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December 14, 2006

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

SUBJECT: Duke Power Company LLC d/b/a Duke Energy Carolinas, LLC (Duke)
McGuire Nuclear Station, Unit 2
Docket Number 50-370
Relief Request 06-GO-001
Response to Request for Additional Information regarding Stress Analysis

On July 27, 2006, Duke submitted Relief Request 06-GO-001 pursuant to 10 CFR 50.55a(a)(3)(i), requesting NRC approval to use alternatives to the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI inservice inspection (ISI) requirements for the McGuire and Catawba Nuclear Stations, Units 1 & 2. This proposed alternative approach is to support application of full structural weld overlays on various pressurizer nozzle-to-safe end welds and will provide an acceptable level of quality and safety.

On August 30, 2006, the NRC Staff electronically requested additional information regarding several issues contained within the relief request. Duke submitted a response to this request on September 11, 2006.

The NRC requested further clarification to the relief request during a conference call on September 20, 2006. This information included further technical clarification as well as a request to incorporate all changes into one document and resubmit the entire relief request. This relief request was resubmitted on September 27, 2006 for McGuire Unit 2 and Catawba Unit 1.

The September 27, 2006 submittal contained a commitment that prior to entry into Mode 4 from the McGuire Unit 2 outage in the fall of 2006, a summary of the results of the stress analyses demonstrating that the preemptive full structural weld overlay will not hinder the components from performing their design function will be submitted to the NRC. The summary of the results of the stress analyses was submitted to the NRC on October 26, 2006.

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On November 13, 2006, the NRC Staff electronically requested additional information regarding the summary of the results of the stress analyses. The requested information is attached.

If you have any questions or require additional information, please contact P. T. Vu at (704) 875-4302.

Sincerely,

Gary R. Peterson

Attachment

xc (with attachment):

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bxc (with attachment):

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R. N. McGill (CN03PS)
J. F. Swan (MG01MM)
MNS MasterFile MC-801.01 (MG01DM)
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Attachment

Responses to Request for Additional Information
Relief Request 06-GO-001 Commitments
McGuire Nuclear Station Unit 2
Duke Energy

REQUEST FOR ADDITIONAL INFORMATION
RELIEF REQUEST 06-GO-001 COMMITMENTS
MCGUIRE NUCLEAR STATION UNIT 2
DUKE ENERGY

By letter dated October 26, 2006, Duke Energy submitted the results of the stress analyses demonstrating that the preemptive full structural weld overlay of the nozzle-to-safe end welds of the pressurizer will not hinder the components from performing their design function. To complete its review, the staff requests the following additional information.

The following questions are related to Attachment 2 to the October 26, 2006 letter, which contains the results of the licensee's stress analyses.

1. The licensee performed stress analysis of the overlaid pressurizer nozzle welds in accordance with Subarticles NB-3200 and NB-3600 of the ASME Code, Section III. The results as shown in Table 2-2, showed that applied stresses of Equation 10 of Subarticle NB-3600 for the overlaid nozzles exceeded the allowable stress. For the spray nozzle, the applied stress (149.09 ksi) calculated based on Equation 10 is 3 times higher than the allowable stress (48.53 ksi). For the safety/relief nozzle welds, the applied stress (67.58 ksi) is about 1.4 times higher than the allowable stress (47.88 ksi). (A) Discuss why the applied stress exceeds the allowable with such high margins after weld overlays. (B) Provide the applied stresses calculated for the original spray and safety/relief nozzle welds without the weld overlay.

   A. The analysis technique for the spray and safety/relief nozzle weld overlays employed detailed three-dimensional finite element models, e.g. Figure 1. Stresses were evaluated on several paths for ASME Code, Section III evaluation, as illustrated in Figure 2 (a total of nine paths were chosen, three at the intrados section of the model, as illustrated in the figure, three at the extrados section, and three at an intermediate location (mid-way between the extrados and intrados, denoted as the "cheek" section). The models predict high elastic primary-plus-secondary stresses at some locations, specifically at the elbow end of the overlay, in the intrados section, on the outside surface (Path 3 in Figure 2). However, a component may still be qualified in accordance with ASME Code, Section III when the $3S_m$ limit on primary-plus-secondary stress range is exceeded, as long as the alternate analysis requirements of NB-3653.6 and NB-3653.7 are satisfied. Such analyses were performed for the McGuire/Catawba spray and safety/relief nozzle weld overlays, and the results were found to be acceptable. The results of these analyses are summarized in the response to Question 3 below.

   The approach taken in reporting stress results for primary-plus-secondary effects was based upon the following:

Structural Integrity Associates, Inc.

- Results reported for the post-overlay analyses are the extreme fiber values of stress intensity from the finite element models. Equation 10 of the ASME Code, as reported for the pre-overlay piping stress analyses, considers stress versus stress intensity.
- Mechanical loads used in the analysis for the spray and safety/relief nozzles bounded all four units (McGuire 1 and 2, and Catawba 1 and 2).
- In addition, mechanical loads used for the spray nozzle were increased by an extra 20% design margin.

B. Results for the Equation 10 plant-specific analyses of the safety/relief and spray nozzles, pre-overlay, are as follows:

Safety/Relief Nozzle-Equation 10 stress equals 56.4 ksi
Spray Nozzle-Equation 10 stress equals 84.1 ksi

Because of the discussion in Item A above, reported results for the overlaid configuration are conservative. The safety/relief nozzle weld overlay results are 20% higher than the Equation 10 results reported in the pre-overlay piping stress analyses. The spray nozzle results are 77% higher. The detailed finite element analysis, different geometry and materials, and the conservative assumptions described above explain the differences.

