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Constellation Energy Group

April 13, 2004

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit No. 1; Docket No. 50-317
Response to Request for Additional Information Regarding Interim Inspection Requirements for Reactor Pressure Vessel Head (TAC No. MC1921)

REFERENCES:

(a) Letter from Mr. G. Vanderheyden (CCNPP) to Document Control Desk (NRC), dated January 30, 2004, Request for Relaxation from NRC Order EA-03-009, "Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors"

(b) Letter from Mr. S. J. Collins (NRC) to Holders of Licenses for Operating Pressurized Water Reactors, dated February 11, 2003, Issuance of Order Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors (EA-03-009)

(c) Letter from Mr. G. S. Vissing (NRC) to Mr. G. Vanderheyden (CCNPP), dated April 5, 2004, Calvert Cliffs Nuclear Power Plant, Unit No. 1, Request for Additional Information Regarding Request for Relaxation of Inspection Requirements of Order EA-03-009 (TAC No. MC1921)

By letter dated January 30, 2004, (Reference a), Calvert Cliffs Nuclear Power Plant, Inc. submitted a request for relaxation from the inspection requirements of Section IV.C(1)(b)(i) of Reference (b). This letter provides Calvert Cliffs Nuclear Power Plant's response to the two sets of questions in the April 5, 2004, letter (Reference c) from the Nuclear Regulatory Commission requesting additional information regarding that relaxation request. The requested information and our responses are contained in Attachment (1) to this letter.

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Should you have questions regarding this matter, we will be pleased to discuss them with you.

Very truly yours,

STATE OF MARYLAND :
: **TO WIT:**
COUNTY OF CALVERT :

I, George Vanderheyden, being duly sworn, state that I am Vice President - Calvert Cliffs Nuclear Power Plant, Inc. (CCNPP), and that I am duly authorized to execute and file this response on behalf of CCNPP. To the best of my knowledge and belief, the statements contained in this document are true and correct. To the extent that these statements are not based on my personal knowledge, they are based upon information provided by other CCNPP employees and/or consultants. Such information has been reviewed in accordance with company practice and I believe it to be reliable.

Subscribed and sworn before me, a Notary Public in and for the State of Maryland and County of St. Mary's, this 13th day of April, 2004.

WITNESS my Hand and Notarial Seal:

Notary Public

My Commission Expires:

March 25 2007
Date

GV/JKK/bjd

Attachment: (1) Response to NRC Request for Additional Information

cc: J. Petro, Esquire
J. E. Silberg, Esquire
Director, Project Directorate I-1, NRC
G. S. Vissing, NRC
H. J. Miller, NRC
Resident Inspector, NRC
R. I. McLean, DNR

ATTACHMENT (1)

RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION

Calvert Cliffs Nuclear Power Plant, Inc.
April 13, 2004

RELAXATION REQUEST 1

NRC Request 1:

Please provide the total number for each type of reactor pressure vessel head nozzles that are affected by this proposed relaxation.

CCNPP Response:

We will provide the total number of Unit 1 nozzles affected by the proposed relaxation and extent of coverage achieved on each nozzle upon completion of the inspection. We do not expect the in-core instrumentation and head vent line nozzles to be affected. For the Unit 2 inspection, we needed relaxation for 62 of the 65 control element drive mechanism (CEDM) nozzles for above the weld coverage and achieved a minimum inspection distance of 0.95 inches above the weld.

NRC Request 2:

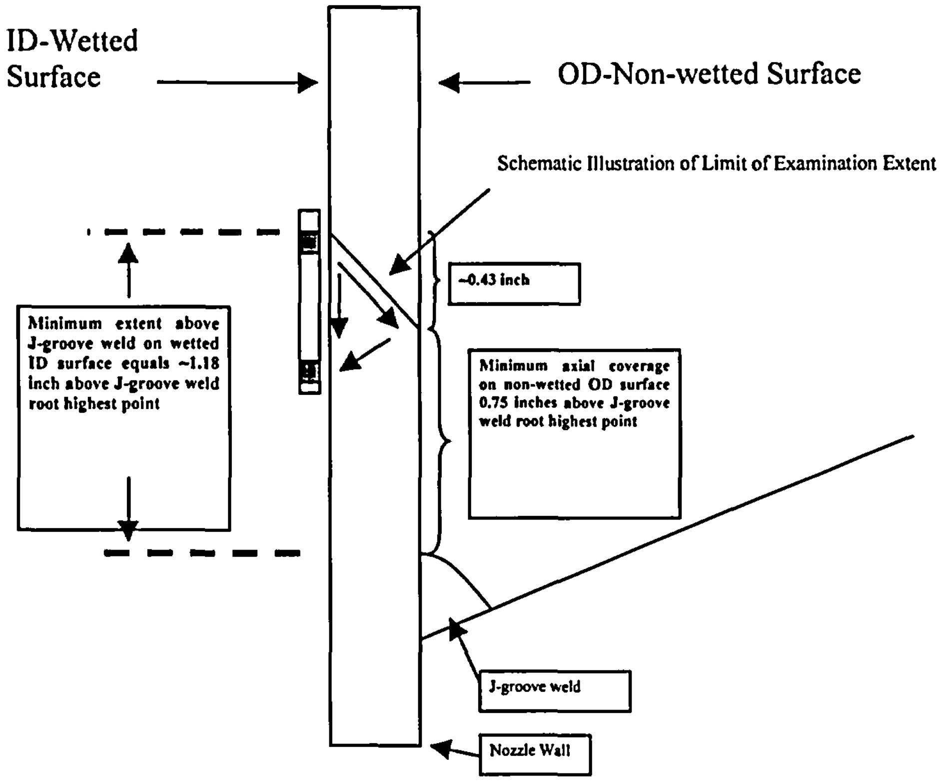
Please provide justification that coverage up to 0.75 inches above the weld will provide an adequate level of quality and safety. Are there residual stress data for Unit 1 that indicates that 0.75 inches is a sufficient level above the weld, or is there any other basis that demonstrates an acceptable level of quality and safety for the restricted inspections?

CCNPP Response:

Based on plant specific analyses, operating stresses at 0.75 inches above the weld on the outside diameter (OD) of the nozzle, which corresponds to 1.18 inches on the inside diameter (ID) with our inspection technique, are all less than 20 ksi for all nozzle groups. This is depicted in Figure 1 of our relaxation request (Reference 1).

Calvert Cliffs Nuclear Power Plant (CCNPP) has had several plant specific stress analyses, fracture mechanics analyses, and operational experience analyses performed. All of these analyses support the conclusion that examination of an inspection volume encompassing the CEDM nozzle material up to 0.75 inches (on the OD) above the highest point of the root of the J-groove weld is sufficient to ensure safety and quality. However, additional inspection of the region between 0.75 inches and 2 inches above the highest point of the root of the J-groove weld will be accomplished wherever possible, and we expect we will be successful on most of the nozzle circumference on nearly every penetration.

We request relaxation of the Order requirements so that we may inspect a minimum of 0.75 inches above the highest part of the root of the J-groove weld for the nozzle OD. On the nozzle ID, we request relaxation so we may inspect a minimum of 1.18 inches above the highest part of the root of the J-groove weld, as shown below.



We have performed a residual stress analysis of the CEDM nozzles. For all of the penetrations, the highest, bounding, residual stress on the ID surfaces at 1.18 inches above the highest point of the root of the J-groove welds is 19.9 ksi. The stresses were calculated for all downhill, sidehill, and uphill locations at all elevations on all nozzle configurations. The peak residual stress on the ID at 1.18 inches above the highest point of the root of the J-groove weld of 19.9 ksi occurs on the uphill side of the 11 degree nozzle. Peak stress values on all nozzle configurations are:

0° Nozzle:

	Hoop (ksi)	Axial (ksi)
ID surface + 1.18"	17.3	16.5
OD surface + 0.75"	6.3	-20.8

11° Nozzle:

