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SOUTHERN COMPANY
Energy to Serve Your World℠

March 1, 2006

Docket No.: 50-321

NL-06-0422

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

Edwin I. Hatch Nuclear Plant – Unit 1
Evaluation of Main Steam Nozzle Indications

Ladies and Gentlemen:

Two indications were identified during the 2006 1R22 in-service inspection of the Hatch Unit 1 reactor pressure vessel (RPV). The indications are in the weld between the vessel shell and the N3A main steam nozzle. Indication #1 is a subsurface indication with a depth of 0.67 inches, a length of 1.9 inches, and a surface separation of 2.57 inches. Indication #2 is a subsurface indication with a depth of 0.49 inches, a length of 1.40 inches, and a surface separation of 1.75 inches. The indications were found to be unacceptable per the rules of the ASME Boiler and Pressure Vessel Code, Section XI, 2001 Edition through the 2003 Addenda, paragraph IWB-3510. Consequently, analytical evaluation is required per the guidelines of Section XI, IWB-3610 to determine if the indications are acceptable for continued service. Based on the results of that analytical evaluation the indications are acceptable. The calculated total fatigue crack growth for 40 years of additional service life is 0.0214 inches. The final crack size would be 0.6914 inches for Indication #1 and 0.5114 inches for Indication #2 at the end of 40 years of additional service life. Section XI, IWB-3134(b) requires the analytical evaluation results be submitted to the regulatory authority having jurisdiction at the plant site (see attached analytical evaluation developed by Structural Integrity Associates).

Two teleconferences were held with NRC to discuss SNC plans with respect to the above mentioned evaluation and potential scope expansion. One was held on February 24, 2006 and the second on February 28, 2006.

SNC's planned actions are discussed below.

Scope Expansion

ASME Section XI, 2001 Edition through the 2003 Addenda, paragraph IWB-2430 requires that even though the indications have been determined to be acceptable for continued operation, examination of additional nozzles equivalent to the number of nozzles scheduled for the current period must be performed. In lieu of this requirement, alternate requirements are provided in Code Case N-586, which allows an engineering

evaluation to be performed to determine the need for the additional examinations. Code Case N-586 requires the engineering evaluation to include: (1) a determination of the root cause of the flaws or relevant condition, and (2) an evaluation of applicable service conditions and degradation mechanisms to establish that the affected welds will perform their intended safety functions during subsequent operation. No additional examinations are required if the engineering evaluation concludes that either: (1) there are no additional welds subject to the same root cause conditions, or (2) no active degradation mechanism exists.

Root Cause – The most likely root cause of these indications is weld porosity and/or slag inclusions associated with original fabrication of the main steam nozzle to shell weld. As such, these indications have probably been in existence since RPV fabrication. These indications were observed during the 1997 examinations and were determined to be acceptable in accordance with the Acceptance Standards in ASME Section XI, IWB-3510. The 1997 examination data files were re-analyzed this outage utilizing the current Performance Demonstration Initiative (PDI) techniques/equipment and compared to the 2006 results. It was determined that the thru-wall depth and length measurements between the 1997 and 2006 data using the PDI methodology are similar; therefore, the reason for the indications now being unacceptable is due to the use of more precise PDI techniques. PDI qualified examinations have been completed for 14 other nozzles that were scheduled for this outage, without any additional unacceptable indications.

Degradation Mechanism – These subsurface flaws were evaluated for corrosion related degradation and mechanical failure degradation. Other than fatigue, it was determined that there are no active degradation mechanisms. The effect of fatigue was evaluated in the attached analytical evaluation and was found to have an insignificant effect on the flaws. Therefore, it is concluded there are no active degradation mechanisms that could prevent the vessel from performing its intended function. Without the presence of active degradation mechanisms, no additional weld examinations are required by Code Case N-586.

Successive Examinations

ASME Section XI, 2001 Edition through the 2003 Addenda, paragraph IWB-3132.3 requires that indications that exceed the acceptance standards of Table IWB-3510-1, that are found acceptable for continued operation by IWB-3600, must subsequently be reexamined during the next three periods in accordance with IWB-2420(b). ASME Section XI, Code Case N-526 provides alternate requirements for re-examination of subsurface flaws found by volumetric examinations in lieu of the IWB-2420(b) requirements. Code Case N-526 states that the reexaminations in accordance with IWB-2420(b) of vessel volumes containing subsurface flaws are not required, provided the following are met:

a. The flaws are characterized as subsurface in accordance with the figure provided in the Code Case.
b. The NDE technique and evaluation that detected and characterized the flaw, with respect to both sizing and location, shall be documented in the flaw evaluation report.

c. The vessel containing the flaw is acceptable for continued service in accordance with IWB-3600, and the flaw is demonstrated acceptable for the intended service life of the vessel.

The largest crack depth of the two indications is Indication #1 with a flaw depth of 0.67 inches. Therefore, the Flaw Half Depth for Indication #1 is 0.335 inches. Using Figure 1 of Code Case N-526, for a Flaw Half Depth of 0.335 inches, the minimum distance from the surface to be classified as a subsurface flaw is 0.25 inches. Both indications are at a greater distance from the surface than this and therefore can be classified as subsurface indications. As such, provision (a) in the Code Case above is met. Provision (b) of the Code Case is satisfied since the NDE techniques used to detect and size the flaw is documented and accepted by the industry (PDI qualified examination). Provision (c) of the Code Case is also satisfied since an IWB-3600 evaluation has been performed to show acceptability of the flaw for the balance of plant life. Therefore, IWB-3132.3 re-examination is not required. These flaws will be re-examined in the next 10 year interval pursuant to IWB-2500.

Sincerely,

H. L. Sumner, Jr.

HLS/OCV/daj

Enclosure: Structural Integrity Associates; Evaluation of Weld N3A (N-SH) at Hatch Unit 1 During 2006 Outage (1R22)

cc: Southern Nuclear Operating Company
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Enclosure

Edwin I. Hatch Nuclear Plant - Unit 1
Evaluation of Main Steam Nozzle Indications

Structural Integrity Associates; Evaluation of Weld N3A (N-SH) at
Hatch Unit 1 During 2006 Outage (1R22)

Structural Integrity Associates, Inc.	CALCULATION PACKAGE	File No.: HTCH-13Q-301 Project No.: HTCH-13Q

PROJECT NAME: Flaw Evaluation of Weld N3A (N-SH) at Hatch Unit 1 During 2006 Outage (1R22)

Contract No: N/A

CLIENT: Southern Nuclear Company	**PLANT:** Hatch Unit 1

CALCULATION TITLE: ASME Code Section XI Flaw Evaluation of Indications in Weld N3A (N-SH)

Document Revision	Affected Pages	Revision Description	Project Mgr. Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1-14 A1-A19 Computer Files	Original Issue	N. G. Cofie 2/28/06	S. S. Tang 2/28/06 G. A. Miessi 2/28/06

1 INTRODUCTION

Two indications were identified during the 2006 Refueling Outage R22 in-service inspection of the reactor pressure vessel (RPV) of Hatch Unit 1. These indications are in the weld between the vessel shell and the main steam nozzle, N3A. The indications were found unacceptable per the rules of the ASME Boiler and Pressure Vessel (B&PV) Code, Section XI, 2001 Edition and Addenda through 2003, IWB-3510, [1]. Consequently, the indications are evaluated per the guidelines of ASME B&PV Code, Section XI, IWB-3610, which include acceptance criteria based on the applied stress intensity factors. Conservative assumptions in the applied stresses were used in this evaluation to determine the stress intensity factors for the two indications for comparison to the Code allowable stress intensity factor.

