Attachment 2

Nine Mile Point Unit 1 Steam Dryer Support Bracket Flaw Evaluation - 2014
(Non-Proprietary)

Structural Integrity Associates, Inc.®

CALCULATION PACKAGE

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Nine Mile Point Unit 1 Steam Dryer Support Bracket Flaw Evaluation – 2014

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1.0 INTRODUCTION

Reportable indications have been observed in the steam dryer brackets at Nine Mile Point Unit 1 (NMP1). Previous SI calculations [1 and 2] have shown acceptance of the indications for one fuel cycle (two years) using several conservative assumptions.

2.0 OBJECTIVE

The objective of the current calculation is to remove some of the conservatism in the old calculations and determine whether the flawed NMP1 steam dryer support brackets can be left in-service, without repair, for two additional operating cycles.

3.0 METHODOLOGY

The overall methodology for the current calculation is consistent with the methodology in References [1 and 2]. The following changes are made in the current calculation:

1. The coefficient of static friction is changed from 1.0 to 0.65 for all cases. This is considered to be an upper bound friction coefficient based on Reference [3]. A more mid-range value of 0.5 is also used in Section 6.4. This value is still a fairly conservative value since vibration can lower the coefficient of friction.
2. Different structural factors (SFs) for membrane and bending stress and service level A and service level B are used consistent with ASME Code Section XI, Appendix C [4] instead of a single, bounding structural factor. For the linear elastic fracture mechanics (LEFM) analysis, the SFs are applied to the stress terms and a $K_{I,allowable}$ of 150 ksi$\sqrt{in}$ is used.
3. The load application location is changed for each bracket to account for actual wear marks found on each bracket using photographs from Reference [5] instead of using a bounding location. Figure 1 shows the inspection photographs for each bracket with the load application location overlaid on the picture.
4. Inspection uncertainty is removed, when applicable, based on EPRI Letter 2012-024 [6] and EPRI Letter 2012-051 [7]. The following uncertainties are determined as:
   a) Ultrasonic Testing (UT) Depth Direction Uncertainty
      Per Reference [6], *{{*
      }}. The UT depth uncertainty identified in Reference [8] is 0.210" or 0.394"; therefore, UT depth uncertainty **cannot** be removed.
   b) UT Length Direction Uncertainty
      Per Reference [6], *{{*
      }}. The UT length uncertainty identified in Reference [8] is 0.210" or 0.394" (uncertainty multiplied by two to account for two sides); therefore, UT length uncertainty **can** be removed.
   c) Visual Testing (VT) Length Uncertainty
      Per Reference [6], *{{*
      }}. The VT length uncertainty applied to measurements in Reference [9], based on BWRVIP-03 [10, Section 3.1], *{{* *}}*; therefore, VT length uncertainty **can** be removed.
5. A stress corrosion cracking (SCC) growth rate of *{{* *}}* in the depth direction is used for stainless steel in normal water chemistry (NWC), which is consistent with BWRVIP-14-A

[11]. The UT data sheets report that the location of the flaw tips in all four brackets are well into the stainless steel side of the Inconel weld; the minimum distance between the weld fusion line and the crack tips varies between 0.58 inches and 0.88 inches [2, Section 6.1]. Considering the fabrication details for the lug and the location of the indications, crack growth is expected to remain in the stainless steel material.

6. Plant duty is considered to occur 355 days/year instead of 365.25 days/year. This accounts for outages and other times when the plant is shut down.
7. The reactor internal pressure difference (RIPD) up-force is included in the limit load analysis. This was conservatively neglected in the previous calculations since it counteracts the deadweight (DW) forces.

A detailed description of all other aspects of the analysis methodology is provided in References [1, Section 4.0 and 2, Section 3.0].

4.0 ASSUMPTIONS

The same assumptions as used in the Reference [1, Section 5.0 and 2, Section 4.0] flaw evaluations are used for the present flaw evaluation with the following exception:

1. Plant duty is considered to occur 355 days/year instead of 365.25 days/year. This accounts for outages and other times when the plant is shut down.

5.0 DESIGN INPUTS

The same design inputs as used in the Reference [1, Section 3.0 and 2, Section 5.0] flaw evaluation are used in the present flaw evaluation. Inspection results from the 2013 inspections are used [8 and 9] in this analysis.