	Hoop (ksi)	Axial (ksi)
ID surface + 1.18"	19.9	13.8
OD surface + 0.75"	2.5	-22.7

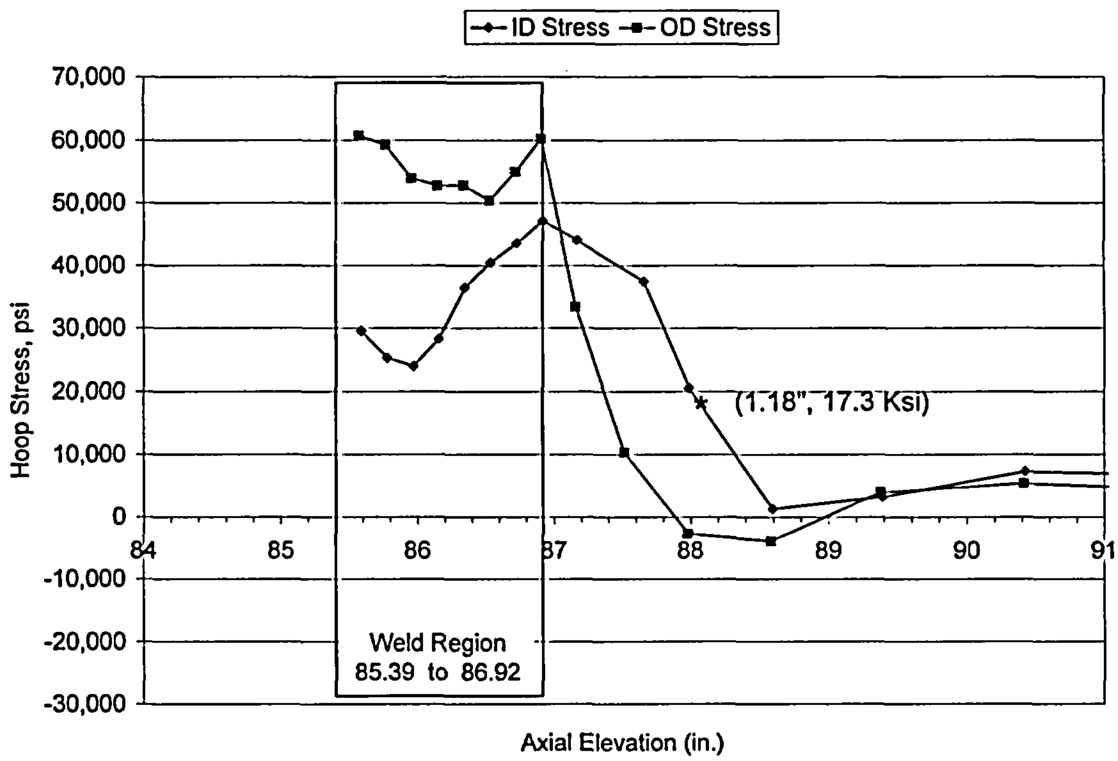
29° Nozzle:

	Hoop (ksi)	Axial (ksi)
ID surface + 1.18"	16.5	4.5
OD surface + 0.75"	-1.1	-21.1

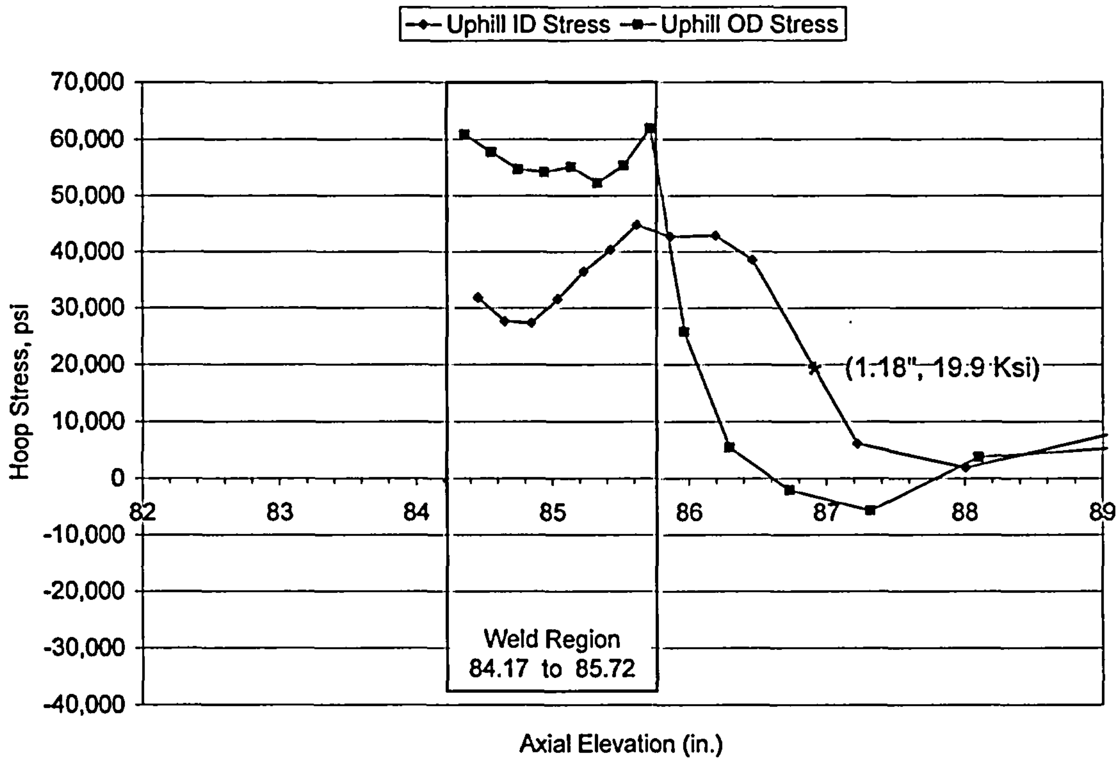
43° Nozzle:

	Hoop (ksi)	Axial (ksi)
ID surface + 1.18"	16.2	-0.1
OD surface + 0.75"	-7.8	-20.4

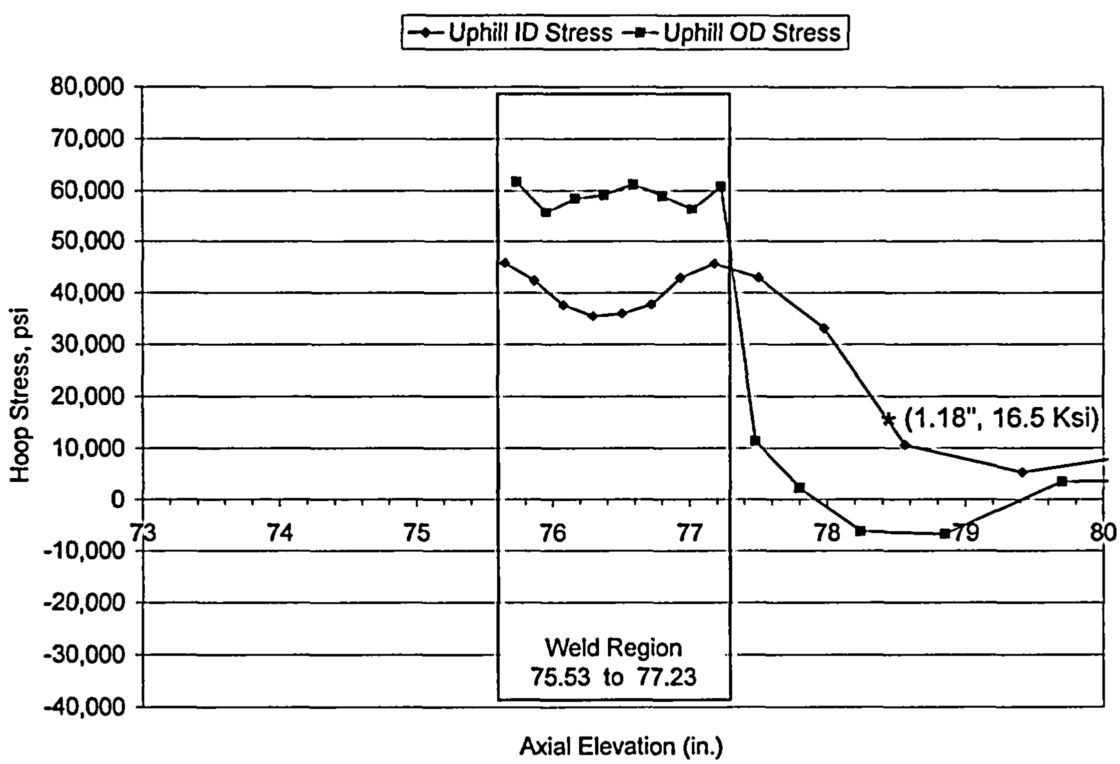
Residual stress profiles are shown in the following plots:



