P.O. Box 63
Lycoming, New York 13093

Constellation Energy Group
Nine Mile Point Nuclear Station

September 19, 2003
NMP1L 1776

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

SUBJECT: Nine Mile Point Unit 1
Docket No. 50-220
Facility Operating License No. DPR-63

Reactor Pressure Vessel Flaw Evaluation

Gentlemen:

In accordance with the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, Paragraph IWB-3610 (1989 Edition), Nine Mile Point Nuclear Station, LLC (NMPNS) is submitting for NRC staff review and approval the attached structural flaw evaluation of a subsurface flaw indication found in a Nine Mile Point Unit 1 reactor pressure vessel closure head meridional weld.

Ultrasonic examinations performed during Refueling Outage 17 identified a subsurface flaw indication in closure head meridional weld RV-WD-005. The indication was characterized per Section XI, Paragraph IWA-3320 and Figure IWA-3320-1 of the ASME Code as a subsurface planar flaw. Supplemental inspections and reviews conducted by NMPNS provide reasonable assurance that the flaw indication is related to the original fabrication, not service induced.

Flaw characteristic calculations were performed to determine acceptability on the basis of IWB-3500, Paragraph IWB-3510.1. The flaw was initially dispositioned as unacceptable. Further analytic evaluation, performed in accordance with the methods prescribed in IWB-3600, demonstrate that the weld containing the flaw is acceptable for continued service. The attached calculation S0VESSELM035, Revision 0, documents the closure head weld flaw evaluation.

Very truly yours,

William C. Holston

William C. Holston
Manager Engineering Services

WCH/JJD/bjh
Attachment

A047

cc: Mr. H. J. Miller, NRC Regional Administrator, Region 1
Mr. G. K. Hunegs, NRC Senior Resident Inspector
Mr. P. S. Tam, Senior Project Manager, NRR (2 copies)

NUCLEAR ENGINEERING	CALCULATION COVER SHEET	Page 1 (Next 2) Total 22 Last A2

Project: NINE MILE POINT NUCLEAR STATION **Unit (1, 2 or 0=Both) :** 1 **Discipline :** MECHANICAL

Title	Calculation No.			
RPV CLOSURE HEAD WELD FLAW EVALUATION	S0VESSELM035			
	(Sub)system(s) RXVE	Building RX	Floor Elev. 340	Index No. S0

Originator(s)
G.L. STEVENS (STRUCTURAL INTEGRITY ASSOCIATES, INC.)

Reviewer(s) / Approver(s)
K. K. FUJIKAWA (SIA)/ G.L. STEVENS (SIA) / ACCEPTED BY R. CORIERI

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Structural Integrity Associates, Inc.

ATTACHMENT
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REVISION 0
PAGE NO 2

6595 S. Dayton Street
Suite 3000
Greenwood Village, CO 80111-6145
Phone: 303-792-0077
Fax: 303-792-2158
www.structint.com
gstevens@structint.com

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Roy Corieri
Constellation Energy Group
Nine Mile Pt. Nuclear Station
Nine Mile Point – U2 Warehouse
348 Lake Road
Oswego, NY 13126

Subject: Nine Mile Point Unit 1 RPV Closure Head Flaw Evaluation

Dear Roy:

This letter report documents Structural Integrity Associates' (SI's) evaluation of the flaw in the Nine Mile Point Unit 1 RPV closure head.

INTRODUCTION

An indication was identified in the Nine Mile Point 1 (NMP-1) closure head. Per the NDE Report NMP1-03-001 [1], the indication is located in the vicinity of axial weld RV-WD-005 of the closure head. The closure head weld seam is seen in View 1A-1A of the Nine Mile Point drawing [3]. The indication was characterized per ASME Section XI, Paragraph IWA-3320 and Figure IWA-3320-1 as a subsurface planar flaw. Flaw characteristic calculations were performed to determine acceptability on the basis of IWB-3500, Paragraph IWB-3510.1. The flaw was dispositioned as unacceptable. See Figure 1 detailing the flaw characterization per IWB-3500.

SI performed the same flaw characterization and evaluated the flaw in accordance with ASME Section XI, IWB-3600, Analytical Evaluation of Flaws. Per the Nine Mile Point Unit 1 purchase order [2] for performing flaw evaluations in case flaws were deemed unacceptable per IWB-3500, the Flaw Evaluation Handbook for Oyster Creek [4] was to be used.

METHODOLOGY

This subsection summarizes the methodology used to develop the Oyster Creek Flaw Evaluation Handbook [4].

Overview of Section XI Evaluation

The 1986 edition of Section XI of the ASME Boiler & Pressure Vessel Code was generally used to develop the allowable flaw sizes, modified with additional more conservative criteria, as discussed below. The rules for evaluation of flaws in reactor vessels are contained in IWA-3000, IWB-3500 and IWB-3600 of Section XI [11]. Appendix A of Section XI provides specific methodology that may be used for detailed fracture mechanics evaluations. The following provides an overview of the Section XI evaluation approach.

In the first step of vessel flaw evaluation, the indications from vessel inspections must be characterized per the requirements of Section XI Article IWA-3000. This requires that the indications be bounded by a rectangular shape with depth (a for surface flaws and 2a for subsurface flaws) and length (l) that will completely contain the suspected material flaws. Closely adjacent flaws must be linked together based on proximity criteria contained in IWA-3000. Similarly, flaws closely adjacent to the base metal surface must be considered surface flaws, based on criteria presented in IWA-3000.