For the limit load analysis, forces are applied to the top of the bracket at a location consistent with actual wear marks found on each bracket using photographs from Reference [5] instead of using a bounding location as was done in Reference [2]. Figure 1 shows the inspection photographs for each bracket with the load application location overlaid on the picture. The reactor internal pressure difference (RIPD) up-force is included in the limit load analysis using the value calculated in Reference [1, Section 4.1]. This was conservatively neglected in the previous calculations since it counteracts the deadweight forces. For the LEFM analysis, the loads at the top of the bracket are applied conservatively at the outside corner, as was done in Reference [2]. RIPD loads are conservatively neglected in the LEFM analysis since they counteract the deadweight vertical loads. Lateral forces are applied to the side of the bracket as a uniform pressure acting on the side of the bracket, identical to Reference [2]. Flow induced vibration (FIV) loads are assumed negligible based upon inspection results from bracket surfaces [1, Section 5.0]. A summary of the applied loads, including load combinations and safety factors used, is given in Table 1.

The boundary conditions applied to the finite element model (FEM) are identical to Reference [1, Section 7.4 and 2, Section 6.3]. The loads and boundary conditions are applied to the FEM identical to Reference [1, Figure 14 and 2, Figure 10] with the exception of the forces of the top of the bracket which are applied at locations shown in Figure 1.

6.0 CALCULATIONS

The calculations performed for the following aspects of the evaluation are documented in this section:

1. Flaw characterization and growth
2. LEFM evaluation for flaw stability
3. Limit Load analysis

Since the remaining ligament for the bounding bracket (Bracket B) would be very small if an additional cycle (6 years total) of crack growth is considered, adding contact elements will not provide any benefit to this analysis and are therefore not considered.

6.1 Flaw Characterization and Growth

The UT data sheets report that the location of the flaw tips in all four brackets are well into the stainless steel side of the Inconel weld; the minimum distance between the weld fusion line and the crack tips varies between 0.58 inches and 0.88 inches [2, Section 6.1]. Considering the fabrication details for the lug and the location of the indications, crack growth is expected to remain in the stainless steel material.

The initial flaw sizes are increased to account for NDE uncertainty (when applicable) as well as crack growth from SCC. In References [1, Section 7.2 and 2, Section 6.1], it was shown that FCG from system cycling is negligible and is therefore not considered in the present calculation. The flaws in brackets 1-587A, 1-587B, and 1-587C are grown for two fuel cycles (4 years) using stainless steel crack growth rates (CGRs). Since the flaw in bracket 1-587A bounds the flaw in bracket 1-587D, bracket 1-587D is not evaluated.

Similar to what was done in References [1, Section 7.2 and 2, Section 6.1], the depth of the visual indications that were not detected by UT are assumed to be the minimum detection limit of the UT method [8] equal to 0.2 inches; therefore, all visual indications that were not detected by UT are assumed to have a depth of 0.2 inches prior to crack growth.

SCC growth is considered using the bounding, K-independent, NWC crack growth for the stainless steel base material reported in BWRVIP-14-A [11, Section 6.1.1]. The SCC CGRs are:

- Length direction: 5.0×10^{-5} in/hr
- Depth direction: {{ }}

The total SCC growth added to each flaw tip, for the evaluation interval, is:

<u>Length:</u> 2 Cycle: $\Delta c_{SCC} = 355 \cdot 4 \cdot 24 \cdot 5.0x10^{-5} = 1.704\, in/tip$

<u>Depth:</u> 2 Cycle: $\Delta a_{SCC} = 355 \cdot 4 \cdot 24 \cdot$ {{ }} $= 0.750$ in / tip

Figure 2 shows the inspection data from RFO22 with uncertainty and SCC growth added. This figure uses inspection data from References [8 and 9] and is similar to Reference [2, Figure 6] with the modifications of inspection uncertainty and two cycles of SCC growth instead of one cycle. Figure 3

shows the crack cases used for the limit load analysis. These cases provide bounding dimensions based on Figure 2 end of interval dimensions.

