIVE ASSUMPTIONS INCLUDED IN LIMIT LOAD EVALUATION

1. A 360° crack was assumed, even though only approximately 150° of the circumference was examined and found to have cracking.

2. Crack depth was based on the bounding maximum crack depth which can be detected with high probability by UT rather than the average crack depth.

3. The bounding crack growth estimated for the next fuel cycle was included in the structural margin assessment.

4. ASME Code pressure boundary safety margins were applied even though the shroud is not a primary pressure boundary.

4.0 REFERENCES

[1] GE Nuclear Energy, "Core Shroud Cracks," GE Services Information Letter No. 572, Revision 1, October 4, 1993.

[2] Letter from M. D. Lyster (CECo) to W. T. Russell (NRC) dated 6/6/94, "Response to NRC Request for Additional Information Concerning Core Shroud Cracking at Dresden Units 2 & 3 and Quad Cities Units 1 & 2."

[3] GENE-523-02-0194, Revision 0, "Evaluation and Screening Criteria for the Quad Cities 1 and 2 Shrouds," W.F. Weitze, GE Nuclear Energy, San Jose, CA, March 1994.

[4] ASME Boiler & Pressure Vessel Code, Section XI, "Rules for Inservice Inspection for Nuclear Power Plant Components," 1989 Edition, American Society of Mechanical Engineers, New York.

[5] Letter from Sylvia Wang (GE) to Gary Stevens (GE), "Estimated Fluences at Shroud Welds H1 to H7 for Dresden 2 and Quad Cities 1 & 2," May 20, 1994.

[6] EPRI Report NP-4767, Project 2680-2, "Evaluation of BWR Top-Guide Integrity," Electric Power Research Institute, Component Reliability Program, Nuclear Power Division, Final Report, November 1986.

[7] Sampath Ranganath and Hardayal S. Mehta, "Engineering Methods for the Assessment of Ductile Fracture Margin in Nuclear Power Plant Piping," Elastic-Plastic Fracture: Second Symposium, Volume II -- Fracture Resistance Curves and Engineering Applications, ASTM STP 803, American Society for Testing Materials, 1983.

[8] GENE-NE-A00-05652-04, "Preliminary Safety Assessment of Core Shroud Indications for Cycle 13 Operation of Quad Cities Unit 2," D. K. Rao, GE Nuclear Energy, May 1994.

[9] EPRI Report TR-103515, Project 2493, "BWR Water Chemistry Guidelines -- 1993 Revision, Normal and Hydrogen Water Chemistry," Electric Power Research Institute, BWR Water Chemistry Guidelines Revision Committee, February 1994.

ATTACHMENT 4

Structural Integrity Report RAM-94-159, Revision 0, dated June 11, 1994, Evaluation of Flaws in Circumferential Core Shroud Welds at Quad Cities Unit 1.

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June 11, 1994
RAM-94-159
SIR-94-052
Revision 0

Mr. Thomas J. Wojcik
Commonwealth Edison Company
Quad Cities Nuclear Station
22710 206th Avenue North
Cordova, Illinois 61242

Subject: Evaluation of Flaws in Circumferential Core Shroud Welds At Quad Cities, Unit 1

Dear Tom:

Structural Integrity Associates (SI) has performed an evaluation of the flaw indications found in circumferential welds H1, H2, H3, H4, H6, and H7 at Quad Cities, Unit 1, in order to determine the ASME Code structural margin in each of these welds. The evaluation of weld H5 was performed elsewhere and will be submitted under separate cover. The evaluation performed here was designed to evaluate operation without repair of these welds for an 18-month operating cycle. The inspection and evaluation were performed following the approach used in the Inspection Criteria [1] and Screening Criteria [2] developed for Quad Cities, Unit 1, based on limit load and linear elastic fracture mechanics (LEFM) techniques. The purpose of the screening criteria was to develop criteria that allowed indications discovered during visual inspection to be screened for further evaluation. The Inspection Criteria refined the screening criteria providing for minimum distributed sound material which would allow for operation for the specified operating period. Since the criteria were based on visual examinations, all flaws were conservatively assumed to be through-wall, and allowable flaw lengths were calculated using the appropriate limit load or LEFM techniques. The following sections of this letter report describe the methodology used in the initial inspection and the evaluation results.

Initial Inspection and Evaluation Methodology

The inspection and evaluation approach employed at Quad Cities, Unit 1 provides the necessary information for determination of the allowable flaw lengths, including crack growth for the next operating period for all flaws observed, while assuming that the cracking is through-wall wherever it is observed. An initial sample of four to eight locations, spaced approximately evenly around the circumference of each horizontal weld in the shroud, represented the examination area for the initial in-vessel visual inspection (IVVI) for the core shroud.