The next step in the vessel flaw evaluation is to compare the flaw with the evaluation standards included in Table IWB-3510-1. This table provides the size of allowable planar flaws that may be accepted without further evaluation. Table IWB-3510-1 defines allowable sizes for surface and subsurface flaws as a function of wall thickness (t), flaw aspect ratio (a/l) and flaw depth ratio (a/t), where t is the measured base metal thickness.

If the indication is larger than may be accepted by IWB-3510-1, then additional analytical evaluation is allowed per IWB-3600. These evaluations are based on the total wall thickness including cladding with characterization and surface proximity rules shown in Figure IWB-3610-1. As shown in the figure, flaws located closely adjacent to the surface must be evaluated as surface flaws. However, flaws located completely within the vessel cladding are acceptable with no further evaluation per IWB-3610 (b)(1). Key points of the evaluation include:

- The ASME Code Section XI criteria allow acceptance by specifying a factor of safety on either the size of the critical flaw, or a factor of safety on the stress intensity factor.
- Separate evaluations are required for Normal/Upset and Emergency/Faulted conditions, with different factors of safety for each condition.

Appendix A of Section XI provides a detailed procedure for vessel flaw evaluation. For evaluation of flaws in shell-like structures such as the reactor vessel wall, the methodology of Appendix A of Section XI is directly applicable. To perform the analysis, the following factors must be considered:

- The flaw must be characterized and resolved into a shape that can be evaluated. This includes determination of the depth ratio (a/t) and the aspect ratio (a/ℓ or $2a/\ell$) of the flaw (Figure IWB-3610(b)(1)). For subsurface flaws, the eccentricity ratio (e/t or 2e/t) must be determined, where *e* is the distance from the center of the vessel wall (including cladding) to the center of the flaw (Figure A-3300-4, of Appendix A of Section XI).

- Stresses and the temperature at the location of the flaw must be determined for all loading conditions.
- The flaw stress intensity factor must be calculated, either by using the equations, charts, and tables of Appendix A of Section XI or through use of other, more sophisticated, documented analytical techniques.
- The material properties must be defined at the location of the flaw, including the effects of irradiation. Any through-wall variation of material properties should be considered.
- The crack growth that can occur during the evaluation interval must be determined (e.g., to the next inspection or to end-of-life).
- The predicted flaw size at the end-of-evaluation period must be less than that allowed by Section XI.
- The primary stress limits of the original code of design (NB-3000) must also be met assuming a local area reduction of the pressure-retaining membrane that is equal to the area of the characterized flaws.

Specific Details of Vessel Shell Evaluation

Stress Intensity Factors

Appendix A of Section XI provides a basic methodology for evaluating vessel flaws. However, there is limited guidance for the determination of stress intensity factors for cracks extending through cladding. In addition, the guidelines are very limited for determining the stress intensity at the surface for surface flaws. The following describes how the stress intensity factors were determined for the Oyster Creek RPV evaluation.

Appendix A Methods

For all stresses, except for those due to cladding for an internal surface flaw, the methods of Appendix A are used for the deepest point of surface flaws and for subsurface flaws.

Surface Stress Intensity Factors (except for cladding)

For surface stress intensity factors of surface flaws, M_m and M_b, as defined in Appendix A of Section XI, have been determined based on the Raju/Newman membrane and bending solutions [12] for the worst case of internal and external cracks for a vessel with thickness-to-radius (t/r) ratio of 0.1. Referencel2 derives surface stress intensity factors for t/r values of 0.1 and 0.25. Based on a comparison of the influence coefficients for t/r values of 0.1 and 0.25, it is noted that t/r has a very minor effect on the stress intensity factor solutions. Therefore, the calculated M_m and M_b values are applicable for Oyster Creek, which has a t/r ratio of approximately 0.06. The resulting surface stress intensity factor is applied at the cladding-to-base metal interface for the vessel inside surface. For flaws with an aspect ratio (*a*/*l*) of zero, the surface stress intensity factor is assumed to be zero since an infinitely long crack does not have a surface point.

Cladding Stress Intensity Factor

For cladding stresses for a long inside-surface flaw, the stress intensity factor at the deepest point of the flaw is determined by integration of the stress over the crack face for an edge-cracked plate using the methods from Tada and Paris [13].

$$\overline{K_I} = \frac{2}{\sqrt{\pi a}} \int_o^a m(x) \bullet \sigma(x)\, dx \qquad (1)$$

where: $\sigma(x)$ = cladding stress distribution in cladding and base metal as a function of distance (x) from clad surface

a = crack depth

$$m(x) = \frac{3.52(1-a^*)}{(1-t^*)^{1.5}} - \frac{4.35-5.28a^*}{(1-t^*)^{0.5}} \qquad (2)$$

$$+\left[\frac{1.3-0.3(a^*)^{1.5}}{(1-(a^*)^2)^{0.5}} + 0.83 - 1.76a^*\right] \bullet \left[1-(1-a^*)t^*\right]$$

where: a^* = x/a

t^* = a/t

t = wall thickness

As shown in a paper by Kuo, Deardorff, and Riccardella [14], this type of solution yields a stress intensity factor that shows a reasonable comparison to "exact" solutions for flaw depth ratios (a/t) up to about 0.33. Above this ratio, the solution is unrealistic and increases significantly whereas solutions based on more sophisticated techniques vary little for deeper cracks. Thus, it is assumed that the stress intensity factor may be described by the following:

For $a \leq a_{min}$,

$$K_I' = \overline{K_I} \qquad (3)$$

For $a > a_{min}$

$$K_I' = \text{lesser of } \overline{K_I}$$

or

$$\bar{K}_{I_{min}} \sqrt{\frac{a}{a_{min}}} \qquad (4)$$

where: $\overline{K}_{I_{min}}$ = minimum $\overline{K_I}$ in base material
a = crack depth size
a_{min} = a at $\overline{K}_{I_{min}}$