6.2 LEFM Analysis for Flaw Stability

Appendix A contains the MathCAD file listing used to perform the LEFM evaluation. The following two cases are chosen to bound all cracks in all four support brackets:

1. A 3.444 inch deep edge crack located across the short axis of the lug with a 0.95 inch deep edge crack located across the long axis of the lug. (A minimum crack depth of 0.95 inch is used since the uncertainty in the depth direction is 0.20 inch with 0.75 inch of SCC growth.) For the 3.444 inch edge crack case, the top 1.404 inches of the weld is considered to be removed to account for additional cracking on the top side of Bracket B. This configuration bounds Brackets A, B and D.
2. A 1.210 x 6/204 inch (a x c) corner crack with a 1.684 inch deep edge crack across the short axis of the lug. This configuration bounds Bracket C.

The effect of the two superposed cracks is treated by adding the K_I values calculated for each crack separately. Figure 4 shows the crack configurations for each case. Table 2 summarizes the calculated K_{IEQ} for each crack case and reports the allowable fracture toughness. All brackets are shown to possess sufficient structural margin for two cycles of operation as-is.

6.3 Limit Load Evaluation

The limit load analysis is performed in the same manner as References [1, Section 7.7.1 and 2, Section 6.3]. The three crack cases analyzed, including which case corresponds to which bracket, are shown in Figure 3.

The acceptance criteria used for this analysis are:

1. The ANSYS solution converges (meaning that the applied load can be supported by the net section and collapse does not occur),
2. The total strain does not exceed the minimum specified elongation at rupture of 40% [1, Section 4.6.5.1] for the bracket material,
3. The primary stress limits in the adjacent RPV shell are satisfied.

Figures 5 through 10 present contour plots of the Von Mises stress, Hydrostatic stress, and Von Mises Strain on the crack plane, for each crack case considered. Tables 2 through 7 present the maximum Primary Membrane plus Bending stress intensity in the RPV shell. Three paths were reviewed for each crack case and the membrane plus bending stress intensity reported in this calculation package is the largest of the three. The paths evaluated were located at the top of the bracket, the bottom of the bracket, and at the location where the stress intensity on the inside surface of the vessel, at the toe of the attachment weld, was the largest. Figure 11 shows the path locations for each crack case.

Review of Figures 5 through 10 reveals that all three crack cases for both service level A and service level B produced converged ANSYS solutions demonstrating that collapse did not occur. The elastic core remaining in the net section can be observed in each figure. Further, the maximum Von Mises strain for all cases is less than that the reported 40% elongation at rupture for this material [1]. Finally,

the results presented in Tables 3 through 8 reveal that the primary local membrane plus bending stress intensity in the RPV shell is less than the allowable limit for all crack cases. Thus, for the limit load analysis, all steam dryer support brackets are acceptable, as-is, for two additional cycles of operation.

6.4 Comparison of Friction Coefficients

Since a friction factor of 0.65 is considered to be very conservative, a sensitivity run is performed to determine how much margin can be gained when a friction factor of 0.5 is used. Since the Case 2, service level B case produced the highest Von Mises strain, that case is re-analyzed using a friction factor of 0.5. Only a limit load analysis is performed since the limit load analysis is bounding over the LEFM analysis. As shown in Figure 12, the Von Mises strain is reduced from about 31% to about 14% using a friction factor of 0.5 instead of 0.65. This shows that there is additional margin to be gained for the current evaluation interval if a more realistic friction factor is used. However, an additional test run in ANSYS showed that when adding additional crack growth to the model, no significant amount of additional time could be added to the evaluation interval when a lower friction factor was used. Therefore, the factor of 0.65 is considered conservative but appropriate.

6.5 Computer Files

Table 9 lists all computer files used for this analysis. All computer files are filed in the project files.

7.0 CONSERVATISMS

Although the methodology utilized for this flaw evaluation is considered to be consistent with the guidance of ASME XI, IWB-3600 [4], it is acknowledged that the component evaluated in this analysis does not clearly fall under the existing flaw evaluation rules given in ASME XI, Appendix C. Further, there is currently lack of detailed data regarding the amplitude of the possible recirculation pump vane passing frequency (VPF) vibration at the steam dryer support brackets [2, Section 6.4]. Consequently, this section is included to clearly identify some of the conservatisms inherent in the methodology used for this evaluation.