2 TECHNICAL APPROACH

The original RPV stress report [2] was performed in accordance with the requirement of ASME B&PV Code, 1965 Edition with Addenda through Winter of 1966. The pages containing the stress analysis results of the main steam nozzle are not available in Reference 2. Conservative applied stresses were assumed using the ASME B&PV Code Section III allowable stress for the RPV material.

The stress intensity factor was calculated based on Reference 1, Appendix A methodology. The flaw acceptance criteria based on applied stress intensity was utilized based on Paragraph IWB-3612 of Reference 1.

3 FLAW CHARACTERIZATION

The two indications are planar indications located in the weld, Weld ID N3A (N-SH), between the vessel shell and the main steam nozzle, N3A [3]. The inspection results for the indications are shown in Figures 1 and 2. For Indication 001, Figure 1 shows that it is a subsurface indication with a depth of 0.67 inches, a length of 1.9 inches, and a surface separation of 2.57 inches. Indication 002, Figure 2, is 0.49 inches in depth, 1.40 inches in length, and 1.75 inches in surface separation.

4 DESIGN INPUTS

From Reference 2, the nominal wall thickness is 5.375 inches for the Main Steam to RPV Weld N3A (N-SH). The measured thickness is 5.88 inches, [2]. For this evaluation, the nominal wall thickness was conservatively used. The inside diameter is 220.75 inches, [2].

The reactor vessel material is ASTM A533 B-1, from Reference 2.

From Reference 2, the allowable stress S_m is 26.7 ksi at 575 °F, the design temperature [2], for ASTM A533 B-1. The yield stress for ASTM A533 B-1 is 43.98 ksi at 575 °F, per Reference 4.

5 ASSUMPTIONS

Since stress information in the Stress Report at the flaw location is not sufficiently detailed, the applied stress was assumed to be at the Code allowable stress at 575 °F, the design temperature, as shown in Table 1, per References 2 and 4. In particular, the membrane stress was assumed to be at $1.0S_m$, and the through-wall bending stress was assumed to be at $2\ S_m$. This assumption is based on the Code stress limits for the Normal and Upset Conditions, where $P_m < S_m$ and $P_l+P_b+Q < 3S_m$. Typical primary and secondary stresses in the reactor vessel are about 25 ksi. Therefore, assuming the applied stress at the Code allowable limit should be bounding the vessel stress.

For Emergency and Faulted conditions, the applied stresses were also assumed to be at the Code stress allowable, as shown in Table 1.

In addition, an 8 ksi cosine shape through wall residual stress was assumed based on References 5 and 6, and added to the membrane and bending stresses. The residual stress is assumed to be pure bending through the reactor vessel wall. This assumption is conservative based on the location of the indications and the residual stress profile specified in Reference 6.

As in the original stress report, the clad thickness is not considered in this evaluation.

The service life is assumed to be 40 years from the date of this evaluation.

6 CALCULATIONS

6.1 Stress Intensity Factor Calculation

A linear elastic fracture mechanics and crack growth evaluation is performed for the indications. Each indication was modeled as a subsurface semi-elliptical crack in an infinite plate subjected to membrane and bending stresses as illustrated in Figure 3, Reference 1. For this subsurface crack model, the flaw depth is defined as 2a, as shown in Figure 3. Therefore, the crack depth, a, is half of the measured crack depth as reported in Figures 1 and 2.

Using the assumption for applied stress as presented in Section 5, for $S_m = 26.7$ ksi, the membrane stress is 26.7 ksi and the bending stress is 53.4 ksi.

For Indication 001, the crack parameters were calculated as follows:

Crack depth	$2a = 0.67$ inch
Crack length	$l = 1.9$ inches
Crack aspect ratio:	$a/l = 0.1763$
Eccentricity	$e = 2.57 + 0.67/2 - 5.375/2 = 0.2175$
Eccentricity ratio:	$2e/t = 2*0.2175/5.375 = 0.0809$

For Indication 002, the crack parameters were calculated as follows:

Crack depth	2a = 0.49 inch
Crack length	l = 1.4 inches
Crack aspect ratio	a/l = 0.175
Eccentricity	e = 5.375/2 – (1.57 + 0.49/2) = 0.8725
Eccentricity	2e/t = 2 * 0.8725/5.375 = 0.3247

The applied stress intensity factors for the two indications above were calculated using **pc-CRACK**, [7]. The minimum crack aspect ratio of 0.1 was conservatively used in the evaluation for both indications.

6.2 End of Life Fatigue Crack Growth Calculation

Since the indications are subsurface, the end of life flaw size due to crack growth was calculated using the fatigue crack growth curves for carbon and low alloy ferritic steels exposed to air environments, Figure A-4300-1 of Appendix A of Reference 1:

$$da/dN = C_o(\Delta K_I)^n \text{ (in/cycle)} \quad (1)$$

$n = 3.07$
$C_o = 1.99 \times 10^{-10} S$
$S = 25.72*(2.88-R)^{-3.07}$ for $0 \le R \le 1$
$R = K_{min}/K_{max}$
$\Delta K_I = K_{max} - K_{min}$ (ksi$\sqrt{in}$)

6.3 Material Fracture Toughness Calculation

The material fracture toughness of the weld metal is provided in References 8 and 9 for weld metal SA-316. The lowest Charpy V notch impacts energy 110 ft-lb.