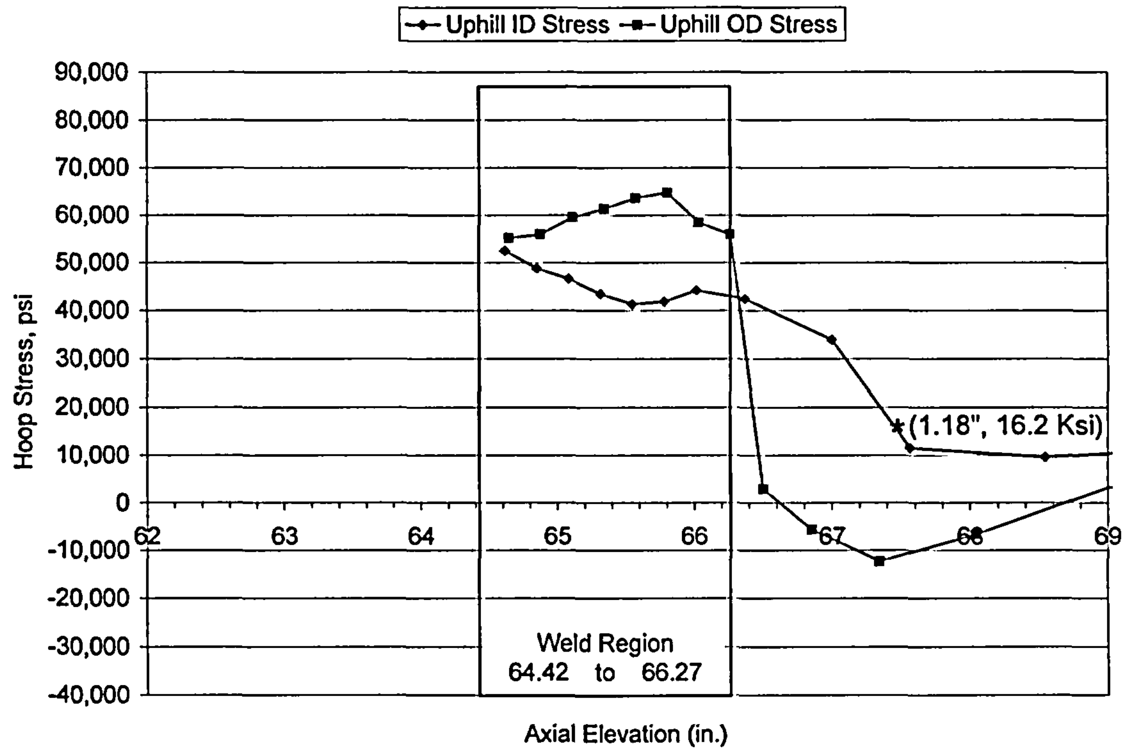
0° (Central) CEDM Nozzle Hoop Stress



11.0° CEDM Nozzle Uphill Hoop Stress



29.0° CEDM Nozzle Uphill Hoop Stress



43° CEDM Nozzle Uphill Hoop Stress

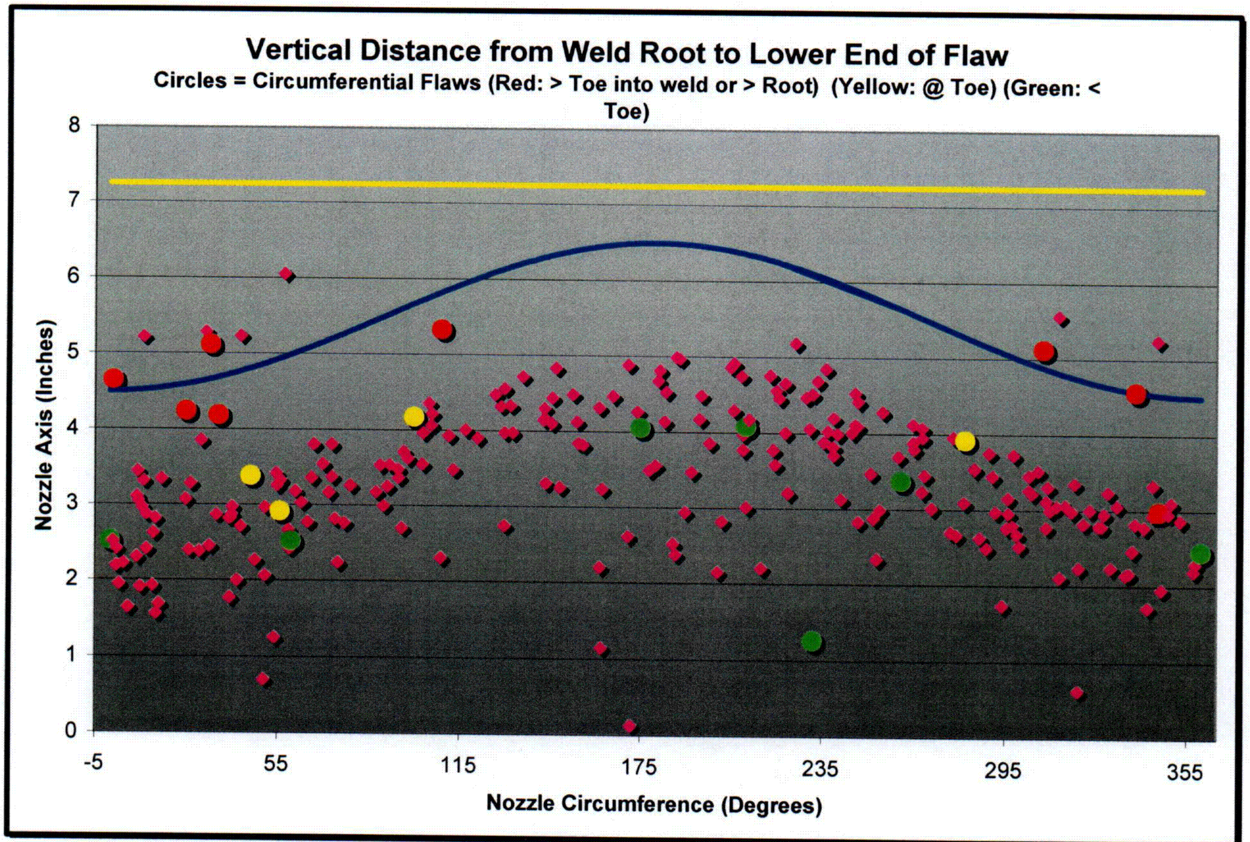
On the OD, both hoop and axial stresses at 0.75 inches above the highest point of the root of the J-groove weld are below 7 ksi in all cases.

As indicated in Materials Reliability Program (MRP)-95 (Reference 2), 20 ksi is a reasonable stress threshold below which primary water stress corrosion cracking (PWSCC) is not expected to occur. Additionally, the yield strength of the Calvert Cliffs material is 42 ksi. The highest residual stresses at the 1.18 inch elevation are less than 48% of the yield strength. As indicated in Reference 2, PWSCC has not been observed in material subjected to stresses lower than yield. Therefore, PWSCC is not expected to initiate in the region for which relaxation is requested.

Primary water stress corrosion cracking is strongly dependent on applied stress. Primary water stress corrosion cracking cracks typically initiate in regions of high stress. The region for which relaxation is requested is a low stress region. While it is possible that PWSCC could initiate in high stress regions and slowly grow into the lower stress region, it is not expected that the converse could occur. In any event, we are inspecting all of the highly stressed regions of the nozzles, so we would detect at least a portion of any crack that could grow into the low stress region.

In a request for relaxation that Calvert Cliffs submitted in 2003, we provided a plot that described past inspection results for our plant and others. Figure 1 below, provides an updated plot that includes the 14 flaws found during the 2003 inspections. The plot shows that at least a portion of every flaw ever discovered by our inspection vendor in an United States reactor vessel head penetration nozzle would have been detected if the inspections had been limited to the region up to 0.75 inches above the highest portion of the root of the J-groove weld.

Figure 1: Location of Flaws with Respect to J-Groove Weld Root



Azimuthal information is schematic only.
Data below the weld were distributed randomly on the azimuthal axis for illustration purposes.
Indications above the weld are accurately represented azimuthally.
The yellow line is the requested OD limit for the examination.
Minimum examination on the wetted surface is 0.43 inches above the yellow line.
Flaws found at other plants during 2003 are shown in green.

The results of the residual stress analyses indicate stresses decrease rapidly with distance above the J-groove weld. We performed a crack growth rate calculation for a hypothetical crack having a 6:1 aspect ratio and spanning the distance between the elevation we are seeking relaxation for (1.18 inches on the ID) and the elevation required by the order (2 inches). We evaluated a 0.82 inch long, ID surface connected, 6:1 aspect ratio crack. We performed crack growth calculations for two different locations. For the first calculation, the lower end of the crack was 1.18 inches above the root of the J-groove weld. For the second calculation, the lower end of the flaw was placed at an elevation 2 inches above the root of the J-groove weld. The results indicate there is little difference in crack growth for flaws located 1.2 inches above the weld or greater than 2 inches above the weld.