1. The bounding, K-independent, NWC, SCC crack growth rate is applied for crack growth. This CGR was shown to predict an average crack growth larger than observed for the steam dryer support bracket indications between 2011 and 2013 by approximately a factor of 2 to 3 [2, Table 11].
2. A linear elastic fracture mechanics analysis is performed to assess the likelihood of unstable crack propagation in the bracket as opposed to a more complex but more appropriate and less conservative elastic-plastic fracture mechanics analysis. The fracture mechanics calculation is performed in addition to limit load because of the high constraint and resulting stress tri-axiality which might retard plastic flow sufficiently that failure would occur by fracture prior to collapse.

8.0 CONCLUSIONS

The results of the flaw evaluation documented in this report support the following conclusions:

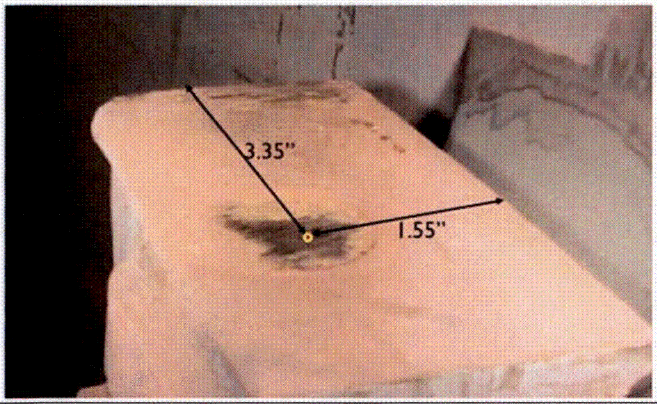
1. The indications reported in the NMP1 steam dryer support brackets 1-587A, 1-587B, 1-587C, and 1-587D are acceptable, as-is, for two additional cycles of operation.
2. There is considerable conservatism and margin built into the analysis. When a more realistic friction factor of 0.5 is used instead of the bounding 0.65 value, the Von Mises strain is approximately cut in half. This shows that there is additional margin to be gained for the current evaluation interval if a more realistic friction factor is used. However, an additional test run in ANSYS showed that when adding additional crack growth to the model, no significant amount of additional time could be gained by using a lower friction factor.

Considering the lack of detailed information regarding the amplitude of the possible recirculation pump VPF vibration and the appearance of active SCC growth in the steam dryer support brackets, SI recommends that Exelon:

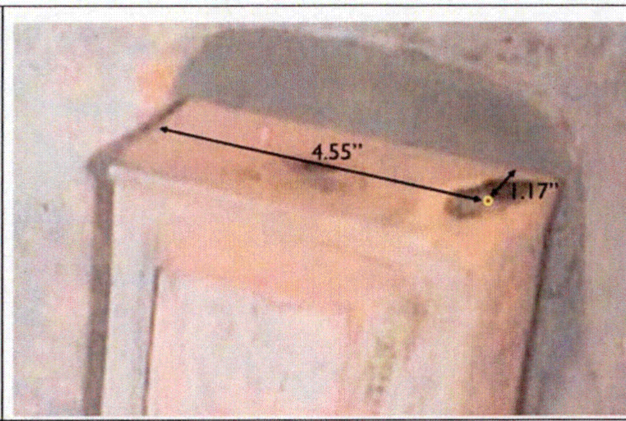
1. Re-examine all four steam dryer support brackets using both visual and UT methods during the next refueling outage to confirm that the behavior of the flaws remains bounded by the flaw growth evaluation documented in this report or to acquire the necessary inspection data to re-evaluate the flaws, as necessary.