To account for the flaw aspect ratio, the stress intensity factor is corrected using the crack shape factor, Q, of Appendix A of Section XI as follows:

$$K_I = K_{I'}\left(\frac{Q_o}{Q}\right)^{0.5} \quad (5)$$

where, Q_o = shape factor for flaw with aspect ratio of $(a/l) = 0$
Q = shape factor for flaw with aspect ratio (a/l) being evaluated

In determining the shape factor ratio, the stress ratio (the other factor affecting Q and Q_o) is determined based on membrane plus bending stress ($\sigma_m + \sigma_b$) for the flaw. However, the cladding induced stresses at the crack are excluded since, in the base material, these stresses are either small or compressive.

ASME Section XI does not require that the stress intensity factor in the cladding be evaluated. However, the stress intensity factor for the cladding-to-base metal interface location is calculated based on determination of the surface stress intensity factor. To calculate the surface stress intensity factor, the cladding stress intensity factor (obtained by Equations 1 and 5 above) for a flaw depth equal to the thickness of the cladding (with the same aspect ratio as the deeper flaw being evaluated) is determined. It is then modified based on the ratio between the membrane stress intensity correction factors for the surface (using the Raju/Newman, M_m) and the crack tip (using the Appendix A, M_m). This formulation is considered conservative for this analysis. Note that ASME Section XI does not require the stress intensity factor due to the cladding to be considered. Thus, this methodology is considered more conservative compared to Appendix A, Section XI of the ASME Code.

For very long flaws with an aspect ratio of zero (a/l = 0), there is no surface point. Therefore, the stress intensity factor due to cladding at the "surface" is set to zero.

Fracture Toughness

The fracture toughness of the reactor pressure vessel material is obtained from Section XI, Appendix A in terms of K_{Ia} and K_{Ic}, which represent the critical values of the stress intensity factor, K_I, based on crack arrest and static crack initiation, respectively.

The conservative lower bound K_{Ic} and K_{Ia} are defined as functions of the local temperature of the vessel wall as follows:

$$K_{Ic} = 33.2 + 20.734\, e^{0.02(T-RT_{NDT})}$$

and,

$$K_{Ia} = 26.8 + 12.445\, e^{0.0145(T-RT_{NDT})}$$

The analyzed vessel wall local fracture toughness, at the location of the associated crack stress intensity factor, is determined with consideration of local temperature (as a function of wall depth), initial RT_{NDT}, local fluence, margins and chemistry factors in accordance with the methods of Regulatory Guide 1.99 Revision 2 [15]. The approach is as follows:

$$ART = RT_{NDT,i} + RT_{NDT}\,Shift + Margin \qquad (6)$$

where:

ART	=	adjusted reference temperature, °F
$RT_{NDT,i}$	=	initial RT_{NDT}, °F
$Margin$	=	required margin = $2\sqrt{\sigma_i^2 + \sigma_\Delta^2}$, °F

($RT_{NDT}\,Shift$, σ_i, and σ_Δ are defined below)

The margin is determined based on the standard deviation of the initial RT_{NDT} (σ_i) and that of the RT_{NDT} *shift* (σ_Δ). The standard σ_Δ is 28°F for welds and 17°F for base metal [15], except that σ_Δ need not exceed 0.5 times the computed shift in RT_{NDT}.

$$RT_{NDT}\,Shift = (CF) \bullet (FF) \qquad (7)$$

where:

CF	=	chemistry factor, °F
FF	=	fluence factor, dimensionless

$$FF = f^{(0.28-0.1\log_{10}(f))} \qquad (8)$$

where: f = local fluence, neutrons/cm^2 x 10^{19} (E>1MeV)

The local fluence, f, at any position in the wall may be calculated from:

$$f = f_{surf}\, e^{-0.24x} \qquad (9)$$

where:

f_{surf}	=	fluence at inside surface, neutrons/cm^2 x 10^{19} (E>1MeV)
x	=	distance from inside surface, inches

The fluence at the surface is a function of the amount of irradiation exposure time:

$$f_{surf} = \frac{f_{ref}}{EFPY_{ref}} \times EFPY \qquad (10)$$

where:

f_{ref}	=	reference surface fluence, neutrons/cm^2 x 10^{19} (E>1MeV)
$EFPY_{ref}$	=	effective full power years associated with f_{ref}
$EFPY$	=	effective full power years for evaluation

This allows the adjusted reference temperature, ART, to be calculated for all the vessel regions at any depth, at any time, and for each specific weld or plate being evaluated.

Fatigue Crack Growth Considerations

The fatigue crack growth law for ferritic steels in water environment is provided by Section XI of the ASME Code [11]. This law is applicable to the inside surface flaws of the reactor vessel. For allowable subsurface and outside surface flaws, a crack growth curve for ferritic steel in air environment is assumed. A conservative estimate of the crack growth for air is defined in Section XI Appendix A of the 1992 Edition of ASME Code. For inside surface flaws, the water environment crack-growth curve used is conservatively based on $R \geq 0.65$, where R is the ratio of the minimum crack tip stress intensity factor to the maximum stress intensity factor (K_{min}/K_{max}). For subsurface and outside surface flaws, the crack growth curve for air environment is conservatively based on R=1.

The stress intensity factor at the allowable flaw size for each flaw is conservatively used in the crack growth evaluation. For flaws accepted by the evaluation standards of Table IWB-3500-1, there is no requirement to consider crack growth.