From Reference 4, the material fracture toughness K_{IC} can be calculated from the Charpy impact energy using the following equations:

$$J = 10\ CVN \quad (2)$$
$$J = 1000*K_{IC}^2/E' \quad (3)$$

Substituting (2) into (3) and rearranging:

$$K_{IC} = \sqrt{\frac{CVN * E'}{100}} \quad (4)$$

where CVN = Charpy energy in ft-lb
J = material toughness
$E' = E/(1-\nu^2)$
E = Young's Modulus (ksi)

7 RESULTS OF ANALYSIS

7.1 Stress Intensity Factor

Using the proximity rule in IWA-3300 of Reference 1, the indications are shown to be subsurface and do not require to be considered as a single flaw. For Indication 001, the surface separation, S, is 2.57 inches which is larger than half of the crack depth, 0.335 inch. For Indication 002, the surface separation is 1.75 inches which is larger than half of the crack depth 0.245 inches. The angle between the two indications is 13.9°. Using the inside diameter, the distance between the two indication is $220.75*\pi*13.9/360 = 26.78$ inches which is larger than the length of either indication. Therefore, these two indications do not have to be considered as a single flaw.

The applied stress intensity factors, using the subsurface crack model for the two indications, are presented in Figure 4. It is shown that, at the inspected crack depths, the applied stress intensity factor, $K_{applied}$, is 40 ksi$\sqrt{in}$ for Indication 001 and 47 ksi$\sqrt{in}$ for Indication 002 for the Normal and Upset Conditions.

For the Emergency Condition, the $K_{applied}$ is 54 ksi$\sqrt{in}$ for Indication 001 and 52 ksi$\sqrt{in}$ for Indication 002. For the Faulted Condition, the $K_{applied}$ is 68 ksi$\sqrt{in}$ for Indication 001 and 65 ksi$\sqrt{in}$ for Indication 002

The **pc-CRACK** output files for the stress intensity factor calculation are listed in Appendix A.

Using Equation 4, with $E = 26.55x10^3$ ksi at 575 °F [4], the K_{IC} is calculated to be

$$K_{IC} = \sqrt{(110*26.55x10^3/(1-0.3^2)/100)} = 179 \text{ ksi}\sqrt{in}$$

For the Normal and Upset conditions, using a safety factor of $\sqrt{10}$, per IWB-3612, Reference 1, the allowable fracture toughness is $179/\sqrt{10} = 56.61$ ksi$\sqrt{in}$, which is higher than the applied stress factor (40 ksi$\sqrt{in}$ and 47 ksi$\sqrt{in}$) for both indications.

For the Emergency and Faulted conditions, using a safety factor of $\sqrt{2}$, per IWB-3612 of Reference 1, the allowable fracture toughness is $179/\sqrt{2} = 126.57$ ksi$\sqrt{in}$, which is higher than the applied stress intensity factors for both indications (54 ksi$\sqrt{in}$ and 68 ksi$\sqrt{in}$ for Indication 001 and 52 ksi$\sqrt{in}$ and 65 ksi$\sqrt{in}$ Indication 002).

7.2 Crack Growth

Conservatively assuming that the stress intensity factor is cycled from zero to positive $K_{applied}$, for the fatigue crack growth calculation, using Equation 1, with $R = K_{min}/K_{max} = 0$ and $\Delta K_I = 46.49$ ksi$\sqrt{in}$ (maximum between Indications 001 and 002), gives

$S = 25.72*(2.88-(0))^{-3.07} = 0.999$
$Co = 1.99x10^{-10}*S = 1.99x10^{-10}$
$da/dN = 1.99x10^{-10}*(47)^{3.07} = 2.62x10^{-5}$ in/cycle

From Reference 2, the significant transients are shown in Table 2. The total number of significant transients is 409 for a design life of 40 years. These cycles are used as 40 years from the date of this evaluation. All these transients are assumed to cycle from 0 to 47 ksi$\sqrt{in}$. Therefore, the total crack growth at the end of the vessel service life is $2*2.62x10^{-5}*409 = 0.0214$ inch, accounting for the crack growth at both end of the subsurface crack. This amount of crack growth is insignificant compared to the initial crack size. The final crack size at the end of vessel service life is 2a = 0.67+ 0.0214 =0.6914 inch for Indication 001, and 2a = 0.49 + 0.0214 = 0.5114 inch for Indication 002. For this final crack size, as shown in Figure 1, the applied stress intensity factor is about 43 ksi$\sqrt{in}$ for Indication 001 and about 50 ksi$\sqrt{in}$ for Indication 002, less than the allowable K_{IC} of 56.6 ksi$\sqrt{in}$.

7.3 Successive Inspections

As required by ASME Code Section XI IWB-3132.3, indications that exceed the acceptance standards of Table IWB-3510-1 and found acceptable for continued operation by IWB-3600 must be subsequently re-examined in accordance with IWB-2420(b) and (c). IWB-2420(b) requires that the area containing the flaw shall be inspected during the next three inspection periods listed in the schedule of the inspection program of IWB-2400. ASME Section XI Code Case N-526 [10] provides alternate requirements for re-examination of subsurface flaws found by volumetric examinations in lieu of the requirements in IWB-2420(b).

Code Case N-526 states that the re-examinations in accordance with IWB-2420(b) of vessel volumes containing subsurface flaws are not required, provided the following are met:

a) The flaws is characterized as subsurface in accordance with the figure provided in the Code Case (shown in Figure 5)
b) The NDE technique and evaluation that detected and characterized the flaw, with respect to both sizing and location, shall be documented in the flaw evaluation report.
c) The vessel containing the flaw is acceptable for continued service in accordance with IWB-3600, and the flaw is demonstrated acceptable for the intended service life of the vessel.

The largest crack depth of the two indications is Indication 001 with half crack depth of is 0.335 inches. From Figure 5, the required minimum distance from surface for a flaw to be classified as a subsurface flaw is 0.25 inches. Both indications are at a distance from the surface greater than this and therefore can be classified as subsurface indications per Code Case N-526. As such provision (a) in the Code case as stated above is met. Provision (b) of the Code Case is also satisfied since the NDE technique used to detect and size the flaw is documented and accepted by the industry (PDI qualified examination). Provision (c) of the Code Case is also satisfied in this calculation since an IWB-3600 evaluation has been performed to show acceptability of the flaw for balance of plant life.

From the above discussions, it has been demonstrated that subsequent re-examination in accordance with IWB-2420 (b) and (c) of the indications identified in Weld N3A (N-SH) are not required.

8 CONCLUSIONS AND DISCUSSIONS

Based on the results of the evaluation presented in this calculation package, the indications found during the inservice inspection of the RPV axial welds are acceptable and meet the requirement of ASME Code, Section XI, IWB-3610 [1]. For the Normal and Upset conditions, the maximum applied stress intensity factor calculated in this analysis is 47 ksi$\sqrt{in}$. This applied stress intensity factor is well below the allowable material fracture toughness of 56.61 ksi$\sqrt{in}$. The fatigue crack growth at the end of vessel service life is 0.0214 inch. The final crack depth at the end of vessel service life is 0.6914 inch and 0.5114 inch for Indications 001 and 002, respectively. The applied stress intensity factor at the end of service life is still less than the allowable fracture toughness.