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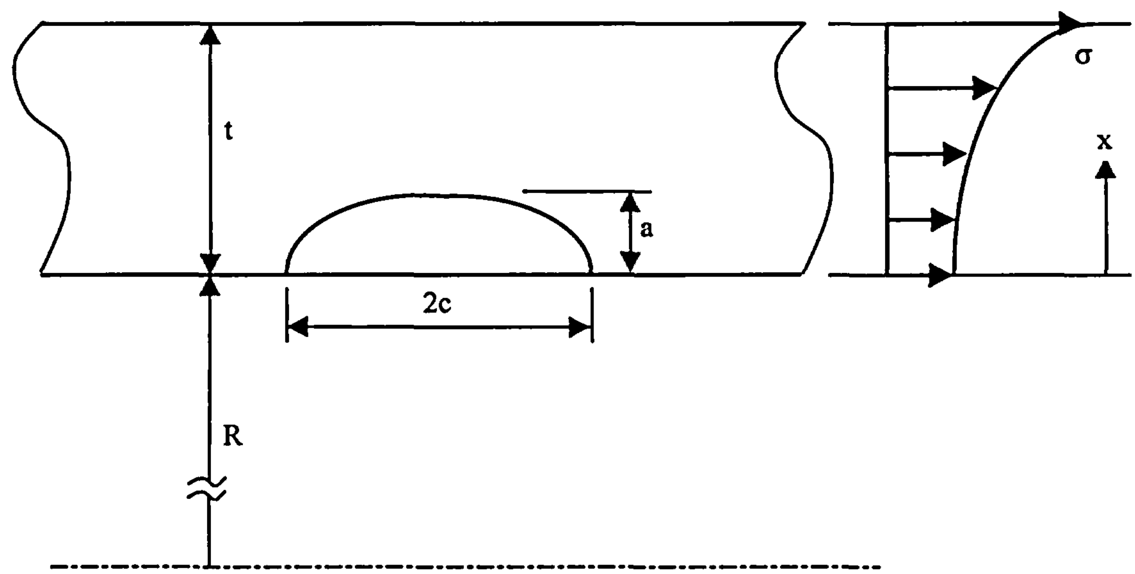
The crack growth calculation was performed by a contractor. The methodology used was conducted in accordance with Nuclear Regulatory Commission (NRC) guidance provided April 11, 2003 from R. Barrett to A. Marion, (Reference 3) which is consistent with MRP-55, as follows:

Flaw Model:

Semi-elliptical Inside Surface Axial Flaw in a Cylindrical Tube

The crack is modeled as a 6:1 semi-elliptical axial flaw on the inside surface of a cylindrical tube, subjected to an arbitrary stress profile.



Stress intensity factors are determined at the point of maximum flaw depth using the solution,

$$K_I = \sqrt{\pi a / Q}\left[G_o(A_0 + A_p) + G_1 A_1 a + G_2 A_2 a^2 + G_3 A_3 a^3\right],$$

where the through-wall hoop stresses in the un-cracked nozzle are represented by the third-order polynomial,

$$\sigma = A_0 + A_1 x + A_2 x^2 + A_3 x^3,$$

and

x = distance from the inside surface
a = flaw depth
A_0, A_1, A_2, and A_3 = third-order stress coefficients
A_p = crack face pressure
Q = $1.464(a/c)^{1.65}$

Crack Growth Rates:

a) Primary Water Stress Corrosion Cracking

Basis: MRP-55 crack growth rate for Alloy 600 material, as expressed in NRC flaw evaluation guidelines, referenced to a temperature of 325°C using an activation energy of 31,000 calories/mole.

$$da/dt = C_o(2.67\times10^{-12})(K_I - 9)^{1.16} \text{ m/sec}$$

where K_I is the applied stress intensity factor in MPa√m, and

$$C_o = e^{-\frac{Q}{R}\left(\frac{1}{T}-\frac{1}{Tref}\right)}$$

where Q = 130 kJ/mole = 31,000 calories/mole
R = 8.314×10^{-3} kJ/mole-°K = 1.987 calories/mole-°K

and T = Operating temperature in degrees Kelvin
T_{ref} = Reference temperature in degrees Kelvin

At an operating temperature of 594°F, the temperature correction term is

$$C_o = 0.566$$

b) Fatigue Crack Growth

Basis: Crack growth rate for Alloy 600 material in a pressurized water reactor water environment as expressed in NRC flaw evaluation guidelines (Reference 3).

$$\frac{da}{dN} = CS_R S_{ENV}(\Delta K)^n,$$

where ΔK is the stress intensity factor range in terms of MPa√m and da/dN is the crack growth rate in terms of m/cycle

$$C = 4.835\text{x}10^{-14} + 1.622\text{x}10^{-16}T - 1.490\text{x}10^{-18}T^2 + 4.355\text{x}10^{-21}T^3$$

$$S_R = [1 - 0.82R]^{-2.2}$$

$$S_{ENV} = 1 + A[CS_R\Delta K^n]^{m-1}T_R^{1-m}$$

A = $4.4\text{x}10^{-7}$
M = 0.33
N = 4.1
T = degrees C
R = K_{min} / K_{max}
T_R = rise time, set at 30 sec

Results of Flaw Growth Analyses:

6:1 Semi-Elliptical Inside Surface Axial Flaws Above the Weld

Location	Initial Flaw Depth*	Flaw Depth* After Two Years
1.18" Above the Weld	24.15%	24.24%
2.00" Above the Weld	24.15%	24.15%

* In terms of percent of wall thickness.

For circumferential flaws, the axial residual stresses decline very quickly with distance above the J-groove weld. In the region above 0.75 inches above the highest point of the root of the J-groove weld (1.18 inches for the ID), residual stresses are very low or are negative, so initiation and growth of circumferential flaws is not predicted for this region.

We are requesting relaxation from NRC Order requirements for a certain portion of the CEDM nozzles. We have performed stress analyses of the regions and determined that hoop and axial residual stresses are so low that PWSCC should not occur. We have performed crack growth calculations and determined that even large hypothetical cracks would grow very slowly. We have evaluated other inspection experience and determined that our proposed minimum scope would have found every reactor pressure vessel head penetration crack found to date in the United States. Based on these analyses, we have determined inspection of the CEDM penetrations from the root of the J-groove weld to an elevation on the ID 1.18 inches above the highest portion of the J-groove weld and on the OD 0.75 inches above the highest portion of the J-groove weld provides substantially the same safety and quality that would be provided by an examination to the full extent required by the Order.

NRC Request 3:

If the guide sleeves are removed, would there be additional geometric constraints on performing the examination required in the Order?

CCNPP Response:

There is a geometric discontinuity (a double counterbore) located above the weld that restricts access for inspection with a blade probe. If we remove the thermal sleeves we could inspect using a rotating probe. We believe the rotating probe would facilitate 100% coverage in the double counterbore region; however, we would not be able to determine the success rate until after we removed the thermal sleeves and applied the rotating probe. It is possible that even with the thermal sleeves removed the double counterbore might interfere with full inspection coverage.

NRC Request 4:

The Order allows either ultrasonic testing (UT) examination or a surface examination. The hardship is for UT only. For a similar situation for Unit 2, the licensee responded to a request for additional information by indicating that there was a contractor that could provide the capability to deliver an eddy current probe to the region where access is limited. However, that contractor was not available for Unit 2 during its 2003 outage. Discuss why the licensee is not proposing the use of eddy current examination for Unit 1. If the eddy current inspections could be performed, there would be no need for relaxation of the Order.

CCNPP Response:

There were two distinct schedule windows for inspecting the CCNPP Unit 2 penetrations during last year's outage. After failing to collect adequate inspection data in the first window, the CCNPP Project

Team considered all options for improving inspection coverage, including the use of an eddy current (ET) probe used by a different vendor. Even though the vendor was not available for the second inspection window, the team understood the ET blade probe is 0.015 inches thinner than the UT probe CCNPP used, however the nozzle counterbore and guide sleeve centering tabs provide limited access to both ET and UT probes.

After the 2003 Unit 2 inspection campaign, Calvert Cliffs reviewed the response to the Unit 2 relief request and evaluated potential options for the Unit 1 inspection. During the 2003 Refueling Outage, CCNPP and our inspection vendor spent significant time and resources improving the CEDM blade probe technique for interrogating Calvert Cliffs Unit 2 Reactor Vessel Head penetrations. A team of CCNPP and inspection vendor personnel conducted root cause analysis investigations of the first inspection. Delivery tooling improvements such as a motorized X-Y table; a stronger mandril; modular and more water resistant components; and improved motor design were developed. Also, UT probe modifications as well as operator and field technician procedures and training enhancements were conducted to improve inspection coverage. Mock-ups of Calvert's specific CEDM configuration were manufactured and the tooling, procedures, and probe improvements were tested and verified.

There are only three reactor vessel heads with our specific CEDM nozzle detail; Calvert Cliffs Units 1 and 2; and, St. Lucie Unit 1. Last year's CCNPP Unit 2 and this year's St. Lucie volumetric nozzle penetration exams on this configuration were conducted by our inspection vendor using the same tooling described above. Both CCNPP and St. Lucie coordinated outage shutdown dates last summer in an effort to utilize the experience gained by the vendor during the CCNPP Unit 2 outage.

The effort to improve and enhance achievable inspection coverage with the UT blade probe would have had to have been duplicated if CCNPP had selected the alternative inspection vendor in order to deliver an ET probe. The ET blade probe delivery equipment has never been deployed for the Combustion Engineering designed thermal sleeve configuration that exists at CCNPP, and if constructed, could not be field-tested until it was deployed under a vessel head. During 2003, Calvert Cliffs had a steam generator replacement and used a four week window during the middle of the outage to identify and implement equipment and operational improvements that enabled us to meet the minimum coverage approved by the NRC. The current Unit 1 outage is projected to be around 30 days and thus additional time to test and modify, if needed, inspection equipment is not practical.