The primary source for crack growth in the vessel low alloy steel is the cyclic loading due to startup/shutdown of the reactor. For purpose of crack growth, the number of cycles from the time of the vessel inspection to the end of the evaluation period is estimated. A conservative estimate of 240 startup/shutdown cycles were considered in the determination of crack growth.

Subsurface Flaw Characterization

Subsurface flaws of various eccentricity ratios (e/t) are evaluated. Per the requirements of Table IWB-3510-1 or Figure IWB-3610-1, a near surface subsurface flaw must be evaluated as a surface flaw when the distance between the surface and the nearest point of the flaw (s) is less than 0.4d, where d is half the depth of the subsurface flaw. Based on these requirements, the maximum subsurface flaw size that does not have to be evaluated as a surface flaw is found with the following equation:

$$\left(\frac{a}{t}\right)_{max} = \frac{0.5 - |e/t|}{1.4} \qquad (11)$$

where: t = thickness of vessel base material (for IWB-3500 evaluation), or total thickness of vessel wall including cladding (for IWB-3600/Appendix A evaluation).

e = flaw eccentricity, measured from center of vessel wall, (determined with or without cladding as appropriate), negative if toward inner vessel wall.

Definition of Allowable Flaw Size and Shape

The development of the flaw acceptance diagrams requires evaluating hypothetical flaws to determine the allowable flaw depth for the complete range of flaw aspect ratios and eccentricities (for subsurface flaws). The evaluation is started with the maximum flaw depth that can be analyzed. For surface flaws, the maximum depth of 0.8 times the total vessel wall thickness is used since it is the limit of applicability of most fracture mechanics solutions. The flaw is checked for acceptability based on the Section XI, IWB-

3600 criteria for crack size and stress intensity factor. Then, the flaw depth is incrementally decreased based on a specified crack size increment and the acceptability check is repeated for the resulting crack size.

In some cases, such as when there is a large bending component to the through-wall stress distribution and, the fracture toughness through the wall is not constant due to irradiation embrittlement and/or local temperature and/or, cladding stresses are a significant contribution to the stress intensity factor, there may be more than one acceptable flaw geometry through the vessel wall. Thus, there may be some flaws near the surface that are not acceptable even though flaws with larger depths may be acceptable. Also, if, due to high surface stresses, the stress intensity factor is larger at the surface point of the flaw rather than at its deepest point, a longer flaw (smaller aspect ratio, e.g., infinitely long flaw) may be acceptable when a similar depth flaw which is shorter would not be acceptable. These cases do not reflect the underlying idea of the acceptance criteria of IWB-3500, which implies that a smaller flaw is more acceptable than a larger one. Therefore, the allowable flaw size at a location can be reported three different ways:

- **Option 1**: Report the largest flaw depth that is acceptable for each of the flaw aspect ratios evaluated. This is analogous to evaluating an actual flaw by assuming a larger bounding flaw size. This approach is the most logical although it appears to be less conservative for the special stress and material conditions discussed above.

- **Option 2**: Report the largest near-surface flaw depth that is acceptable for each of the flaw aspect ratios evaluated, regardless of the fact that flaws with larger depths are also acceptable. This approach is more conservative as compared to Option 1.

- **Option 3**: Report the largest near-surface flaw depth that is acceptable as in Option 2 but use a smaller flaw aspect ratio (assume a longer flaw). This approach is specifically applicable to cases where, due to the fact that the surface stress intensity factor is controlling, a longer flaw is more acceptable than a shorter flaw of the same depth.

In the evaluations performed in this report, the first option has been chosen since the stress intensity factor solutions for surface stresses and cladding are believed to be very conservative. In addition, when the stress/material conditions at the surface are controlling, the limiting acceptable flaw is shallow and less likely to grow to any significant depth. Moreover, if such a flaw were to grow, it would eventually become large enough to meet the acceptance criteria for the larger flaw. In most cases, more sophisticated analysis, as allowed by Section XI, Appendix A, A-3300 (c), could result in lower values of stress intensity factors.

The stress intensity factor within the cladding does not have to be evaluated for acceptability per Section XI requirements. Thus, the allowable inside surface flaw size will always be equal to the cladding thickness plus that allowed by the acceptance standards of IWB-3500.

Vessel Shell Analysis Implementation

The flaw acceptance analysis has been prepared using a computer program developed and verified by SI for this specific purpose. APPENDA (Appendix A Analysis) [16] is a computer program written to perform reactor pressure vessel flaw evaluation in accordance with Appendix A of Section XI and Subarticle IWB-3600 of Section XI of the ASME Boiler and Pressure Vessel Code [11]. It uses the methodology described

above, and determines allowable inside surface, outside surface and subsurface flaws. It is intended to provide a rapid assessment of all possible flaws to allow construction of flaw acceptance diagrams that may be used to provide guidance in reactor vessel inspections.

APPENDA performs an evaluation to determine the acceptable size of surface and subsurface flaws in accordance with the requirements of ASME Code, Section XI, Appendix A and Subarticle IWB-3600 [11]. In addition, the acceptability of relatively smaller flaws is evaluated in accordance with Section XI, Table IWB-3510-1 [11] for planar flaws. The program output includes the acceptable flaw size for the complete range of flaw aspect ratios and flaw eccentricities (for subsurface flaws). The key features of the program include:

- ability to include an arbitrary stress distribution for pressure, bending, thermal, and residual stresses, including load multiplier factors for each.
- evaluation of cladding stresses, with several methods to handle the effects of the cladding stresses at the surface for inside surface flaws.
- ability to evaluate flaws based on either the maximum acceptable size, minimum acceptable size, or the minimum acceptable size assuming a smaller aspect ratio, a/ℓ.
- consideration of the varying safety factors associated with Normal/Upset condition, Emergency/Faulted condition or regions near local discontinuities (per IWB-3613 (a)).
- automatic determination of the wall fracture toughness distribution given initial material properties and accumulated surface fluence at the end of the evaluation period.
- conservative assessment of flaw growth to the end of the evaluation period.