In addition, successive examinations as required by ASME Section XI, IWB-2420(b) and (c) are not required per ASME Section XI, Code Case N-526.

9 REFERENCES

1. ASME Boiler and Pressure Vessel Code, Section XI, 2001 Edition and Addenda through 2003.
2. Combustion Engineering Inc. 'Analytical Report for Hatch No. 1 Reactor Vessel,' Report No. CENC 1160, August, 1971, SI File GPCO-42Q-235P.
3. GE Nuclear Energy, UT Examination Summary Sheet, Summary No. G2K-1R22-011, February 23, 2006, SI File HTCH-13Q-201.
4. ASME Boiler and Pressure Vessel Code, Section III, Appendices, 1998 Edition with Addenda through 1999.
5. EPRI TR-100251, "White Paper on Reactor Vessel Integrity Requirements for Level A and B Conditions,' Electric Power Research Institute, January 1993.
6. EPRI Report, 'BWRVIP-60A: BWR Vessel and Internals Project, Evaluation of Stress Corrosion Crack Growth in Low Alloy Steel Vessel Materials in BWR Environment," EPRI Technical Report 1008871, June 2003.
7. **pc-CRACK** for Windows, Version 3.1-98348, Structural Integrity Associates, 1998.
8. ABB/Combustion Engineering, Document #RVG-0000000322, Weld Material Certification Report, 7/13/94, SI File HTCH-13Q-202.
9. ABB/Combustion Engineering, Document #RVG-0000000326, Weld Material Certification Report, 7/13/94, SI File HTCH-13Q-202.
10. ASME, Boiler and Pressure Vessel Code, Code Case N-526, 1998 Edition.

Table 1: Stress Allowable at 575 °F for SA 533 Grade B Class 1

Stress Categories	Design	Normal and Upset Condition	Emergency Condition	Faulted Condition
P_m	S_m (26.7 ksi)	--	Greater of 1.2 S_m (32.04 ksi) and S_y (43.98 ksi)	Lesser of 2.4 Sm(64.08 ksi) and 0.7 S_u (56 ksi)
P_l+P_b	1.5 S_m (40.05 ksi)	--	Greater of 1.8 S_m (48.06 ksi) and 1.5S_y (65.97 ksi)	1.5 P_m (84 ksi)
$P_l+P_b+P_e+Q$	--	3 S_m (80.1 ksi)	--	--

Note: S_m = Code allowable stress intensity, 26.7ksi
S_y = yield strength, 43.98 ksi
S_u = ultimate tensile strength, 80 ksi
The ultimate tensile strength was obtained from 1974 Edition of B&PV Code.

Table 2: Significant Transient Conditions

Transient Condition	Occurrences
Normal Start Up	120
Loss of Feedwater Heaters - Turbine Trip at 25% Power	10
Loss of Feedwater Heaters - Feedwater Heater Bypass	70
Loss of Feedwater Pump	10
Turbine Generator Trip	40
Safety Valve Blowdown	2
All Other Scrams	147
Improper Start of Cold Recirc. Loop	5
Sudden Start of Cold Recirc. Loop	5
Total	409

GE Energy - Nuclear

Reactor Pressure Vessel Flaw Evaluation Sheet

Project : Plant / Unit / Year
Weld ID : N3A(N-SH)
Indication : 001

Exam Data Sheet : N3A(N-SH)-01
Sizing Data Sheet : N3A-001

	Measured	Rounded		Measured	Rounded
Flaw Through Wall =	0.67	0.65	*"T" nominal =*	5.88	5.9
Flaw Length "l" =	1.90	1.9	*"T" measured =*	5.88	5.9
Surface Separation "S" =	2.57	2.6			

ASME Section XI, 1989 Edition, No Addenda
TABLE IWB-3510-1 for 4" to 12"

a/l	Surface %	Subsurface %	Surface %	Subsurface %
0.00	1.9	2.0	~	~
0.05	2.0	2.2	~	~
0.10	2.2	2.5	~	~
0.15	2.5	2.9	2.63	3.07 Y
0.20	2.8	3.3	~	~
0.25	3.3	3.8	~	~
0.30	3.8	4.4	~	~
0.35	4.4	5.1	~	~
0.40	5.0	5.8	~	~
0.45	5.1	6.7	~	~
0.50	5.2	7.6	~	~
			Allowed	Allowed
			2.63	3.07

a = 0.325
a/l value = 0.171
Y = 1.000

Flaw is Subsurface

Allowed a/t = 3.1%
a/t = 5.5%

Flaw is unacceptable by Table IWB-3510-1.

Rev. 0 8/26/05

Comments: ASME Section XI rounding performed in accordance with IWA-3200.

Evaluated By: Philip Hunter Level: III Date: 2-22-06

Reviewed By: [illegible] Level: III Date: 2-22-06

Plant / Unit / Year

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2-23-06

Figure 1 Summary No. G2K-1R22-011, Indication #1 Data

GE Energy - Nuclear

Reactor Pressure Vessel Flaw Evaluation Sheet

Project : Plant / Unit / Year
Weld ID : N3A(N-SH)
Indication : 002

Exam Data Sheet : N3A(N-SH)-01
Sizing Data Sheet : N3A-001

	Measured	Rounded		Measured	Rounded
Flaw Through Wall =	0.49	0.5	*"T" nominal =*	5.88	5.9
Flaw Length "l" =	1.40	1.4	*"T" measured =*	5.88	5.9
Surface Separation "S" =	1.75	1.8			

ASME Section XI, 1989 Edition, No Addenda
TABLE IWB-3510-1 for 4" to 12"

a/t	Surface %	Subsurface %	Surface %	Subsurface %
0.00	1.9	2.0	~	~
0.05	2.0	2.2	~	~
0.10	2.2	2.5	~	~
0.15	2.5	2.9	2.67	3.13 Y
0.20	2.8	3.3	~	~
0.25	3.3	3.8	~	~
0.30	3.8	4.4	~	~
0.35	4.4	5.1	~	~
0.40	5.0	5.8	~	~
0.45	5.1	6.7	~	~
0.50	5.2	7.6	~	~
			Allowed	Allowed
			2.67	3.13

a = 0.250
a/t value = 0.179
Y = 1.000

Flaw is Subsurface

Allowed a/t = 3.1%
a/t = 4.2%

Flaw is unacceptable by Table IWB-3510-1.

Rev. 0 92605

Comments: ASME Section XI rounding performed in accordance with IWA-3200.