The sample was structured such that if sufficient sound metal was found visually to satisfy the screening criteria, the weld was accepted for continued operation for the next operating period. If sufficient sound metal was not observed, the IVVI was to be expanded as additional accessible locations were identified, given the physical constraints associated with the inspection, to other areas around the shroud, and was continued until sufficient sound metal was found, or until all accessible areas were inspected.

This IVVI was performed on the outside surfaces of the core shroud for the H1, H2, H3, H4, H5, H6, and H7 welds and on the inside surface of welds H3 and H4. Additionally, ultrasonic examination (UT), using sophisticated state-of-the-art equipment, was performed on welds H2, H6 and H7 in order to corroborate the visual qualification.

Acceptance Criteria

The core shroud is a core support structure which provides lateral support for the fuel. The applicable codes, standards and classifications for the core shroud are as follows:

- The core shroud is classified as a safety-related component.
- The core shroud is not an ASME Code component. However, the original design is in accordance with the intent of Section III of the ASME Code.
- The evaluation of the core shroud was performed in accordance with the requirements of Section XI of the ASME Code, 1989 Edition, Paragraph IWB-3142.4. [3]

Flaw Evaluation Results

Following completion of the inspection of the H1, H2, H3, H4, H6, and H7 welds, flaw analyses were performed to demonstrate that the structural margins identified in the screening criteria were maintained for the actual flaw configurations which were identified. The flaw analyses were performed using limit load as the failure criterion for each of the

welds. The evaluation performed here takes into account the distribution of uncracked material around the circumference of the shroud, an approach less restrictive than assuming in the limit load analysis that the cracks are continuous. In addition, the H4 weld, which is the core beltline shroud weld, was also evaluated using LEFM fracture methodology to be consistent with the screening criteria [2]. The visual inspections of weld H4 were performed on the ID and the OD as separate examinations. The examinations did not overlap precisely at all azimuths. As a result, approximately 260-inches of circumferential length was examined combining the OD and ID results. The inspection length examined during the OD inspections was 162-inches, while 116-inches were inspected during the ID examination. A total of 15-inches of overlap occurred in the examinations.

The flaw analyses for the evaluated welds were performed using limit load as the failure criterion for each of the welds. Substantial conservatisms were built into the flaw evaluation to account for the weld area examined and that area which was not examined, through-the-thickness crack growth and circumferential crack growth, and the screening criteria flaw proximity criteria as applied to adjacent flaws. The specific conservatisms utilized in this evaluation are as follows:

1. A bounding crack growth rate ($5x10^{-5}$ in/hr) through-wall and around the circumference was applied to the cracks detected for the next operating cycle (18-months) for the structural margin assessment.

2. All inspected regions which are identified as cracked, whether by IVVI, or as reduced by UT in previously uncracked IVVI locations, are treated as through-wall cracks and grow by 0.625 inches at each end during the next 18-month operating cycle.

3. All uninspected regions associated with the IVVI examination are assumed to be cracked through-wall and are grown by a length of 0.625 inches on each side during the next 18-month operating cycle.

4. ASME Code pressure boundary safety margins were applied to these evaluations even though the core shroud is not a primary pressure boundary.

5. ASME Code, Section XI proximity rules for adjacent flaws were applied.

The conservative assumptions described above were applied to each of the horizontal welds examined in this report. According to the screening criteria [2], the loading condition which governs the limit load analysis is the faulted condition. Table 1 presents the membrane and bending stresses for the faulted condition which were used for the limit load analyses for each of the welds identified in the table. One notes from Table 1 that the highest loads are observed at the H6 and H7 welds, and the lowest loads occur at the H1 and H2 weld

locations. The limit load analysis was performed for all welds evaluated, the H1, H2, H3, H4, H6, and H7 welds.

Table 2 presents the results of the IVVI inspection taken from Reference 4 for each of the horizontal welds evaluated in this report. The Table 2 IVVI results for the H6 weld are reduced by the UT results on that weld, as described in the conservatisms discussion above. The IVVI for H6 was performed on the OD. The UT examination of the H6 weld detected a single 2-inch flaw on the ID. Therefore, the visual inspection results were reduced by the UT results. These combined IVVI and UT results were used for the limit load analysis performed on weld H6. For weld H4, the IVVI results presented in Table 2 are ID results, representing an inspection extending a total of 116-inches in length. The ID inspection identified two 1/2-inch long flaws separated by 17° in circumference. The OD inspection of weld H4 extended a total of 162-inches and identified no flaws. Therefore, the ID inspection is limiting and is used in the limit load and LEFM analyses for weld H4. Table 2 also presents the IVVI sound metal locations (no flaws) which were used in the limit load analyses for all of the remaining welds (H1, H3, and H7).