A separate utility program MAPPA (Multiple Appendix Analysis) provides an evaluation of multiple input cases (load conditions) and determines the controlling loading condition (or combination of conditions) for a location based on a number of individual evaluations using APPENDA.

Code Reconciliation

* The current evaluation is generally based on methodology from the 1986 edition of Section XI of the ASME Code. The Oyster Creek reactor pressure vessel was constructed in accordance with the 1959 ASME Code, Section I, with Addenda through Summer 1963 and the 1963 ASME Code, Section III. The following steps of the evaluation contain criteria taken from ASME Code Edition issued after the Oyster Creek's Code of Construction:

1. For this evaluation, the 1995 Code with 1996 Addenda is used as the basis for fatigue crack growth curves. This provides a more conservative curve for an air environment (subsurface or outside surface flaws) that is dependent on the R ratio (K_{min}/K_{max}).

2. In this evaluation, the methodology of Reg. Guide 1.99, Rev. 2 [15] is used for determining the total shift in RT_{NDT} as affected by uncertainties, fluence and materials composition. Use of this approach is consistent with current regulatory requirements for evaluation of reactor vessel materials.

* NOTE: THE APPLICABLE CODE EDITION FOR THE NINE Mile POINT Unit 1 ISI PROGRAM IS ASME XI, 1989. THE FLAW EVALUATION METHODOLOGY USED IN THE ASME XI 1986 and 1989 EDITION ARE GENERALLY THE SAME. 7/22/03

3. For purposes of stress analysis, material properties were obtained from the 1995 edition of the ASME Code (Section II, Part D), which provides more detailed temperature dependent material properties.

The 1995 edition of the ASME Code with 1996 Addenda was the most recent version of the Code approved by 10CFR50 when the Oyster Creek flaw handbook was developed.

A default maximum flaw size was determined such that the nominal stress would increase to approximately 1.5 times the nominal stress if a long flaw existed at the location. The additional limitation was based on primary stress limits in Subsection NB-3000 of Section III of the ASME Code. The stress limits were added since IWB-3610(d)(2) requires that the primary stress limits of NB-3000 (of ASME Section III) be satisfied for the size of the evaluated flaw. For actual flaws found in a reactor pressure vessel, this should never become limiting because NB-3000 allows local primary membrane stresses to approach 1.5 S_m provided that the extent of the region with stress exceeding 1.1 S_m does not exceed $\sqrt{Rt}$ (where R is the mean vessel radius and t is the thickness). This compares to the requirement for the design equations for pressure sizing where the stress must be maintained below S_m. Based on this ratio, if the pressure stress is near the allowable stress, the additional primary stress criterion might become governing for axial flaws with depths approaching one-third of the wall thickness that have any significant extent. Since the stresses acting on circumferential flaws are about one half of that for axial flaws, greater flaw depths would be allowed for flaws with a circumferential orientation, assumed in this evaluation to be limited to 50% of the wall thickness, except at regions near discontinuities where the one-third of wall thickness default maximum size is used.

Therefore, the maximum allowable flaw sizes defined by Section III stress limits were evaluated for each region and incorporated in into the flaw acceptance diagrams.

ANALYSIS AND RESULTS

The flaw handbook for Oyster Creek RPV [4] was used to evaluate the flaw in the closure head of NMP-1, due to the availability of a detailed finite element model for Oyster Creek and since the RPVs between the two plants are nearly identical. The validity of using the Oyster Creek RPV flaw handbook was based on a comparison of the associated RPV geometries and stresses. Each of these comparisons is discussed in the sections that follow.

Geometry Comparison

A comparison of the two RPV geometries and materials was performed and is summarized below:

- Vessel closure head materials, SA-302 Gr. B, are the same for both plants [4, 6].
- The limiting RT_{NDT} for the top head material (for Region B) for Oyster Creek is 45°F [4]. Per Constellation input, the limiting RT_{NDT} for the top head material for NMP-1 is 40°F.
- The dimensions of the Oyster Creek finite element model are shown in Figure 2, as extracted from Reference [8]. These dimensions are identical to those found on the final machining drawing applicable to NMP-1 [7].

Based on the above, the Oyster Creek flaw handbook results are applicable and bounding for application to NMP-1 from a materials and geometry point-of-view.

Stress Comparison

A comparison of the stresses for the two RPVs was performed and is summarized in Table 1. The stresses in Table 1 come from four sources: (1) the original Combustion Engineering (CE) RPV stress report for Oyster Creek, (2) the original CE RPV stress report for NMP-1 [6], (3) the RPV flaw handbook for Oyster Creek [4], and (4) the RPV head tensioning evaluation report for NMP-1 [5]. The stresses listed in Table 1 were extracted from similar locations in all evaluations for a consistent comparison, and bound the stresses at the flaw location (but are not coincident with the flaw location).

The following conclusions can be made with respect to the results shown in Table 1:

- Considering the different models, techniques and boundary conditions used between all of the analyses, there is very reasonable agreement between all of the stress reports.
- The revised bolting procedure evaluation caused increased boltup stresses in the top head region.
- The stresses from the revised bolting procedure evaluation are slightly higher than those used in the RPV flaw handbook. These higher stresses should be considered before application of the Oyster Creek flaw handbook to NMP-1.