Evaluated By: [signature] Level: III Date: 2-22-06

Reviewed By: [signature] Level: III Date: 2-22-06

Plant / Unit / Year

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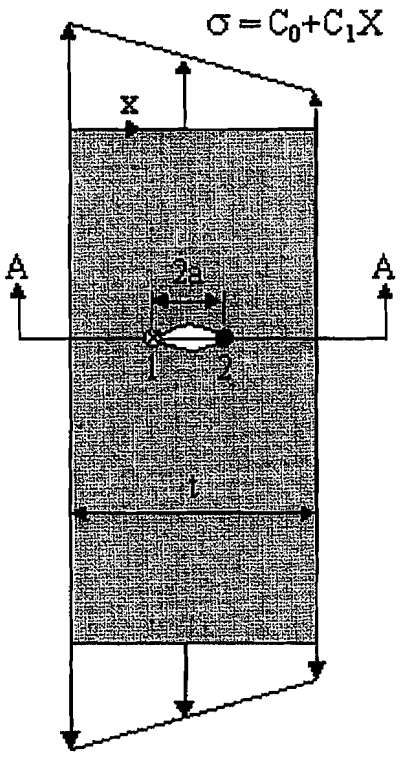
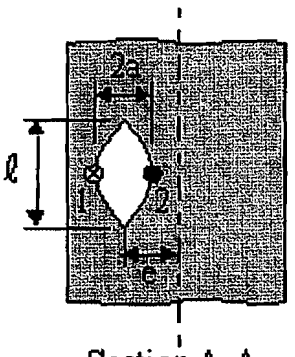
10 2-23-06

Figure 2: Summary G2K-1R22-011, Indication #2 Data



- Calculated K is maximum of K at points 1 & 2.
- Model assumes that the center of the crack is positioned at $x \leq t/2$



$C_0 = \sigma_m + \sigma_b$

$C_1 = -2\sigma_b/t$

$\sigma_m = C_0 + C_1(t/2)$ (membrane stress)

$\sigma_b = -C_1(t/2)$ (bending stress)

REQUIRED INPUTS:

t: wall thickness

a: maximum crack depth ($a_{max} \leq \min[(0.95 - 2e/t)t/2, 0.325t]$)

σ_y: material yield stress

a/ℓ: crack aspect ratio ($0.1 \leq a/\ell \leq 0.5$)

2e/t: eccentricity ratio ($0 \leq 2e/t \leq 0.6$)

Figure 3 ASME B&PV Code Section XI Subsurface Crack Model

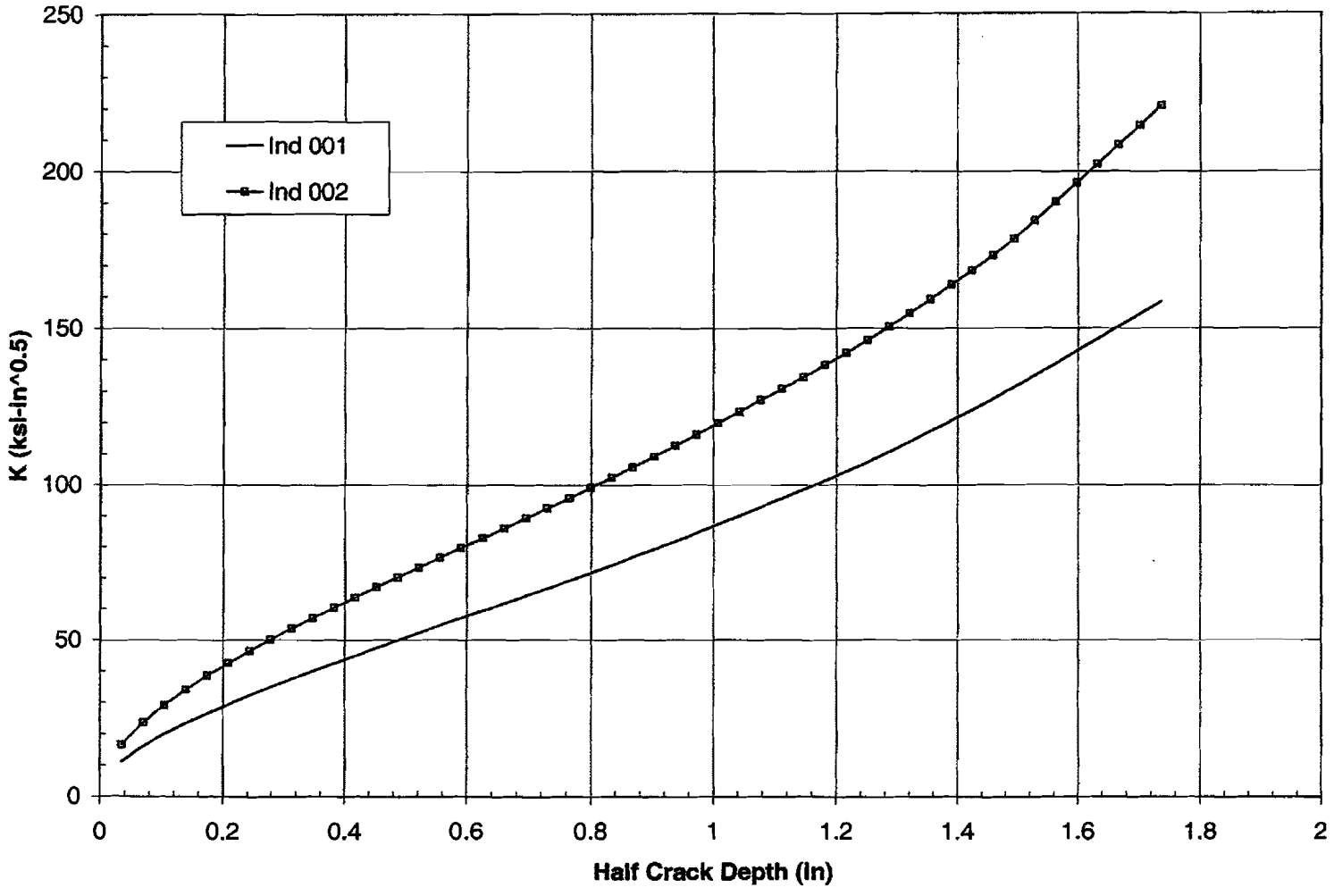


Figure 4: Applied Stress Intensity Factor, Normal and Upset Conditions, Weld ID N3A(N-SH)