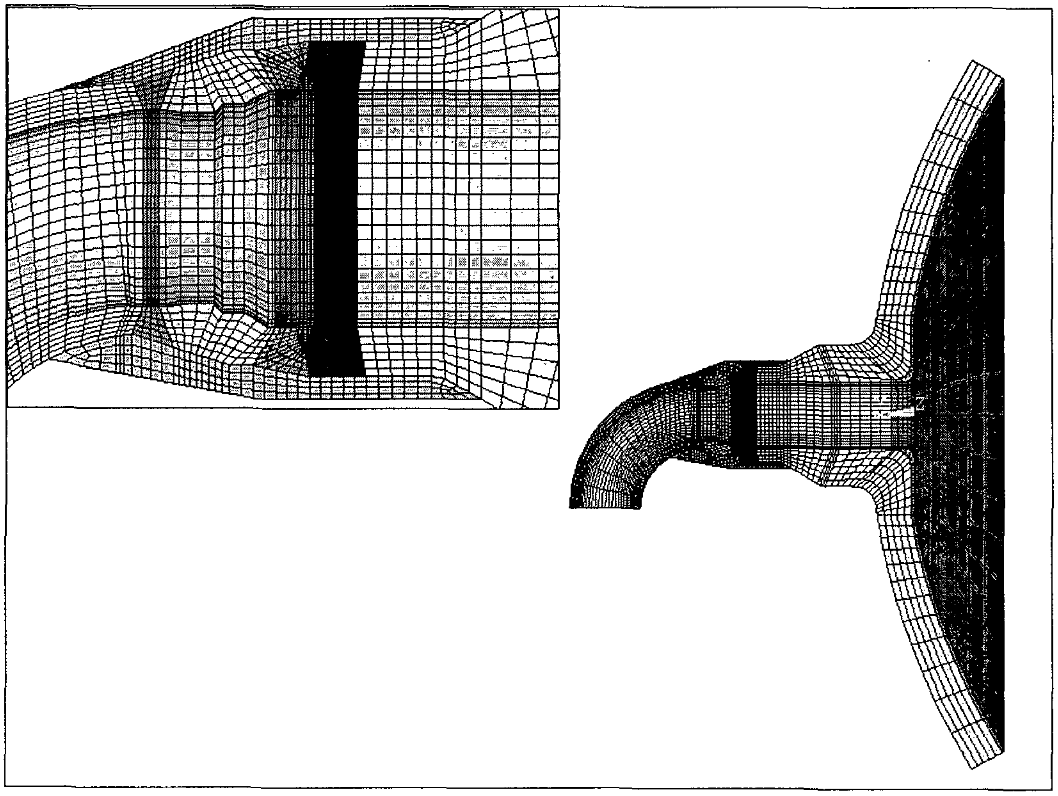


Figure 1: Three-Dimensional Finite Element Model for McGuire/Catawba Spray Nozzle

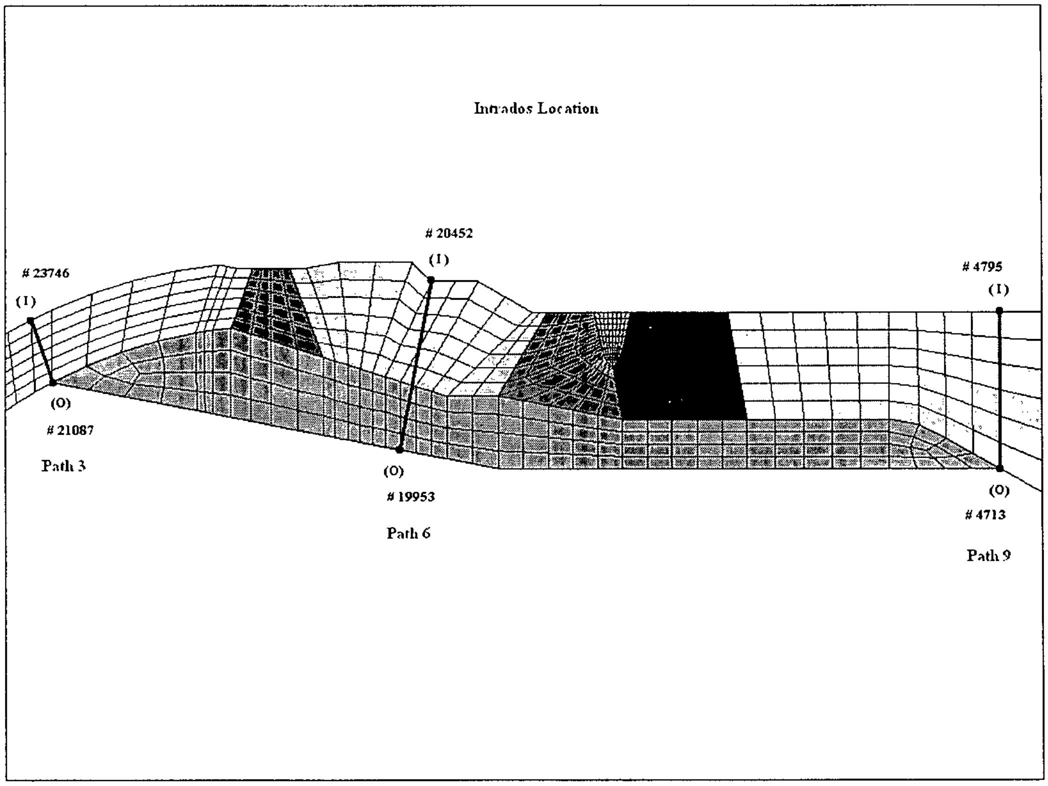


Figure 2: Stress Paths for ASME Code, Section III Stress Evaluation – Intrados Location

2. Table 2-2 showed that the cumulative usage factor for spray and surge nozzles are 0.986 and 0.994, respectively. (A) Discuss whether the cumulative usage factors are applicable to the end of the current license or license renewal period. The NRC has approved license renewal for McGuire Unit 2. If the above cumulative usage factor is applicable to the end of 40-year license, it is highly likely that the cumulative usage factor at the end of 60-year license renewal period would exceed the allowable usage factor of 1.0. Discuss whether this is the case. (B) Discuss how the cumulative usage factors are calculated for the weld overlay. That is, discuss whether the cumulative usage factor is calculated by adding the usage factor for the operating years prior to the weld overlay installation and the usage factor for the operating years after the weld overlay installation.