Since the stresses from the revised bolting procedure evaluation were not bounded by those used in the flaw handbook [4], additional refined stress values were obtained at the flaw location of interest. Reference [10] documents the stresses from the revised bolting procedure evaluation to be 5.6 ksi on the outside surface, and 1.5 ksi on the inside surface at the flaw location. These stresses are well below the stresses tabulated in Table 1 that were used in the Reference [4] flaw evaluation handbook.

Based on the above, the Oyster Creek flaw handbook results are applicable for this flaw and bounding for application to NMP-1 from a stress point-of-view.

Results

Figure 3 details the flaw characterization calculation as well as flaw evaluation based on Reference [4]. According to the revised Oyster Creek flaw acceptance diagram for the closure head axial welds (Appendix B, Figure B-2 Subsurface Flaw [e/t = -0.4]), the flaw RV-WD-005 is acceptable per IWB-3600. Figure 4 shows a plot of Allowable Flaw Depth (in.) versus Flaw Aspect Ratio (2a/l). Flaw RV-WD-005 is below the acceptable flaw limit determined using the methods of IWB-3600. The allowable flaws shown in the revised Oyster Creek flaw acceptance diagrams include allowance for fatigue crack growth with an assumed 240 cycles of startup/shutdown.

CONCLUSION

Based on the analysis documented herein, RPV top head flaw RV-WD-005 is considered acceptable for continued operation at NMP-1.

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PAGE NO 13

If you have any questions, please feel free to give me a call at (303) 792-0077.

Prepared By: *Gary L. Stevens*
G. L. Stevens, P.E.
Associate

Reviewed By: *Karen K Fujikawa*
K. K. Fujikawa, P.E.
Associate

Approved By: *Gary L. Stevens*
G. L. Stevens, P.E.
Senior Associate

cc: NMP-05Q-106 (ODL), -404

Table 1. Comparison of Boltup Hoop Stresses

Reference →	NMP-1 CE Stress Report [6] (at Cut I)	Oyster Creek CE Stress Report [9] (at Cut I)	Oyster Creek Flaw Handbook [4] (Region B, 90°F)	Dominion Head Tensioning Report [5] (at Cut Line 6)	
				Design Case	Revised Process
Inside Surface Hoop Stress (ksi)	3.7	3.7	2.1	6.4	7.6
Outside Surface Hoop Stress (ksi)	14.6	14.6	17.6	15.2	18.1

NIAGARA MOHAWK — Evaluation of Reportable Indications

Nine Mile Point Unit 1
ISO/Dwg.: F-45183-C SH. 28
System: 00 RPV

NDE Report: NMP1-03-001
Page 1 of 12
Work Document: NMP1-ISI-003-10 Rev. 2
Exam Item: RV-WD-005
Procedure: G9M12-ISI-PDI-UT-6 Rev. 1

Indication(s): 1

Applicable ASME Code Standard(s) used for evaluation:
Section XI Edition 1989 Addenda NO

Size of Indication:
Length 7.0" Depth 4.25" Width .3" (2a)
* (Specify how width 'A' is determined. ie: ~~50% points~~, Tip Diffraction, Graphically, etc.) Tip Diffraction

Component Thickness: 4.8"

Characterization of flaw indication per paragraph: * IWA-3320-1
Type of indication: SUBSURFACE PLANAR

Flaw characteristics calculations: (Attach sketch if necessary)
(Attach separate calibration reports for evaluation examinations)

$2d = .3"$

$d = .15" \times 0.4 = 0.06 \quad S = .2" \quad S > 0.06 \therefore$ * "SUBSURFACE"

$a/l = \frac{.15"}{7.0"} = 0.0214$

$a/t = \frac{.15"}{4.8"} = 0.03125 = 3.125\%$

NOTES: ① Supplemental 45° & 60° RL examinations were performed from the I.D. surface to verify indication position. (Ref: 1-6.27-03-0001 and -0002)
② Supplemental P.T. examination was performed from the I.D. surface to verify that indication did not extend into the I.D. (Ref: 1-3.00-03-0284)
③ Original C.E. construction R.T. film was digitized & reviewed at the RG&E lab. (2) Locations were noted in the area of the U.T. indication that show surface preparation indicating a weld repair region. There were also areas noted in this region that appeared to be indicative of lack of fusion.

Comparison to pertinent evaluation standard to actual indication size:
Actual A/T % 3.125 Allowable A/T % 2.0 2.6

Disposition: Paragraph IWB-3510.1 Table No. IWB-3510-1

NOT ACCEPTABLE

CONCLUSION: Based on Notes ① thru ③ above, this indication is considered to be the result of original construction.
JJ Clontz 3-26-03 UT-III

Examiner 1: Kenneth R. Smith Level: II Date: 3-24-03
Examiner 2: JJ Clontz (Evaluator) Level: III Date: 3-26-03
Reviewer: [signature] Level: III Date: 3/26/03
Previous Outage Data Reviewed? Yes ✓ No ___ Reviewer KRS
ANII: ____ Date: ____