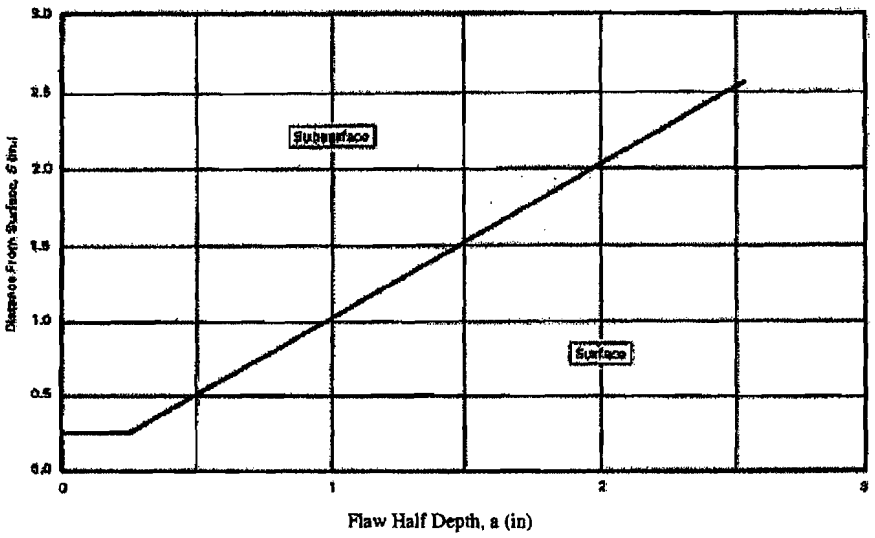


Figure 5: Successive Examination

APPENDIX A

pc-CRACK OUTPUT FILES

pc-CRACK Output File for Weld N3A(N-SH) Indication 001, Normal and Upset Condition

```
                                tm
                          pc-CRACK   for Windows
                            Version 3.1-98348
                          (C) Copyright '84 - '98
                      Structural Integrity Associates, Inc.
                        3315 Almaden Expressway, Suite 24
                             San Jose, CA 95118-1557
                              Voice:  408-978-8200
                              Fax:    408-978-8964
                          E-mail: pccrack@structint.com


                          Linear Elastic Fracture Mechanics


Date: Fri Feb 24 09:47:41 2006
Input Data and Results File: IND001.LFM

Title: HTCH-13Q, Weld N3A(N-SH), Indication #001

Load Cases:

                                  Stress Coefficients
Case ID                          C0          C1          C2          C3   Type
-------------------------------------------------------------------------------
Pm+Pb                          88.1      -22.85           0           0   Coeff



       ------Through Wall Stresses for Load Cases With Stress Coeff-------
         Wall          Case
        Depth         Pm+Pb
-----------------------------

       0.0000          88.1
       0.1737       84.1312
       0.3474       80.1625
       0.5211       76.1937
       0.6947        72.225
       0.8684       68.2562
       1.0421       64.2874
       1.2158       60.3187
       1.3895       56.3499
       1.5632       52.3812
       1.7369       48.4124

Crack Model: Elliptical Subsurface Cracked Plate Under Membrane & Bending Stresses

   Reference: ASME Boiler and Pressure Vessel Code, Section XI, '86 Ed.
   WARNING: The stress intensity factor (K) is the maximum of
            K at point 1 and K at point 2 as identified in Section XI.

Crack Parameters:
Wall thickness:       5.3750
```

Max. crack depth: 1.7369
Crack aspect ratio: 0.1000
Eccentricity ratio: 0.0809
Material yield strength: 43.9800
Co = Sigma(membrane) + Sigma(bending)
C1 = -2*Sigma(bending)/thickness

----------Stress Intensity Factor----------

Crack Size	Case Pm+Pb
0.0347	11.2398
0.0695	16.127
0.1042	20.035
0.1389	23.4618
0.1737	26.5972
0.2084	29.5368
0.2432	32.3365
0.2779	35.019
0.3126	37.5813
0.3474	40.0759
0.3821	42.5163
0.4168	44.9493
0.4516	47.4081
0.4863	49.8445
0.5211	52.2636
0.5558	54.6691
0.5905	57.0644
0.6253	59.4522
0.6600	61.8349
0.6947	64.2631
0.7295	66.7181
0.7642	69.1766
0.7990	71.6397
0.8337	74.1747
0.8684	76.7368
0.9032	79.3096
0.9379	81.8935
0.9726	84.6138
1.0074	87.3613
1.0421	90.126
1.0769	92.908
1.1116	95.7075
1.1463	98.5247
1.1811	101.36
1.2158	104.27
1.2505	107.455
1.2853	110.666
1.3200	113.905
1.3548	117.219
1.3895	120.669
1.4242	124.149
1.4590	127.659
1.4937	131.297
1.5284	135.089

```
1.5632      138.916
1.5979      142.777
1.6327      146.671
1.6674      150.599
1.7021       154.56
1.7369      158.554

                    End of pc-CRACK Output
```

pc-CRACK Output File for Weld N3A(N-SH) Indication 001, Emergency Condition

tm
pc-CRACK for Windows
Version 3.1-98348
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Structural Integrity Associates, Inc.
3315 Almaden Expressway, Suite 24
San Jose, CA 95118-1557
Voice: 408-978-8200
Fax: 408-978-8964
E-mail: pccrack@structint.com

Linear Elastic Fracture Mechanics

Date: Fri Feb 24 19:23:27 2006
Input Data and Results File: IND001C.LFM

Title: HTCH-13Q, Weld N3A(N-SH), Indication #001, Emerg Condition

Load Cases:

Case ID	Stress Coefficients C0	C1	C2	C3	Type
Pm+Pb	73.97	-11.16	0	0	Coeff

------Through Wall Stresses for Load Cases With Stress Coeff-------

Wall Depth	Case Pm+Pb
0.0000	73.97
0.1737	72.0316
0.3474	70.0933
0.5211	68.1549
0.6947	66.2166
0.8684	64.2782
1.0421	62.3399
1.2158	60.4015
1.3895	58.4632
1.5632	56.5248
1.7369	54.5865

Crack Model: Elliptical Subsurface Cracked Plate Under Membrane & Bending Stresses

Reference: ASME Boiler and Pressure Vessel Code, Section XI, '86 Ed.
WARNING: The stress intensity factor (K) is the maximum of
K at point 1 and K at point 2 as identified in Section XI.