The results of the limit load analysis for each of the horizontal welds evaluated is presented in Table 3. One observes from this table that the factors of safety for the faulted condition (Table 1) range from 1.5 for weld H7 to 56.0 for weld H3. This compares to an ASME Code factor of safety of 1.4 specified for pressure boundary components under faulted loading conditions. One should note that the conservatisms utilized are as described previously in this section.

The H4 weld was evaluated using the methodology incorporated in the initial Inspection Criteria [1] for the ID surface IVVI inspection. The combined lengths inspected on the ID and on the OD far exceeded the minimum inspection lengths. A total of 162-inches of weld length were inspected on the OD by IVVI with no indications observed. A total of 116 inches of weld length were inspected on the ID containing a total of two indications, each approximately 1/2-inch in length at locations remote from one another. Consequently, a total of approximately 25 percent of the OD circumference and approximately 16 percent of the ID were inspected and found to be almost entirely defect free. The results of the limit load analysis for the H4 ID is presented in Table 3. The LEFM results for this location are presented in Table 4.

Summary

Based upon a review of the IVVI data for circumferential welds H1, H2, H3, H4, H6, and H7, as supplemented by the UT results for welds H2, H6, and H7, there is ASME Code margin for each of these welds under very conservative conditions to allow for continued operation for a minimum of one 18-month operating cycle. The analyses performed included limit load analyses under bounding design basis accident conditions, and LEFM for

the postulated highest fluence weld, and the evaluation was performed with the assumptions that all regions uninspected by IVVI or UT were cracked through-wall and that any cracking observed by UT was cracked through wall. Additionally, all uninspected regions were treated as through-wall cracks growing around the circumference. ASME Code safety margins were used and were met or exceeded in all cases for the next 18-month operating cycle.

Very truly yours,

for

R. A. Mattson, P.E.
Associate

/mm
attachments

References

1. GE Nuclear Energy, "Recommended Inspection Criteria for the Quad Cities Unit 1 and 2 Shrouds", GENE-523-30-0294, March, 1994.

2. GE Nuclear Energy, "Evaluation and Screening Criteria for the Quad Cities Unit 1 and 2 Shrouds", GENE-523-02-0194, March, 1994.

3. American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, 1989 Edition.

4. Commonwealth Edison Company, "Response to NRC Request for Additional Information concerning Core Shroud Cracking At Dresden, Units 2 and 3, and Quad Cities, Units 1 and 2", June 6, 1994.

5. GE Nuclear Energy, "Quad Cities, Unit 1 UT Inspection Results, Weld H2, H6, and H7 Examination Summary Sheet", Report No. R-S04, Data Sheet Nos. D-S05 through D-S09, June 1, 1994.

Table 1

Membrane/Bending Stresses

Weld Location	Shroud Stresses	
	Membrane	Bending
H1	0.425 ksi	0.139 ksi
H2	0.410 ksi	0.309 ksi
H3	0.369 ksi	0.374 ksi
H4	0.330 ksi	1.303 ksi
H6	0.610 ksi	2.560 ksi
H7	0.599 ksi	3.631 ksi

NOTE: 1. All values are for the Faulted Condition. Per the Screening Criteria, the Faulted Condition governs for limit load and LEFM analyses for these welds.

Table 2

"Sound Metal" Locations

Weld Location	IVVI Locations
H1	42°-49°, 132°-139°, 222°-229°, 322°-329°
H2	42°-49°, 132°-139°, 222°-234°, 322°-329°
H3	0°-85°, 92°-148°, 152°-160°, 165°-185°, 215°-225°, 260°-360°
H4	83°-97°, 173°-187°, 260.14°-276.86°, 277.14°-280°, 355°-15°
H6	15°-25°, 75°-85°, 105°-115°, 140°-145.4°, 146.38°-175°, 195°-205°, 255°-257°, 261°-265°, 285°-295°, 320°-355°
H7	41°-49°, 135°-170°, 296°-304°, 320°-355°

NOTES:

1. Values are from the "Shroud Visual Inspection Status", except as noted.
2. Values exclude identified indications.

Table 3

Limit Load Factors-of-Safety
Based Upon IVVI Results

Weld Location	Factors-of-Safety
H1	7.1
H2	5.8
H3	56.3
H4	5.6
H6	4.5
H7	1.5

Table 4
LEFM Factor-of-Safety
Based Upon IVVI Results

Weld Location	Factor-of-Safety
H4	1.7