Figure 1. NMP-1 Flaw Characterization

ATTACHMENT
CALC NO SOVESSELM035
REVISION 0
PAGE NO 16

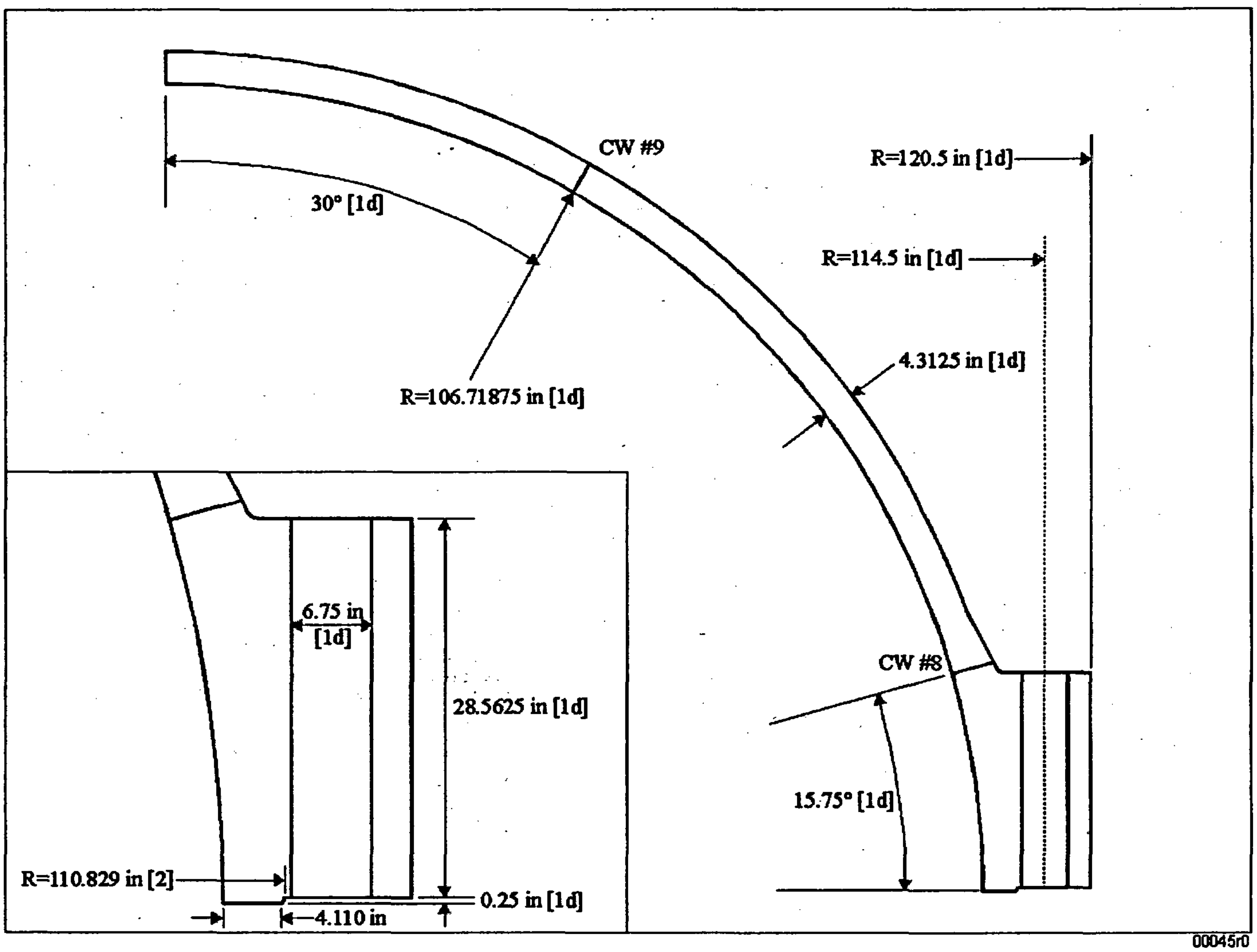

Figure 2. Oyster Creek Finite Element Model Dimensions

ATTACHMENT
CALC NO S0VESSELM035
REVISION 0
PAGE NO 17

Flaw No. 1 **NDE Report** NMP1-03-001
System: OO RPV **Exam Item** RV-WD-005
Evaluate as a Subsurface Flaw

Per Figure IWA-3310-1

l =	7 inches	Criteria for flaw to be characterized as Subsurface			
2d =	0.3 inches	S = 0.4a ?	0.4a =	0.06	
S =	0.2 inches	TRUE			

Surface flaw is characterized as Subsurface flaw.

Per Table IWB-3510-1

2a =	0.3 inches
a =	0.15 inches
t =	4.8 inches
a/l =	0.0214
Y = S/a =	1.3333 Per note 4 of IWB-3510-1 if Y > 1, then use Y = 1.
Allowable a/t, % =	2.086 % interpolated per Table IWB-3510-1
Actual a/t =	0.031
	3.1250 %

Acceptability of flaw is Actual (a/t) < Allowable (a/t) FALSE

Per Oyster Creek Flaw Handbook

t_{clad} =	0.21875 inches						
t =	4.8 inches						
Clad ID to Flaw CL =	0.569 inches			negative sign since flaw nearer to ID.			
e =	1.83 no clad	e/t =	0.38	-0.38	a/t =	0.085	8.46 %
e_t =	1.94 with clad	e_t/t =	0.39	-0.39	a/t =	0.081	8.09 %
		use	-0.4		a/t =	0.071	7.14 %

2a/l = 0.043 inches
Max Allowable Depth per Fig. B-2
IWB-3600 0.328 inches
From 2a/l = 0.1 for Region B Flaw Acceptance Diagram B-2