   A. The cumulative usage factors are applicable to the license renewal period. As discussed in NUREG-1722, "Safety Evaluation Report Related to the License Renewal of McGuire Nuclear Station, Units 1 and 2, and Catawba Nuclear Station Units 1 and 2, Section 4.3," the projected number of transients for the 60 year operating period is not expected to exceed that assumed in the original design. As further described in NUREG-1722, Duke relies on the Thermal Fatigue Management Program to monitor the number and severity of transient occurrences even though the projected number of transients for the 60 year operating period is not predicted to exceed the original design number of transients.

B. The fatigue analyses for the spray and surge nozzles utilized the complete set of operating transients, as discussed in Item A above, which were conservatively grouped into bounding transients for analysis. Where applicable, the analyses also included K_e factors, as required by the simplified elastic-plastic analysis requirements of NB-3653.6. This conservative, bounding approach yielded usage factors at most locations that were acceptable by large margins. However, for limiting locations (i.e., Path 3, outside surface), additional refinements of the cyclic assumptions were required to achieve acceptable usage. These also encompassed the complete set of operating transients, but they were analyzed individually, without the conservative grouping discussed above, and with appropriate alternating stress levels and cycles defined for each. The resulting fatigue usage factors are acceptable. The values reported (0.986 and 0.994) are the maximum values calculated at the limiting location. The next highest cumulative fatigue usage factors in these nozzles are 0.58 for the spray nozzle and 0.56 for the surge nozzle.

3. In the notes to Table 2-2, the licensee stated that even though the results of the elastic analysis of the nozzles exceed the allowable stresses, criteria for simplified elastic plastic analysis and thermal ratchet are met. The licensee needs to provide the results of the elastic plastic analysis.

   Results of the simplified elastic-plastic analyses of the spray and safety/relief nozzles are summarized in the following tables.

Table 1: Simplified Elastic-Plastic Evaluation Results for Spray Nozzle (1)

Path	**Surface**	**Equation (12)**			**Equation (13)**		
		Moment Stress, (ksi)	**Allowable $3S_m$, (ksi)**	**Accept**	**Maximum Stress Intensity Range (S_n), (ksi)**	**Allowable $3S_m$, (ksi)**	**Accept**
1	Inside	15.217	48.528	Yes	31.556	48.528	Yes
	Outside	26.797	48.528	Yes	33.032	48.528	Yes
2	Inside	16.392	48.528	Yes	35.246	48.528	Yes
	Outside	33.371	48.528	Yes	36.630	48.528	Yes
3	Inside	16.245	48.528	Yes	43.930	48.528	Yes
	Outside	44.845	48.528	Yes	45.719	48.528	Yes
4	Inside	4.462	41.064	Yes	23.612	41.064	Yes
	Outside	11.793	69.900	Yes	23.211	69.900	Yes
5	Inside	5.390	41.064	Yes	23.744	41.064	Yes
	Outside	7.729	69.900	Yes	21.690	69.900	Yes
6	Inside	7.395	41.064	Yes	25.402	41.064	Yes
	Outside	3.172	69.900	Yes	20.261	69.900	Yes

(1) - Reported only for locations that exceeded Equation 10.

Table 2: Simplified Elastic-Plastic Evaluation Results for Safety/Relief Nozzles (1)

Path	Surface	Equation (12)			Equation (13)		
		Moment Stress, (ksi)	**Allowable $3S_m$, (ksi)**	**Accept**	**Maximum Stress Intensity Range (S_n), (ksi)**	**Allowable $3S_m$, (ksi)**	**Accept**
2	Outside	19.756	47.880	Yes	38.559	47.880	Yes
3	Outside	25.923	47.880	Yes	42.247	47.880	Yes
4	Inside	4.736	40.740	Yes	20.817	40.740	Yes
5	Inside	7.381	40.740	Yes	22.196	40.740	Yes
6	Inside	9.558	40.740	Yes	25.538	40.740	Yes

(1) – Reported only for locations that exceeded Equation 10.

Table 3: Elastic-Plastic K_e Factors used in Fatigue Evaluations

Path	Surface	K_e	
		Safety/Relief Nozzles	**Spray Nozzle**
1	Inside	1.000	3.333
	Outside	1.000	3.333
2	Inside	1.000	3.333
	Outside	1.634	3.333
3	Inside	1.000	2.569
	Outside	2.318	1.000 to 3.333
4	Inside	1.075	3.333
	Outside	1.000	1.392
5	Inside	1.006	3.333
	Outside	1.000	1.299
6	Inside	1.122	3.333
	Outside	1.000	1.095
7	Inside	1.000	1.000
	Outside	1.000	1.000
8	Inside	1.000	1.000
	Outside	1.000	1.000
9	Inside	1.000	1.000
	Outside	1.000	1.000

Table 4: Results of Thermal Ratchet Evaluations (1)

Path	Safety/Relief Nozzles		Spray Nozzle	
	ΔT_1 (Allow)	**ΔT_1 (Actual)**	**ΔT_1 (Allow)**	**ΔT_1 (Actual)**
1	183°F	175°F	629°F	437°F
2	183°F	175°F	629°F	437°F
3	183°F	175°F	629°F	437°F
4	187°F	187°F	707°F	576°F
5	187°F	187°F	707°F	576°F
6	187°F	187°F	707°F	576°F

(1) - Reported only for locations that exceeded Equation 10.