Crack Parameters:
Wall thickness: 5.3750
Max. crack depth: 1.7369
Crack aspect ratio: 0.1000

Eccentricity ratio: 0.0809
Material yield strength: 43.9800
Co = Sigma(membrane) + Sigma(bending)
C1 = -2*Sigma(bending)/thickness

Crack Size	Case Pm+Pb
0.0347	16.275
0.0695	23.1449
0.1042	28.5041
0.1389	33.0955
0.1737	37.2053
0.2084	40.979
0.2432	44.503
0.2779	47.8264
0.3126	50.9744
0.3474	53.9919
0.3821	56.9001
0.4168	59.7758
0.4516	62.6729
0.4863	65.5122
0.5211	68.3016
0.5558	71.0478
0.5905	73.7561
0.6253	76.4313
0.6600	79.0773
0.6947	81.7777
0.7295	84.502
0.7642	87.2119
0.7990	89.9095
0.8337	92.629
0.8684	95.3498
0.9032	98.0649
0.9379	100.775
0.9726	103.688
1.0074	106.624
1.0421	109.565
1.0769	112.514
1.1116	115.469
1.1463	118.433
1.1811	121.405
1.2158	124.481
1.2505	127.988
1.2853	131.52
1.3200	135.075
1.3548	138.678
1.3895	142.358
1.4242	146.064
1.4590	149.795
1.4937	153.714
1.5284	157.865
1.5632	162.049
1.5979	166.266

1.6327	170.517
1.6674	174.8
1.7021	179.116
1.7369	183.465

End of pc-CRACK Output

pc-CRACK Output File for Weld N3A(N-SH) Indication 001, Faulted Condition

```
                                tm
                          pc-CRACK   for Windows
                            Version 3.1-98348
                          (C) Copyright '84 - '98
                      Structural Integrity Associates, Inc.
                        3315 Almaden Expressway, Suite 24
                             San Jose, CA 95118-1557
                              Voice:  408-978-8200
                              Fax:    408-978-8964
                          E-mail: pccrack@structint.com


                            Linear Elastic Fracture Mechanics


Date: Fri Feb 24 10:37:21 2006
Input Data and Results File: IND001D.LFM

Title: HTCH-13Q, Weld N3A(N-SH), Indication #001, Faulted

Load Cases:

                                 Stress Coefficients
Case ID                       C0          C1          C2          C3   Type
-------------------------------------------------------------------------------
Pm+Pb                         92       -13.4           0           0   Coeff



      ------Through Wall Stresses for Load Cases With Stress Coeff-------
       Wall         Case
      Depth        Pm+Pb
-------------------------

     0.0000           92
     0.1737      89.6726
     0.3474      87.3452
     0.5211      85.0178
     0.6947      82.6904
     0.8684      80.3629
     1.0421      78.0355
     1.2158      75.7081
     1.3895      73.3807
     1.5632      71.0533
     1.7369      68.7259

Crack Model: Elliptical Subsurface Cracked Plate Under Membrane & Bending Stresses

   Reference: ASME Boiler and Pressure Vessel Code, Section XI, '86 Ed.
   WARNING: The stress intensity factor (K) is the maximum of
            K at point 1 and K at point 2 as identified in Section XI.

Crack Parameters:
Wall thickness:       5.3750
Max. crack depth:     1.7369
Crack aspect ratio:          0.1000
```

Eccentricity ratio: 0.0809
Material yield strength: 43.9800
Co = Sigma(membrane) + Sigma(bending)
C1 = -2*Sigma(bending)/thickness

Crack Size	Stress Intensity Factor — Case Pm+Pb
0.0347	20.6512
0.0695	29.3612
0.1042	36.151
0.1389	41.9641
0.1737	47.164
0.2084	51.9357
0.2432	56.3888
0.2779	60.5864
0.3126	64.5614
0.3474	68.3696
0.3821	72.0381
0.4168	75.6646
0.4516	79.3176
0.4863	82.8965
0.5211	86.4113
0.5558	89.8703
0.5905	93.2805
0.6253	96.6479
0.6600	99.9774
0.6947	103.376
0.7295	106.804
0.7642	110.213
0.7990	113.605
0.8337	117.023
0.8684	120.441
0.9032	123.851
0.9379	127.255
0.9726	130.915
1.0074	134.604
1.0421	138.3
1.0769	142.003
1.1116	145.716
1.1463	149.438
1.1811	153.17
1.2158	157.032
1.2505	161.445
1.2853	165.887
1.3200	170.359
1.3548	174.889
1.3895	179.513
1.4242	184.169
1.4590	188.857
1.4937	193.783
1.5284	199.003
1.5632	204.265
1.5979	209.569

```
1.6327      214.914
1.6674      220.301
1.7021      225.728
1.7369      231.196

                    End of pc-CRACK Output
```

pc-CRACK Output File for Weld N3A(N-SH) Indication 002, Normal and Upset Condition

```
                                tm
                          pc-CRACK   for Windows
                            Version 3.1-98348
                          (C) Copyright '84 - '98
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                        3315 Almaden Expressway, Suite 24
                             San Jose, CA 95118-1557
                              Voice:  408-978-8200
                              Fax:    408-978-8964
                          E-mail: pccrack@structint.com


                            Linear Elastic Fracture Mechanics


Date: Fri Feb 24 09:52:44 2006
Input Data and Results File: IND002.LFM

Title: HTCH-13Q, Weld N3A(N-SH), Indication #002

Load Cases:

                                  Stress Coefficients
Case ID                        C0          C1          C2          C3    Type
-------------------------------------------------------------------------------
Pm+Pb                        88.1      -22.85           0           0    Coeff


      ------Through Wall Stresses for Load Cases With Stress Coeff-------
       Wall          Case
      Depth         Pm+Pb
-------------------------------

     0.0000          88.1
     0.1737       84.1313
     0.3474       80.1625
     0.5211       76.1938
     0.6947        72.225
     0.8684       68.2563
     1.0421       64.2875
     1.2158       60.3188
     1.3895         56.35
     1.5632       52.3813
     1.7369       48.4125

Crack Model: Elliptical Subsurface Cracked Plate Under Membrane & Bending Stresses

   Reference: ASME Boiler and Pressure Vessel Code, Section XI, '86 Ed.
   WARNING: The stress intensity factor (K) is the maximum of
            K at point 1 and K at point 2 as identified in Section XI.

Crack Parameters:
Wall thickness:       5.3750
Max. crack depth:     1.7369
Crack aspect ratio:          0.1000
```

Eccentricity ratio: 0.3247
Material yield strength: 43.9800
Co = Sigma(membrane) + Sigma(bending)
C1 = -2*Sigma(bending)/thickness