Acceptability of flaw is 2a/l < 2af (IWB-3600) TRUE

Figure 3. Flaw Evaluation

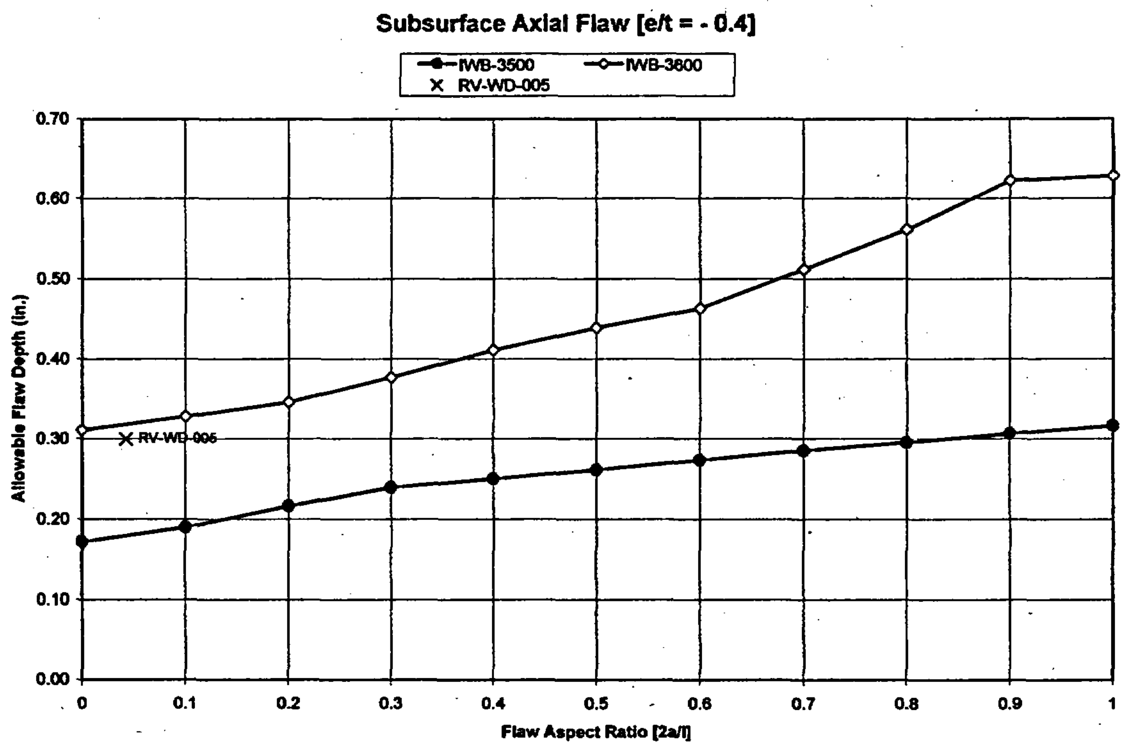

Figure 4. Flaw Acceptance Diagram

References:

1. NMP Report No. NMP1-03-001, SI File No. NMP-05Q-212.

2. Constellation Energy Group Purchase Order No. 02-42537-001, dated 03/03/04.

3. Niagara Mohawk Drawing No. F-45183-C, Revision 1, "Weld Map – Reactor Vessel," Sheet 28, SI File No. NMP-05Q-210.

4. Structural Integrity Associates Report Number SIR-00-109, Revision 1, "Flaw Acceptance Handbook for Oyster Creek Reactor Pressure Vessel Shell-Weld Inspections," SI File No. NMP-05Q-114.

5. Dominion Engineering, Inc. Document Number R-3661-00-1, Revision 0, February 2003, "Reactor Vessel Tensioning Optimization Stress Report Nine Mile Point Nuclear Generating Station Unit 1," SI File No. NMP-05Q-213. (NMP1 CALCULATION # S0.0RXVESTUD02, REV. 1) RC 7/23/03

6. Combustion Engineering Report No. CENC-1142, "Analytical Report for Niagara Mohawk Reactor Vessel," SI File No. NMP-05Q-210. (NMP1 CALCULATION # SOVESSELMO26, REV. 1) RC 7/23/03

7. Combustion Engineering Drawing No. E-231-575-3, "Closure Head Final Machining," SI File No. NMP-05Q-210.

8. Structural Integrity Associates Calculation No. GPUN-27Q-301, Revision 0, "Development of RPV Finite Element Model," SI File No. NMP-05Q-110.

9. Combustion Engineering Report No. CENC-1143, "Analytical Report for Jersey Central Reactor Vessel," SI File No. NMP-05Q-116.

10. Dominion Engineering, Inc. Letter No. L-3661-00-2, Revision 0, "Flaw Location Specific Membrane and Bending Stresses for Nine Mile Point Unit 1 Reactor Vessel Head," March 31, 2003, SI File No. NMP-05Q-214. (NMP1 CALCULATION # S0.0RXVESTUD02-01A) RC 7/23/03

11. "Rules for In-service Inspection of Nuclear Power Plant Components," Section XI of the ASME Boiler and Pressure Vessel Code, 1989 Edition, American Society of Mechanical Engineers, New York, July 1, 1989.

12. Raju, I. S., and Newman, J. C., "Stress-Intensity Factors for Internal and External Surface Cracks in Cylindrical Vessels," Journal of Pressure Vessel Technology, 104/298, November 1982.

13. Tada, Paris and Irwin, "Stress Analysis of Cracks," Del Research Corporation, 1973.

14. Kuo, A. Y., Deardorff, A. F., and Riccardella, P. C., "Thermal Stress Intensity Factor of an Axial Crack in a Cladded Cylinder," presented at 1993 ASME Pressure Vessel & Piping Conference.

15. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.99, Revision 2, May 1988.

16. APPENDA and MAPPA, "Computer Programs for Performing Flaw Tolerance Analysis of Reactor Vessel Shells," Structural Integrity Associates (QA-1800), Version 1.1.