Calvert Cliffs does not want to be in the position of deploying a first of a kind ET blade probe delivery system, only to find that it could not achieve coverage comparable to the UT blade probe. Failure of an ET blade probe to achieve coverage comparable to what we experienced during the 2003 Unit 2 inspection could place us in a situation during the Unit 1 outage where we would have to either seek relaxation from the Order requirement on an exigent basis, and possibly for reduced extent in comparison to what we know is achievable with a UT blade probe, or we would need to sever thermal sleeves, which is a hardship due to increased dose and cost without a commensurate increase in safety or quality.

Following the Unit 2 outage, CCNPP did pursue an alternate UT inspection technique in an effort to fully meet the requirements stated in the Order. Calvert Cliffs worked with our vendor to develop a supplemental inspection technique using a Normal Beam Ultrasonic Technique from the bottom of the penetration.

The work performed during development of the supplemental inspection technique included the design and fabrication of two calibration standards and special scanning software. An ultrasonic approach was developed using the calibration standard and a nozzle to assure adequate coverage. The ability of the sound wave to penetrate through the nozzle material when inspecting from the bottom surface was a critical characteristic. A series of tests were performed on a Calvert Cliffs mockup and a nozzle contained in a reactor vessel upper head mockup (from the cancelled Midland reactor). These tests indicated the technique was capable of producing a reflection off of the opposite end of the Calvert Cliffs mockup. Similarly, the J-groove weld related reflections were noted from the Midland head nozzle mockup. A procedure was written and an evaluation was conducted at Electric Power Research Institute on two blind mockups. One was a full CEDM mockup with flaws located at the weld and near the tube bottom. The other mockup was a partial scale mockup with flaws located above the weld in the tube. Both mockups were fabricated using a cold-isostatic implantation process to produce tight electrical discharge machining notches. Between the two mockups, flaws were oriented axially, circumferentially, and with a 45° skew.

Although significant time and resources were expended, the results of the blind demonstration clearly showed limitations in defect detection; therefore the technique did not prove deployable based on the Electric Power Research Institute MRP demonstration.

We are currently in a situation where the only deployable techniques for inspection of our CEDM reactor vessel head penetrations is either the UT blade probe technique, or severance of the thermal sleeves and inspection using a rotating probe. The latter technique is a destructive examination evolution that presents considerable hardship in terms of outage extension, radiological dose, industrial safety risk, and expense.

<u>NRC Request 5</u>:

Is the 10-million dollar cost just for the removal of the thermal guide sleeves? Please expand on what this estimate includes.

<u>CCNPP Response</u>:

Approximately $2.5M are direct costs associated with guide sleeve removal, inspection and re-installation of new guide funnels, and approximately $7.5M are non-direct costs due to outage extension.

<u>NRC Request 6</u>:

Did the licensee perform a crack growth evaluation above the weld? If so, what was the initial flaw size and was it through-wall? The licensee is requested to describe the methodology in <u>detail</u>, [emphasis is the original] *and provide examples for the crack growth calculations. Did the licensee perform this evaluation in accordance with the MRP-55 guidelines? Did the licensee perform the evaluation, or was it performed by a contractor? Was the crack growth evaluation based on the as-built weld geometry? Please provide justification if the crack growth evaluation was not based on the as-built weld geometry.*

<u>CCNPP Response</u>:

As indicated in our response to NRC Request 2, we have performed crack growth calculations. The methods and results are discussed in the response to NRC Request 2. The calculation was performed in accordance with MRP-55 guidelines. We contracted to Dominion Engineering and AREVA (formerly Framatome-ANP) for the stress analyses and fracture mechanics analyses. A parametric study was performed to determine the effects of as-built weld size below the weld on the residual stresses in the nozzle. The analysis indicated there was little effect of the as-built weld geometry on the stresses above the weld, particularly on the high hillside portion of the nozzle above the weld. The parametric study indicated that it was not necessary to consider the as-built weld geometry during a crack growth analysis above the weld.

RELAXATION REQUEST 2

NRC Request 1:

What is the maximum hoop stress in the bottom portion of the nozzle? Please provide crack growth predictions for through-wall axial flaws located at various angles in the CEDM's.

CCNPP Response:

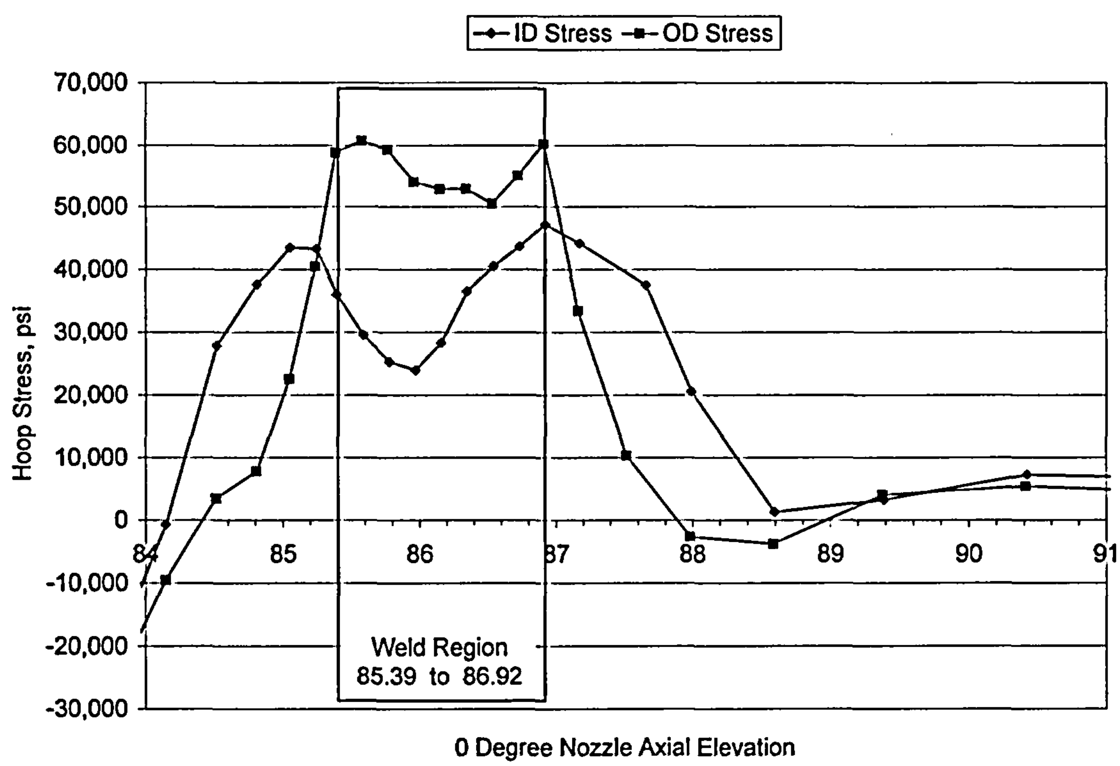
We performed plant specific stress analysis for all of the CEDM nozzle groups. For the 43° angle nozzle below the weld we assumed four different fillet weld sizes to represent various cases of as-built conditions. The stress analysis results depend on fillet weld size, on nozzle angle, and vary around the circumference of the nozzle.

The following table provides a summary of the results for the 0 degree nozzle:

0° CEDM Nozzle Distance Below Weld to 20 ksi Hoop Stress (in)					
Downhill		Sidehill		Uphill	
ID	OD	ID	OD	ID	OD
1.0*	0.4	**1.0***	0.4	**1.0***	0.4

*** Lowest elevation to reach 20 ksi hoop stress**

This table shows that the lowest elevation in the 0 degree nozzle that experiences a hoop stress of 20 ksi or above is 1.0 inch below the toe of the weld on the ID, uniformly around the circumference. The following plot shows the results graphically.