Crack Size	Stress Intensity Factor — Case Pm+Pb
0.0347	16.5744
0.0695	23.6745
0.1042	29.2828
0.1389	34.1449
0.1737	38.5463
0.2084	42.6321
0.2432	46.4871
0.2779	50.16
0.3126	53.6748
0.3474	57.0759
0.3821	60.3836
0.4168	63.6648
0.4516	66.9664
0.4863	70.2228
0.5211	73.4415
0.5558	76.6288
0.5905	79.7899
0.6253	82.9291
0.6600	86.0502
0.6947	89.2597
0.7295	92.5172
0.7642	95.7723
0.7990	99.0269
0.8337	102.391
0.8684	105.791
0.9032	109.201
0.9379	112.62
0.9726	116.219
1.0074	119.85
1.0421	123.5
1.0769	127.168
1.1116	130.856
1.1463	134.564
1.1811	138.292
1.2158	142.116
1.2505	146.301
1.2853	150.519
1.3200	154.768
1.3548	159.148
1.3895	163.777
1.4242	168.445
1.4590	173.152
1.4937	178.388
1.5284	184.283
1.5632	190.242
1.5979	196.263

```
1.6327      202.346
1.6674      208.491
1.7021      214.696
1.7369      220.961

                    End of pc-CRACK Output
```

pc-CRACK Output File for Weld N3A(N-SH) Indication 002, Emergency Condition

```
                                    tm
                              pc-CRACK   for Windows
                                Version 3.1-98348
                              (C) Copyright '84 - '98
                          Structural Integrity Associates, Inc.
                            3315 Almaden Expressway, Suite 24
                                 San Jose, CA 95118-1557
                                  Voice:  408-978-8200
                                  Fax:    408-978-8964
                               E-mail: pccrack@structint.com


                                Linear Elastic Fracture Mechanics


Date: Fri Feb 24 19:24:26 2006
Input Data and Results File: IND002C.LFM

Title: HTCH-13Q, Weld N3A(N-SH), Indication #002, Emerg Cond

Load Cases:

                                  Stress Coefficients
Case ID                      C0          C1          C2          C3   Type
-------------------------------------------------------------------------
Pm+Pb                     73.97      -11.16           0           0   Coeff



      ------Through Wall Stresses for Load Cases With Stress Coeff-------
        Wall         Case
       Depth       Pm+Pb
-----------------------------

      0.0000       73.97
      0.1737     72.0317
      0.3474     70.0933
      0.5211      68.155
      0.6947     66.2166
      0.8684     64.2783
      1.0421     62.3399
      1.2158     60.4016
      1.3895     58.4632
      1.5632     56.5249
      1.7369     54.5865

Crack Model: Elliptical Subsurface Cracked Plate Under Membrane & Bending Stresses

   Reference: ASME Boiler and Pressure Vessel Code, Section XI, '86 Ed.
   WARNING: The stress intensity factor (K) is the maximum of
            K at point 1 and K at point 2 as identified in Section XI.

Crack Parameters:
Wall thickness:       5.3750
Max. crack depth:     1.7369
Crack aspect ratio:          0.1000
```

Eccentricity ratio: 0.3247
Material yield strength: 43.9800
Co = Sigma(membrane) + Sigma(bending)
C1 = -2*Sigma(bending)/thickness

Crack Size	Case Pm+Pb
0.0347	18.8857
0.0695	26.846
0.1042	33.0481
0.1389	38.3553
0.1737	43.1001
0.2084	47.4522
0.2432	51.5117
0.2779	55.3404
0.3126	58.9766
0.3474	62.4612
0.3821	65.8186
0.4168	69.1519
0.4516	72.533
0.4863	75.8494
0.5211	79.1102
0.5558	82.323
0.5905	85.4939
0.6253	88.6283
0.6600	91.7307
0.6947	94.9755
0.7295	98.2946
0.7642	101.604
0.7990	104.907
0.8337	108.257
0.8684	111.62
0.9032	114.983
0.9379	118.348
0.9726	121.994
1.0074	125.677
1.0421	129.375
1.0769	133.089
1.1116	136.819
1.1463	140.566
1.1811	144.329
1.2158	148.236
1.2505	152.721
1.2853	157.244
1.3200	161.803
1.3548	166.447
1.3895	171.233
1.4242	176.059
1.4590	180.925
1.4937	186.637
1.5284	193.41
1.5632	200.264
1.5979	207.196

```
1.6327      214.207
1.6674      221.294
1.7021      228.459
1.7369      235.698

                    End of pc-CRACK Output
```

pc-CRACK Output File for Weld N3A(N-SH) Indication 002, Faulted Condition

Linear Elastic Fracture Mechanics

Date: Fri Feb 24 10:36:04 2006
Input Data and Results File: IND002D.LFM

Title: HTCH-13Q, Weld N3A(N-SH), Indication #002, Faulted

Load Cases:

Case ID	Stress Coefficients C0	C1	C2	C3	Type
Pm+Pb	92	-13.4	0	0	Coeff

------Through Wall Stresses for Load Cases With Stress Coeff-------

Wall Depth	Case Pm+Pb
0.0000	92
0.1737	89.6726
0.3474	87.3452
0.5211	85.0178
0.6947	82.6904
0.8684	80.363
1.0421	78.0356
1.2158	75.7082
1.3895	73.3808
1.5632	71.0533
1.7369	68.7259

Crack Model: Elliptical Subsurface Cracked Plate Under Membrane & Bending Stresses

Reference: ASME Boiler and Pressure Vessel Code, Section XI, '86 Ed.
WARNING: The stress intensity factor (K) is the maximum of
K at point 1 and K at point 2 as identified in Section XI.

Crack Parameters:
Wall thickness: 5.3750
Max. crack depth: 1.7369
Crack aspect ratio: 0.1000

Eccentricity ratio: 0.3247
Material yield strength: 43.9800
Co = Sigma(membrane) + Sigma(bending)
C1 = -2*Sigma(bending)/thickness

Crack Size	Case Pm+Pb
0.0347	23.7864
0.0695	33.8067
0.1042	41.6098
0.1389	48.2839
0.1737	54.2481
0.2084	59.7161
0.2432	64.8143
0.2779	69.6209
0.3126	74.1844
0.3474	78.556
0.3821	82.7665
0.4168	86.9469
0.4516	91.1885
0.4863	95.3481
0.5211	99.4372
0.5558	103.465
0.5905	107.44
0.6253	111.368
0.6600	115.256
0.6947	119.324
0.7295	123.487
0.7642	127.638
0.7990	131.78
0.8337	135.978
0.8684	140.191
0.9032	144.404
0.9379	148.619
0.9726	153.19
1.0074	157.809
1.0421	162.447
1.0769	167.104
1.1116	171.781
1.1463	176.479
1.1811	181.198
1.2158	186.098
1.2505	191.735
1.2853	197.419
1.3200	203.149
1.3548	208.982
1.3895	214.989
1.4242	221.045
1.4590	227.152
1.4937	234.335
1.5284	242.868
1.5632	251.503
1.5979	260.237

```
1.6327      269.071
1.6674      278.001
1.7021      287.029
1.7369      296.152

                    End of pc-CRACK Output
```