4. Figure 2-5 showed the typical residual stress results along (in the longitudinal direction) the inside surface of the original welds. Provide the residual stress profiles (for axial and hoop stresses) along the wall thickness of the original weld and the weld overlay for the spray, surge, and safety/relief nozzles. The staff requests these residual stress profiles to determine the profiles of the tensile and compressive stresses along the wall thickness (in the radial direction).

   Nozzle specific residual stress analyses were performed for the McGuire/Catawba safety/relief, spray and surge nozzles using the methodology described in MRP-169. A typical finite element model showing the through-wall stress paths selected for crack growth evaluation is illustrated in Figure 3. Computed post-overlay residual stresses (at operating temperature) along these stress paths are illustrated in Figures 4 through 6. The vertical dashed lines in these figures represent the boundary between the original dissimilar metal welds (DMWs) and the overlays.

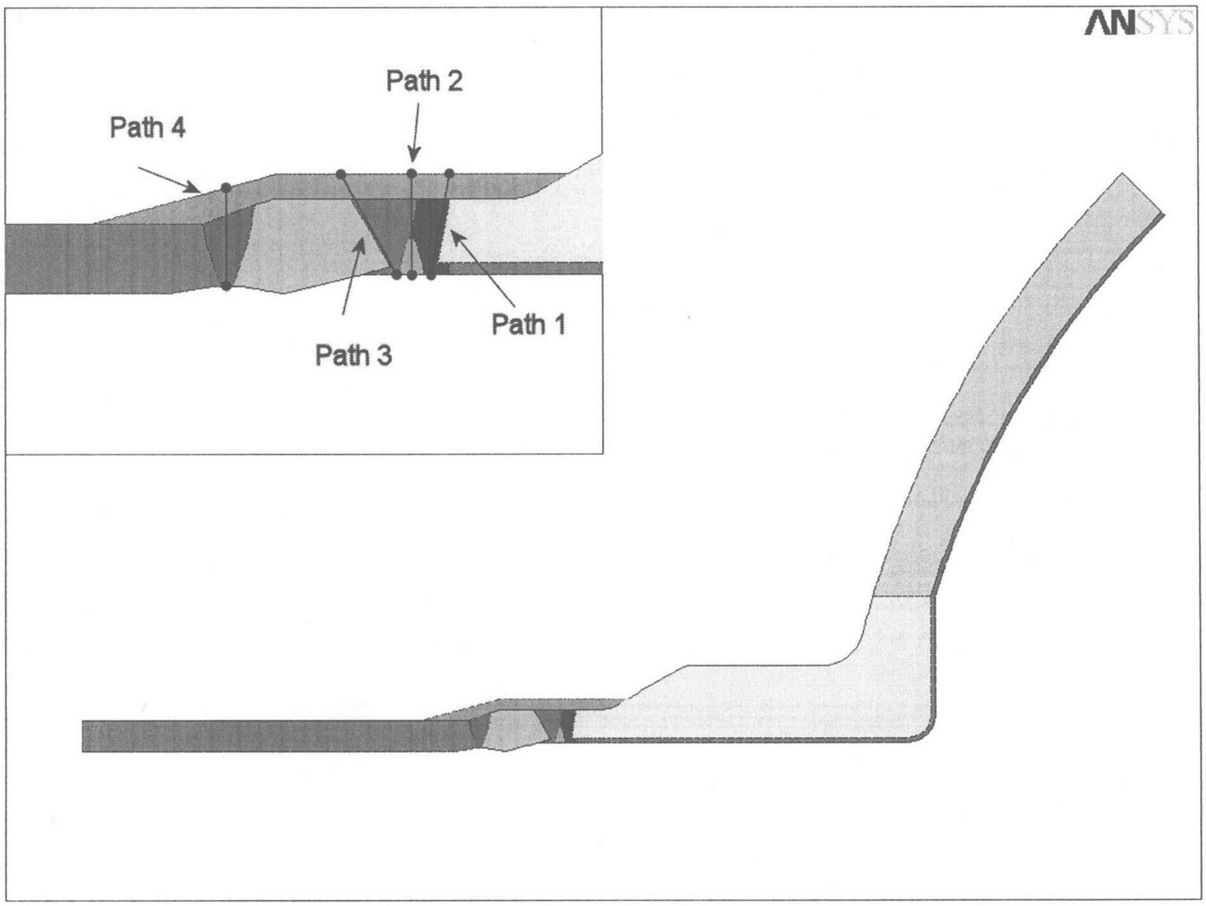


Figure 3: Though-wall Stress Paths in Residual Stress Model of Surge Nozzle (Typical). Paths 1 through 3 are in the DMW