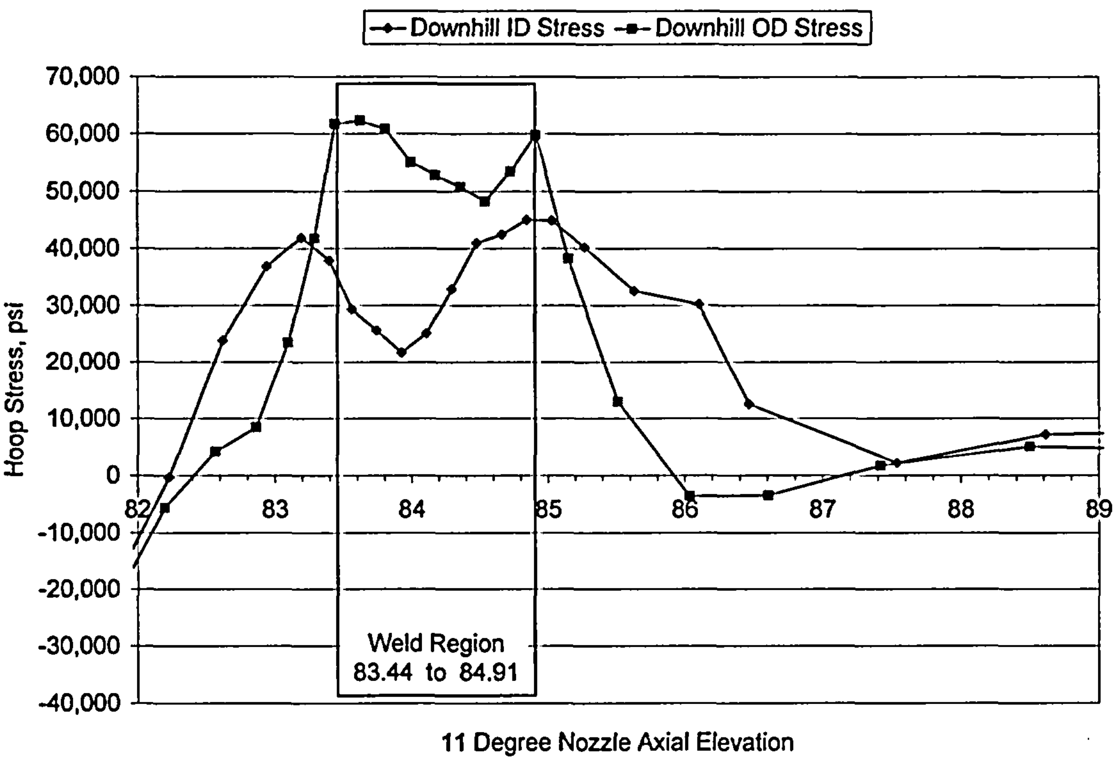


The following table provides a summary of the results for the 11 degree nozzle:

11° CEDM Nozzle					
Dist Below Weld to 20 ksi hoop stress (in)					
Downhill		Sidehill		Uphill	
ID	OD	ID	OD	ID	OD
0.9 *	0.4	1.1	0.3	1.1	0.4
Hoop Stress at Minimum Elevation (ksi)					
Downhill		Sidehill		Uphill	
ID	OD	ID	OD	ID	OD
20.0	4.2	12.9	-6.2	3.5	-11.8

*** Lowest elevation to reach 20 ksi hoop stress**

This table shows that the lowest elevation in the 11 degree nozzle that experiences a hoop stress of 20 ksi or above is 0.9 inches below the toe of the weld on the downhill portion of the weld. Note that the hoop stresses at the sidehill and uphill azimuths at the same elevation are far less than 20 ksi. The following plot shows the results graphically.

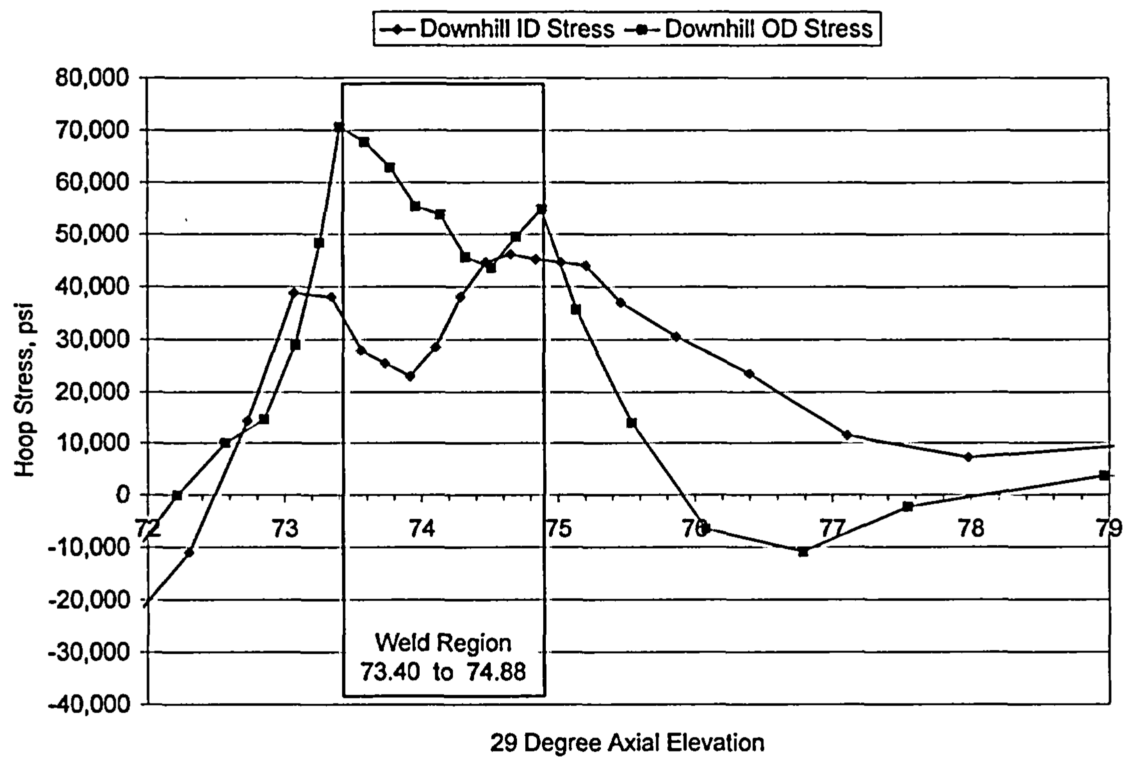


The following table provides a summary of the results for the 29 degree nozzle:

29° CEDM Nozzle Dist Below Weld to 20 ksi hoop stress (in)					
Downhill		Sidehill		Uphill	
ID	OD	ID	OD	ID	OD
0.6 *	0.5	1.4	0.3	1.4	0.4
Hoop Stress at Minimum Elevation (ksi)					
Downhill		Sidehill		Uphill	
ID	OD	ID	OD	ID	OD
20.0	14.0	13.5	-11.1	-8.3	-8.4

*** Lowest elevation to reach 20 ksi hoop stress**

This table shows that the lowest elevation in the 29 degree nozzle that experiences a hoop stress of 20 ksi or above is 0.6 inches below the toe of the weld on the downhill portion of the weld. Note that the hoop stresses at the sidehill and uphill azimuths at the same elevation are far less than 20 ksi. The following plot shows the results graphically.

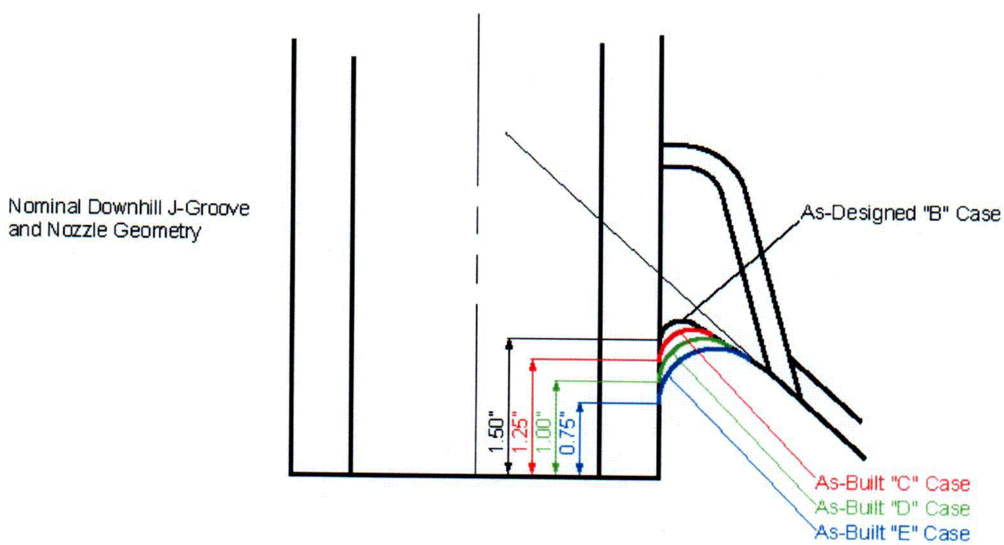


The following table provides a summary of the results for the 43 degree nozzle:

43° CEDM Nozzle Dist Below Weld to 20 ksi hoop stress (in)					
Downhill		Sidehill		Uphill	
ID	OD	ID	OD	ID	OD
0.4	**0.5 ***	2.0	0.3	1.9	0.3
Hoop Stress at Minimum Elevation (ksi)					
Downhill		Sidehill		Uphill	
ID	OD	ID	OD	ID	OD
2.5	20.0	17.9	-14.7	-28.3	5.9

*** Lowest elevation to reach 20 ksi hoop stress (Case "B" enveloping)**

This table shows that the lowest elevation in the 43 degree nozzle that experiences a hoop stress of 20 ksi or above is 0.5 inches below the toe of the weld on the downhill portion of the weld. Note that the hoop stresses at the sidehill and uphill azimuths at the same elevation are far less than 20 ksi. The 43 degree nozzle was also modeled with several different assumptions about the as-built weld geometry. The following illustration shows the variety of as-built geometries that were modeled.