9.0 REFERENCES

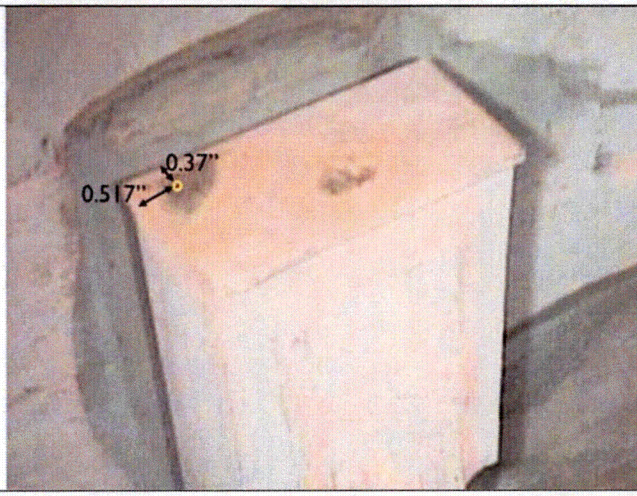
1. SI Report 1100539.401, Revision 1, "Nine Mile Point Unit 1 Steam Dryer Support Bracket Flaw Evaluation".
2. SI Calculation 1300596.301, Revision 0, "Nine Mile Point Unit 1 Steam Dryer Support Bracket Flaw Evaluation – N1R22".
3. Mark's Standard Handbook for Mechanical Engineers, 11th Edition.
4. American Society of Mechanical Engineers Boiler and Pressure Vessel Code:
    a. Section XI, 2004 Ed., No Addenda.
    b. Section XI, 2010 Ed., No Addenda.
5. RFO22 Inspection Photographs, SI File No. 1300596.204:
    a. SD lug 50 (A) top.jpg.
    b. SD lug B top view.jpg.
    c. SD Lug C top view.jpg.
    d. SD Bracket 310 (D) top view.jpg
6. EPRI Letter 2012-024, "NRC Final Safety Evaluation of NDE Uncertainty." **EPRI Proprietary**.
7. EPRI Letter 2013-051, "New NDE Demonstration for UT Steam Dryer Support Bracket/Lug."
8. Design Input Request, Revision 1, SI File No. 1300596.200, UT Data.
9. Westinghouse Indication Notification Forms, SI File No. 1300596.202:
    a. NMP1-RFO-22-INF-13-05, Rev. 2, April 26, 2013
    b. NMP1-RFO-22-INF-13-06, Rev. 0, April 26, 2013
    c. NMP1-RFO-22-INF-13-07, Rev. 3, April 26, 2013
10. TR-105696-R11 (BWRVIP-03) Revision 11: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines. EPRI, Palo A lot, CA: 2008. 1016584. **EPRI Proprietary**.
11. BWRVIP-14-A: BWR Vessel and Internals Project, Evaluation of Crack Growth in BWR Stainless Steel RPV Internals, EPRI Report 1016569, September 2008. **EPRI Proprietary**.
12. ANSYS Mechanical APDL and PrepPost, Release 14.5 (w/Service Pack 1), September 2012.



1-587A



1-587B



1-587C

1-587D (Bounded by 1-587A)

Note: When multiple wear marks are present, a conservative load application location is selected.

Figure 1. RFO22 Inspection Photographs Showing Contact Locations on Top Surface of Support Brackets and Location of Load Application.