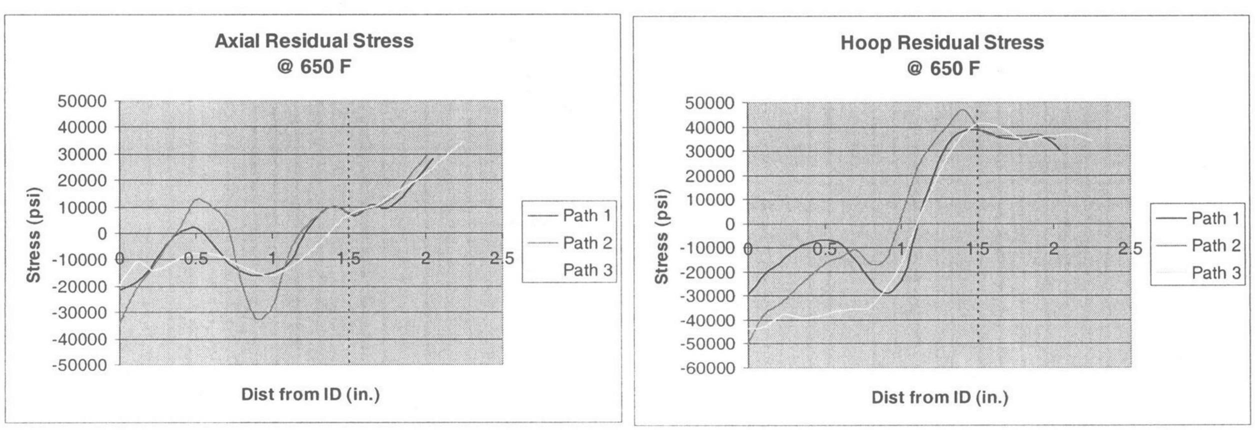


Figure 4: Post Weld Overlay Residual Stress Profiles in Surge Nozzle along Radial Stress Paths in the DMW (at Operating Temperature)

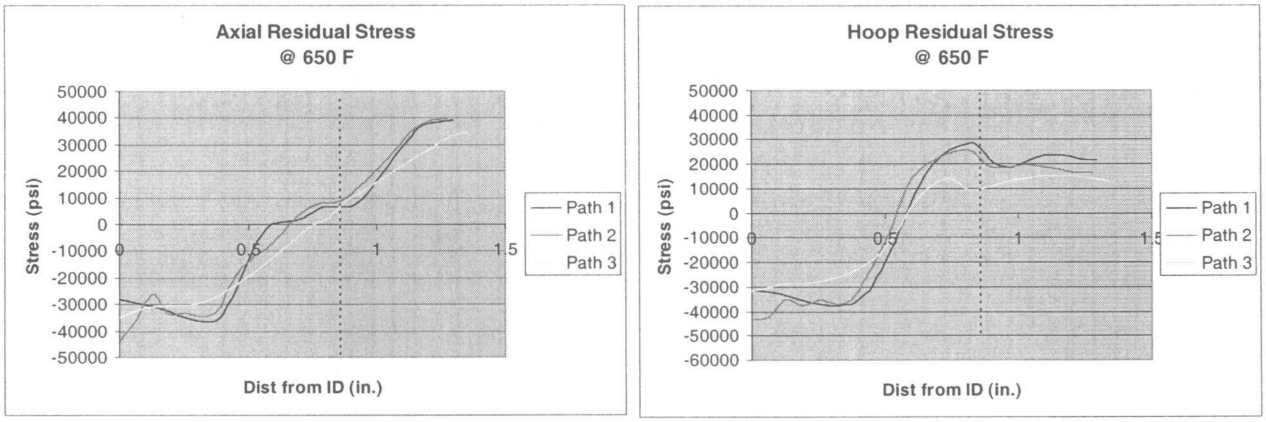


Figure 5: Post Weld Overlay Residual Stress Profiles in Spray Nozzle along Radial Stress Paths in the DMW (at Operating Temperature)

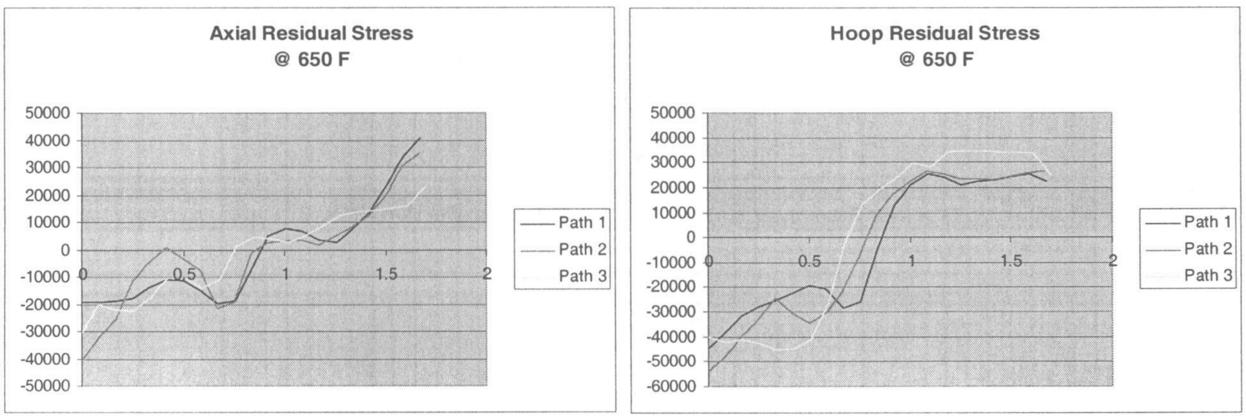


Figure 6: Post Weld Overlay Residual Stress Profiles in Safety/Relief Nozzles along Radial Stress Paths in the DMW (at Operating Temperature)

5. Page 5, 2nd paragraph. The licensee stated that in the fatigue crack growth calculation, each applied transient was assumed to be applied in the 10-year interval. (A) Explain why the fatigue crack growth calculation is based on the 10-year inspection interval, and not based on the remaining licensed years. The fatigue crack growth should be calculated for various crack depth to determine how many years the crack would exceed the allowable weld thickness. (B) Discuss whether a fatigue crack growth calculation was perform to determine whether the crack in the original weld would extend into the weld overlay.