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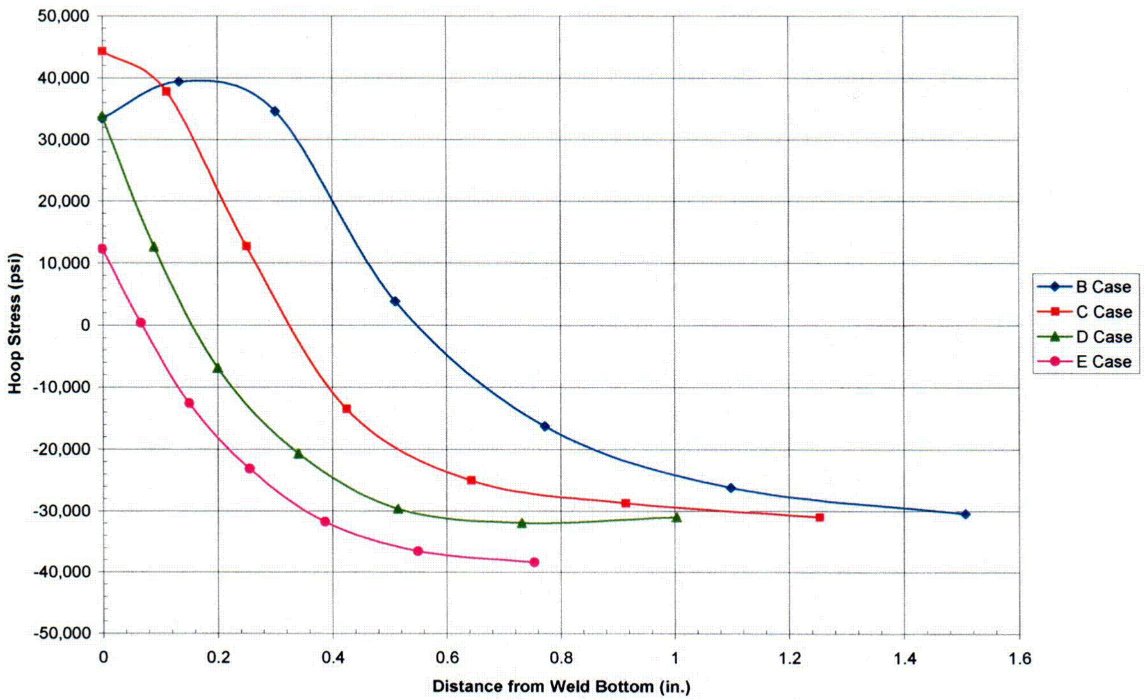
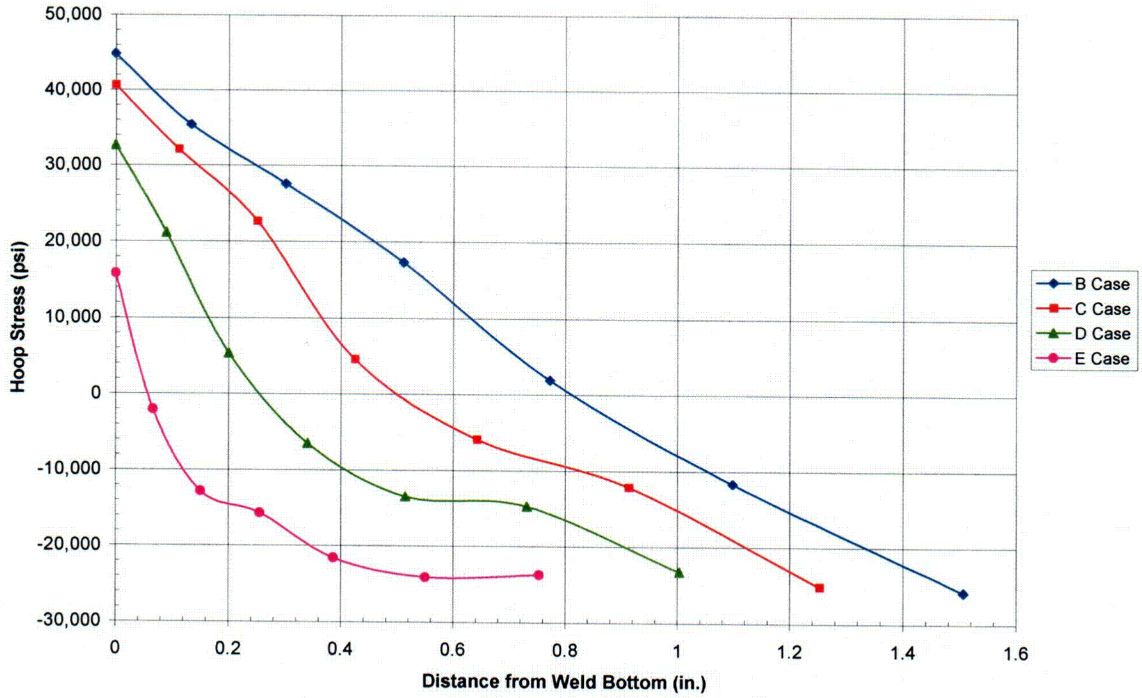
The following figures show the results of the stress analyses for the four as-built weld geometry variants. These figures show that as the weld fillet size is increased, the stresses in the nozzle below the weld decrease at a greater rate as a function of distance below the weld. The results of the analyses of the 43 degree nozzle indicate that hoop stresses decay to a value less than 20 ksi at an elevation 0.5 inches below the toe of the J-groove weld for all of the assumed weld geometries.

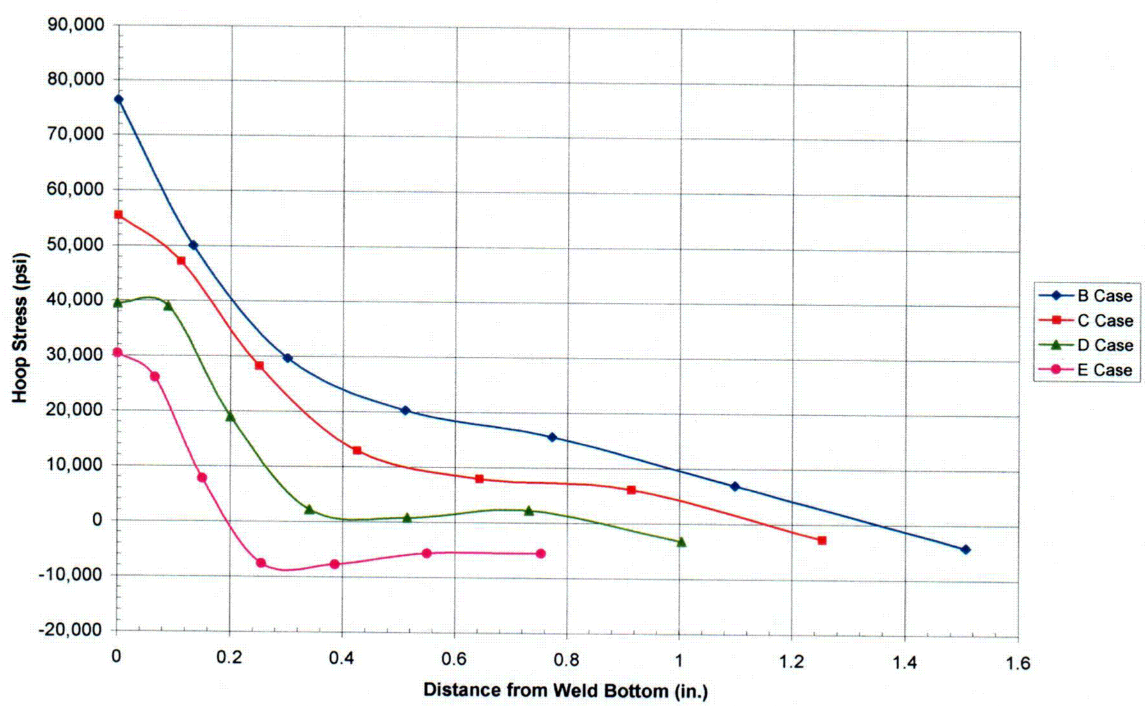


43 Degree Nozzle ID Operating Hoop Stresses Below the Weld - Downhill Plane

C03



43 Degree Nozzle Midwall Operating Hoop Stresses Below the Weld - Downhill Plane



43 Degree Nozzle OD Operating Hoop Stresses Below the Weld - Downhill Plane

C04

In summary, the hoop stresses decrease along the nozzle as the distance below the toe of the weld increases. The elevation where the hoop stresses decrease to a value below 20 ksi is different for different nozzle angles. The results are summarized as follows:

Nozzle angle (degrees)	0	11	29	43
Distance below the weld to an elevation where the hoop stress is reduced to 20 ksi (inches)	1	0.9	0.6	0.5

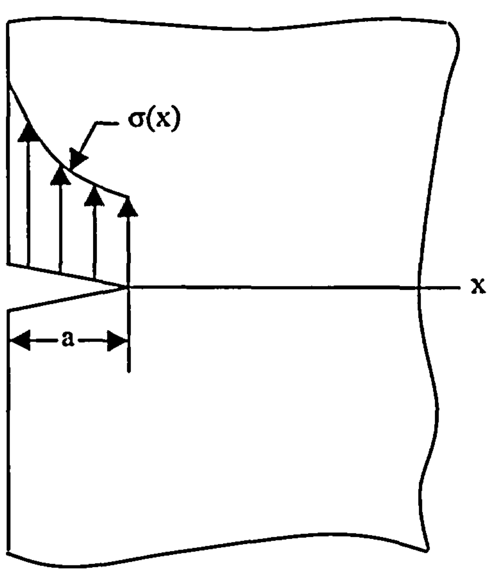
We have performed plant specific flaw growth analyses to determine the maximum flaw sizes that would satisfy NRC flaw evaluation guidelines for axial flaws that might be located in CEDM nozzles below the weld.

We postulated through-wall axial flaws extending from the bottom of the nozzle towards the weld to determine the maximum-length-flaws that would not grow to the bottom of the weld in a single two-year inspection interval. We performed analyses for all four penetration angles and for four different assumed as-built weld dimensions for the 43 degree nozzle. In order to cover the entire range of penetration angles and as-built configurations, interpolation was used to establish the maximum acceptable flaw sizes from the results of detailed flaw analyses.

The analyses were performed as follows:

Single Edge Crack Model for Axial Flaws

The crack is modeled as a continuous surface crack of length *a* in a semi-infinite body, subjected to an arbitrary stress profile.



Stress intensity factors are determined at the crack tip using the solution,

$$K_I = 1.12\sqrt{\pi a}\left[\left(A_0 + A_p\right) + A_1\left(\frac{2a}{\pi}\right) + A_2\left(\frac{a^2}{2}\right) + A_3\left(\frac{4a^3}{3\pi}\right)\right],$$

where the average through-wall hoop stresses in the uncracked nozzle are represented by the third-order polynomial,

$$\sigma = A_0 + A_1 x + A_2 x^2 + A_3 x^3,$$

and x = distance from the bottom of the nozzle
A_0, A_1, A_2, and A_3 = third-order stress coefficients
A_p = crack face pressure.

Crack Growth Rates:

a) Primary Water Stress Corrosion Cracking

Basis: MRP-55 crack growth rate for Alloy 600 material as expressed in NRC flaw evaluation guidelines, referenced to a temperature of 325°C using an activation energy of 31,000 calories/mole.

$$da/dt = C_o(2.67\times10^{-12})(K_I - 9)^{1.16} \text{ m/sec}$$

where K_I is the applied stress intensity factor in MPa√m, and

$$C_o = e^{-\frac{Q}{R}\left(\frac{1}{T}-\frac{1}{Tref}\right)}$$

where
Q = 130 kJ/mole = 31,000 calories/mole
R = 8.314×10^{-3} kJ/mole-°K = 1.987 calories/mole-°K

and
T = Operating temperature in degrees Kelvin
T_{ref} = Reference temperature in degrees Kelvin

At a operating temperature of 594°F, the temperature correction term is

$$C_0 = 0.566$$

b) Fatigue Crack Growth

Basis: Crack growth rate for Alloy 600 material in a PWR water environment as expressed in NRC flaw evaluation guidelines.

$$\frac{da}{dN} = CS_R S_{ENV}(\Delta K)^n$$

where ΔK is the stress intensity factor range in terms of $MPa\sqrt{m}$ and da/dN is the crack growth rate in terms of m/cycle

$$C = 4.835\text{x}10^{-14} + 1.622\text{x}10^{-16}T - 1.490\text{x}10^{-18}T^2 + 4.355\text{x}10^{-21}T^3$$

$$S_R = [1 - 0.82R]^{-2.2}$$

$$S_{ENV} = 1 + A[CS_R\Delta K^n]^{m-1}T_R^{1-m}$$

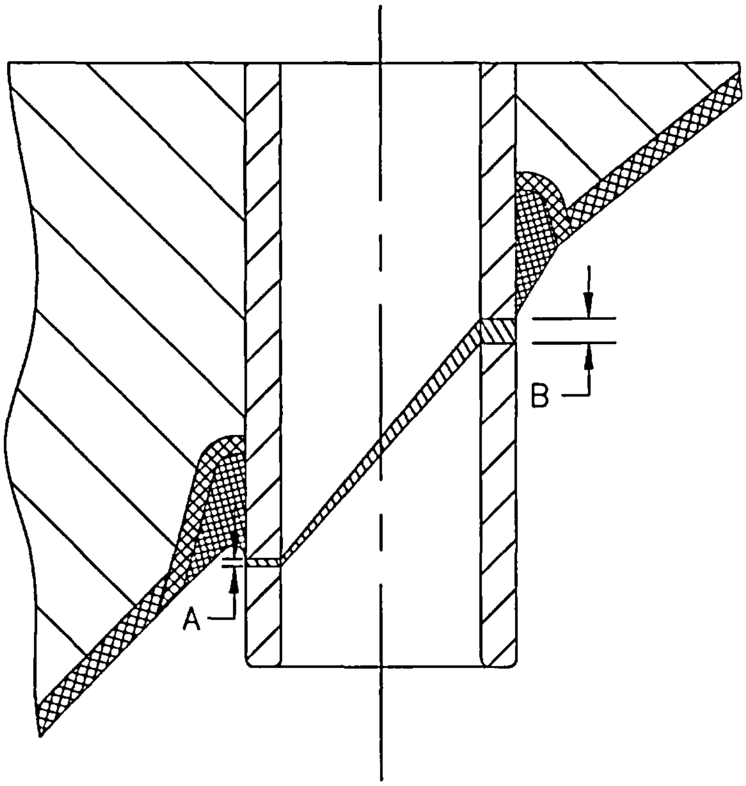
$A = 4.4\text{x}10^{-7}$
$M = 0.33$
$N = 4.1$
T = degrees C
$R = K_{min} / K_{max}$
T_R = rise time, set at 30 sec.

Results of Flaw Growth Analyses:

Maximum Growth of Bounding Axial Through-Wall Flaws Below the Weld
(Bounding for all Weld Lengths)

Location	Downhill Side (A)	Uphill Side (B)
0° Nozzle	0.324"	0.324"
11° Nozzle	0.179"	0.386"
29° Nozzle	0.191"	0.361"
43° Nozzle	0.200"	0.360"

See Figure below for location of the downhill and uphill sides identified on the Table above.



Since there is not a situation where the inspection extent is greater on the downhill side than on the uphill side, our minimum inspection distance is selected from the flaw tolerance evaluation for the downhill side. The results indicate that, provided we inspect nozzles for a distance of 0.324 inches below the weld (regardless of actual weld size), any flaw existing in the un-inspected region below this elevation could not grow to a point that it would reach the elevation of the weld within an additional cycle of operation.

NRC Request 2:

What are the yield strengths and heat numbers of the material used in Unit 1?

CCNPP Response:

All of the Unit 1 CEDM nozzles are fabricated from Huntington Alloys, Alloy 600 material, heat number NX 9739, which has a yield strength of 42 ksi.

NRC Request 3:

Was the crack growth rates assessed using MRP-55? What was the initial flaw size used? Please provide more detail of what was used in the calculations and what assumptions were used. The licensee is requested to describe the methodology in detail and provide examples for the crack growth calculations. Was the crack growth evaluation based on the as-built weld geometry? If not, please provide justification if the crack growth evaluation was not based on the as-built weld geometry.

CCNPP Response:

Please see the response to Relaxation Request 2, NRC Request 1.

NRC Request 4:

What is the distance from below the J-groove weld to the area of the nozzle that can not be inspected?

CCNPP Response:

We will provide this information when we complete the inspection of the Unit 1 nozzles. The distance that cannot be inspected is approximately 0.56 inches on the nozzle OD and 1/8 inches on the nozzle ID from the bottom of the nozzle as depicted on Figure 1 of our relaxation request (Reference 1).

REFERENCES:

1. Letter from Mr. G. Vanderheyden (CCNPP) to Document Control Desk (NRC), dated January 30, 2004, Request for Relaxation from NRC Order EA-03-009, "Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors"
2. Materials Reliability Program Generic Evaluation of Examination Coverage Requirements for Reactor Pressure Vessel Head Penetration Nozzles (MRP-95), WPRI Report 1009129, September 2003
3. Letter from Mr. R. Barrett, Director Division of Engineering, Office of Nuclear Reactor Regulation, to Mr. Alex Marion, Director of Engineering, Nuclear Energy Institute, dated April 11, 2003, "Flaw Evaluation Guidelines"