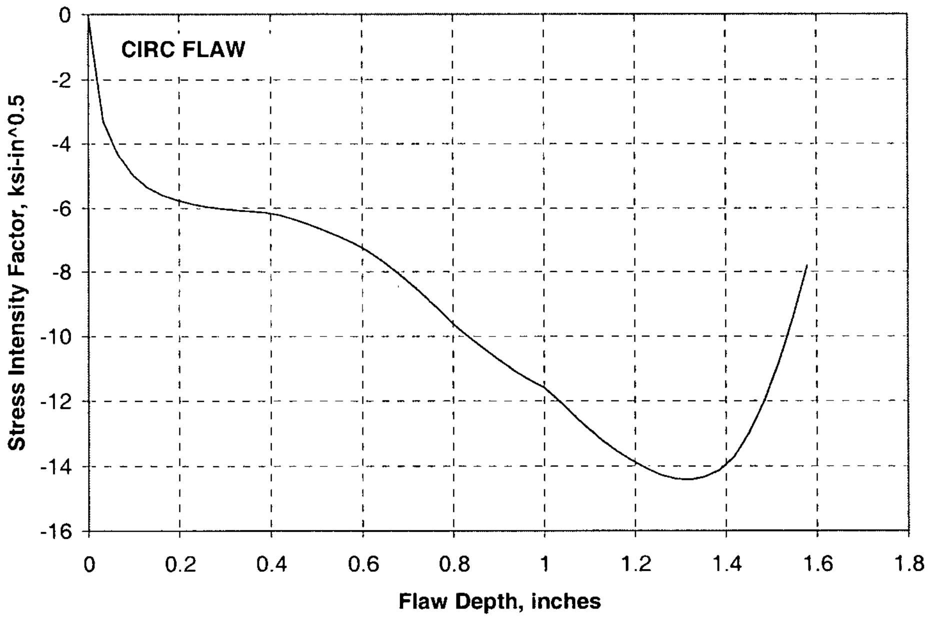
   A. Structural Integrity's standard approach to crack growth analyses in weld overlays is to perform fatigue and stress corrosion crack growth analyses for the time interval until the next scheduled inservice inspection of the overlays (maximum = ten years). This is consistent with the requirements for flaw evaluation of Section XI, Paragraph IWB-3641, which states that "The time interval selected for flaw growth analysis (i.e. evaluation period) shall be until the next inspection or until the end of the evaluation period for the item." Since subsequent inspections of the overlays will include the outer 25% of the DMW thickness, and since initial flaw sizes for flaw evaluation up to 75% through the original DMW thickness were analyzed, this evaluation period assumption is self consistent. If the subsequent inspections are clean, as expected because of the beneficial residual stresses of the overlays, then the start of the ten year evaluation period may be reset to the time of that inspection. That said, however, the maximum crack growth amounts reported for the DMWs (Table 2-3 of Attachment 2 to the October 26, 2006 letter) for the ten year evaluation period were very small, on the order of 0.050 in. for a 75% starting flaw assumption. Thus, the analyses demonstrate that the design basis flaw sizes for the overlay will not be exceeded for a time interval much greater than ten years.

B. Fatigue crack growth analyses were not performed for assumed initial flaw sizes greater than 75% of the original wall thickness. Such flaw size assumptions are not required because the weld overlays and the outer 25% of the DMWs were examined using PDI qualified procedures and personnel, following application of the overlays, with no reportable indications.

6. Page 5, third paragraph. The licensee stated that PWSCC crack growth is zero because the stress intensity factors remained negative for crack depth up to and beyond 75 percent of the original weld wall thickness (the crack initiates from the inside surface of the pipe and grows 75 percent of the wall thickness). In MRP-169, the residual stress profile of typical pressurizer nozzles showed that the axial stress changed from being compressive to tensile at about 50 percent of weld wall thickness. This means that a PWSCC crack may grow if its depth is more than 50 percent through wall. The licensee's statement contradicts the results of residual stresses in MRP-169. Provide results of stress profiles to support that PWSCC crack does not grow beyond 75 percent through wall.

   The post weld overlay residual stress profiles illustrated in Figures 4 through 6 above were combined with pressure stresses and other sustained loads during normal operation, and input to fracture mechanics models applicable to the nozzle and assumed flaw geometries. These stress profiles were developed specifically for the plant-specific McGuire/Catawba nozzle configurations, and the MRP-169 results were not utilized. It is Structural Integrity's opinion that residual stress analyses should be performed on a plant-specific basis as opposed to utilizing the sample plant results in MRP-169. For circumferential flaws, the fracture mechanics model consisted of a 360° flaw in a cylinder with a thickness-to-inside radius ratio, t/R_i, varying from 0.2 to 0.46 (nozzle specific). For axial flaws, an elliptical inside surface flaw with an aspect (depth-to-length) ratio of 0.2 in an infinite flat plate was used. The 0.2 aspect ratio is conservative because for deep flaws (for example 75% through-wall in the DMW) the crack length on the inside surface associated with this flaw assumption would be > 5 inches, which is longer than the length of PWSCC susceptible material on the inside surface. The flat plate assumption is also conservative since the cylindrical pipe/nozzle geometry is stiffer, and thus more resistant to crack opening than a flat plate. The resulting sustained stress intensity factors for normal operation are shown in Figures 7, 8 and 9. Residual stresses for these analyses were chosen for the most limiting of Paths 1, 2, and 3 in Figures 4, 5 and 6.

Note that the stress intensity profiles remain compressive to a depth beyond the point at which the stresses transition from compressive to tensile. This is because the fracture mechanics models integrate the stresses over the entire crack front to determine K, not just the stress at the crack tip.



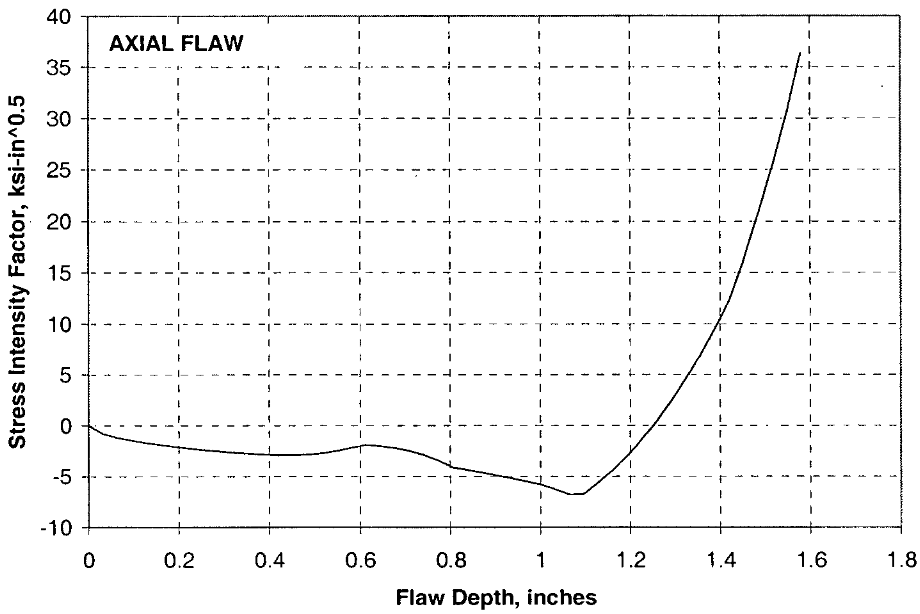
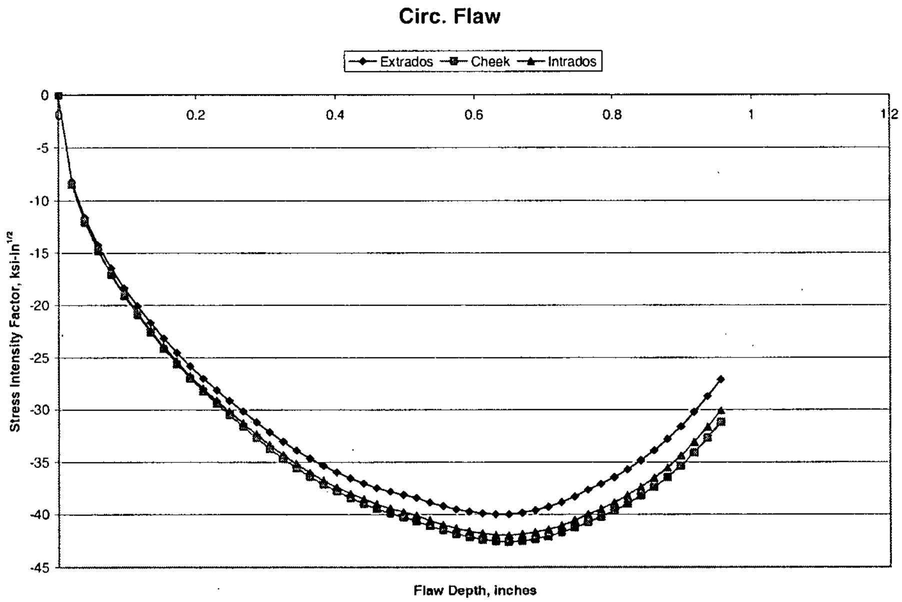


Figure 7: Surge Nozzle Stress Intensity Factors due to Sustained Operating plus Residual Stresses along Limiting Crack Path in DMW – Plant-specific to McGuire/Catawba



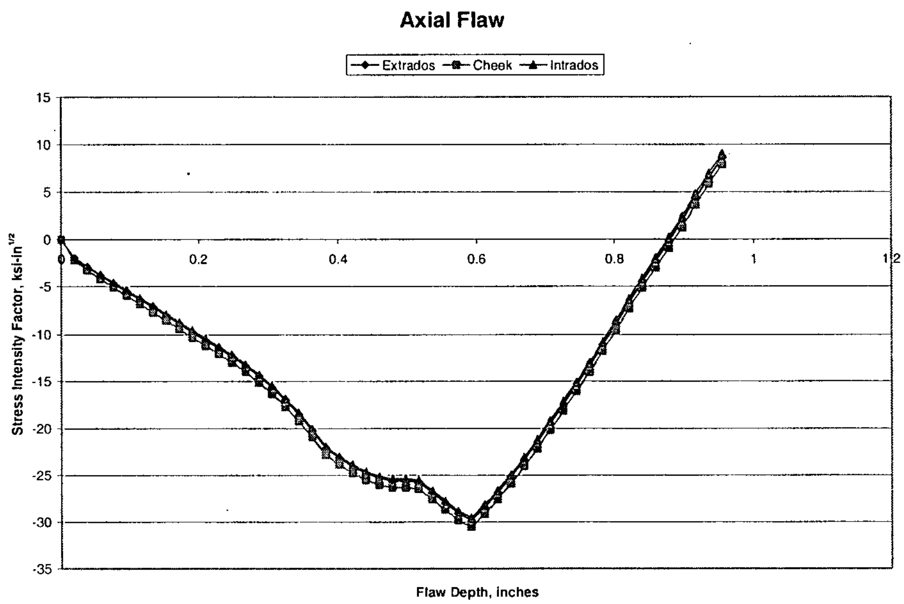
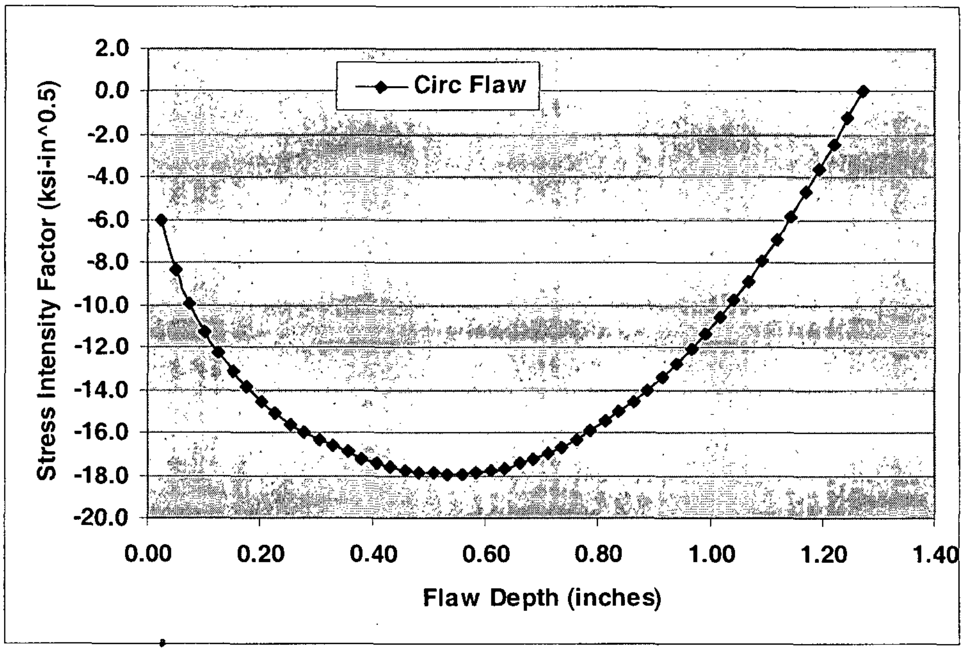


Figure 8: Spray Nozzle Stress Intensity Factors due to Sustained Operating plus Residual Stresses along Limiting Crack Path in DMW – Plant-specific to McGuire/Catawba



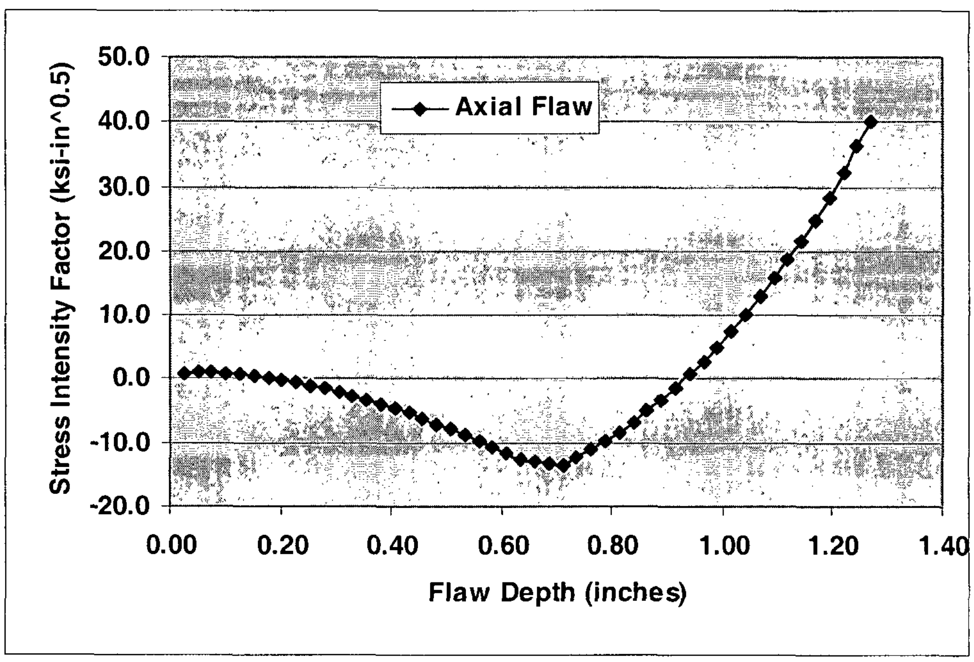


Figure 9: Safety/Relief Nozzle Stress Intensity Factors due to Sustained Operating plus Residual Stresses along Limiting Crack Path in DMW on Extrados – Plant-specific to McGuire/Catawba

7. In the Conclusion section (the 5th bullet), the licensee stated that "...Application of the weld overlays was shown to not impact the conclusions of the existing nozzle stress reports. Following application of the overlay, all ASME Code, Section III stress and fatigue criteria are met...". The staff does not agree with the above statement because the stress analysis results in Table 2.2 clearly showed that the weld overlays affect the stress condition of the pressurizer nozzles. Clarify the above conclusion statement.

   The referenced conclusion statement is accurate as stated. The analyses demonstrated that the pressurizer nozzles meet all ASME Code, Section III stress and fatigue criteria after application of the weld overlays. The weld overlays have affected the stress conditions in the nozzles, but not the conclusion that they are in compliance with ASME Code, Section III requirements.