Table 1: Summary of Steam Dryer Support Bracket Loads

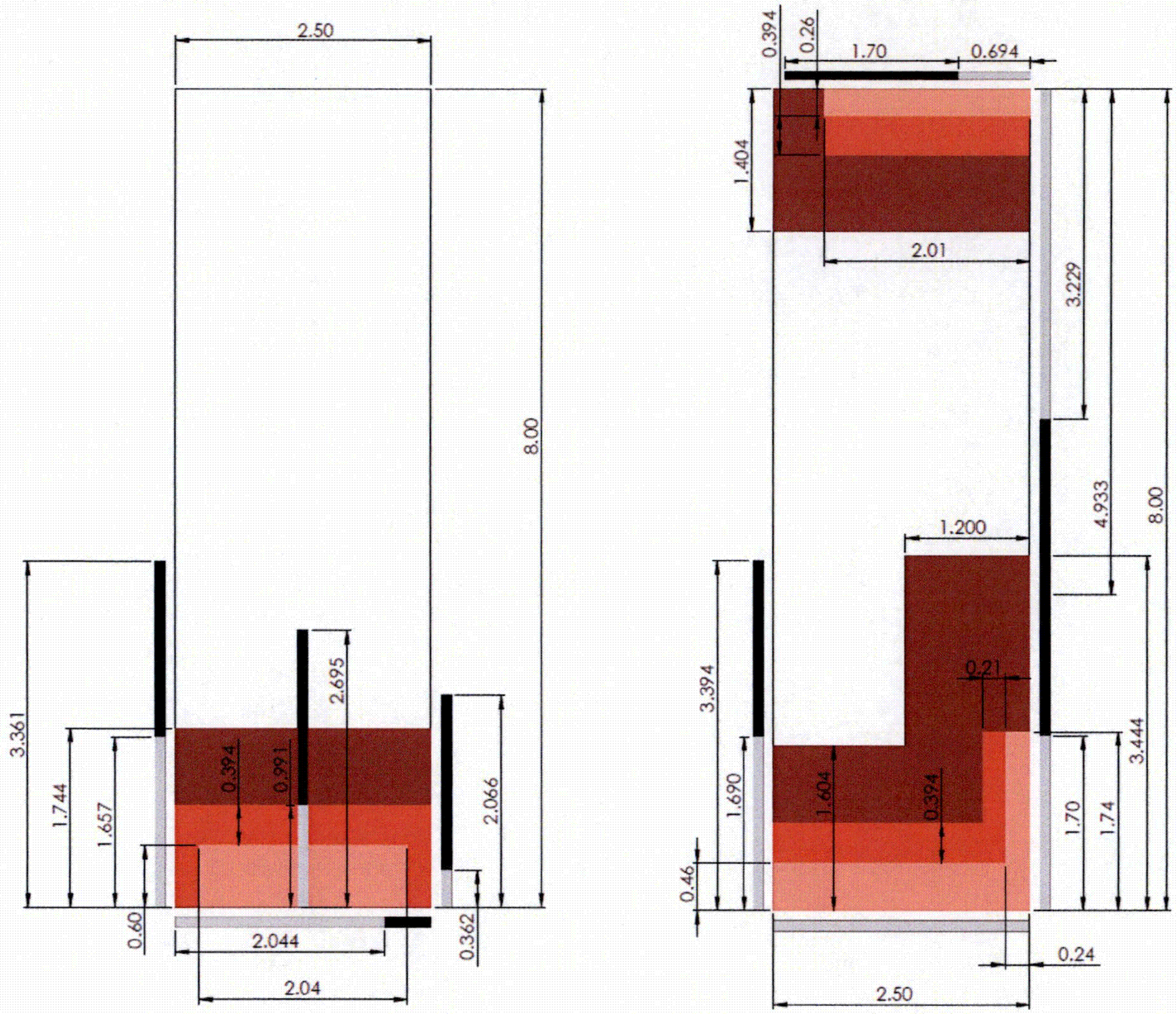
Load	Service Level	Value
DW	A/B	V_{DW} = 15 kips F1 = 15 kips
Seismic (OBE & SSE) and Thermal	A	H = 5.0 kips F2 = 5 kips
	B	H = 16.25 kips V_{seis} = 3.75 kips F2 = 5 kips
RIPD	A/B	3431lbs / 4 brackets = 857.75 lbs
FIV	A/B	assumed negligible based upon inspection results from bracket surfaces [1, Section 5.0].

Notes: 1. Service Level A = DW + Thermal + RIPD
= SF (V_{DW} + F1 + F2 + RIPD)
Service Level B = DW + Thermal + RIPD + Seismic (bounding of OBE and SSE)
= SF (V_{DW} + V_{seis} + F1 + F2 + RIPD + H)

2. Safety Factors (SFs) are taken from ASME Section XI [4]. For Service Level A, the SF is 2.7 for membrane stress and 2.3 for bending stress. For Service Level B, the SF is 2.4 for membrane stress and 2.0 for bending stress. These factors are used for the LEFM analysis, applying the appropriate SF to the appropriate stress. For the limit load analysis, bounding SFs of 2.7 for SLA and 2.4 for SLA applied to the loads in ANSYS.

3. RIPD loads are evaluated for Limit Load only and are oriented upward (opposite of DW).

4. V_{DW} = Vertical force due to deadweight
V_{seis} = Vertical force due to seismic
F1 = Friction force assumed to be caused by differential thermal expansion
F2 = Friction force assumed to be caused by differential thermal expansion
H = Horizontal force, including seismic

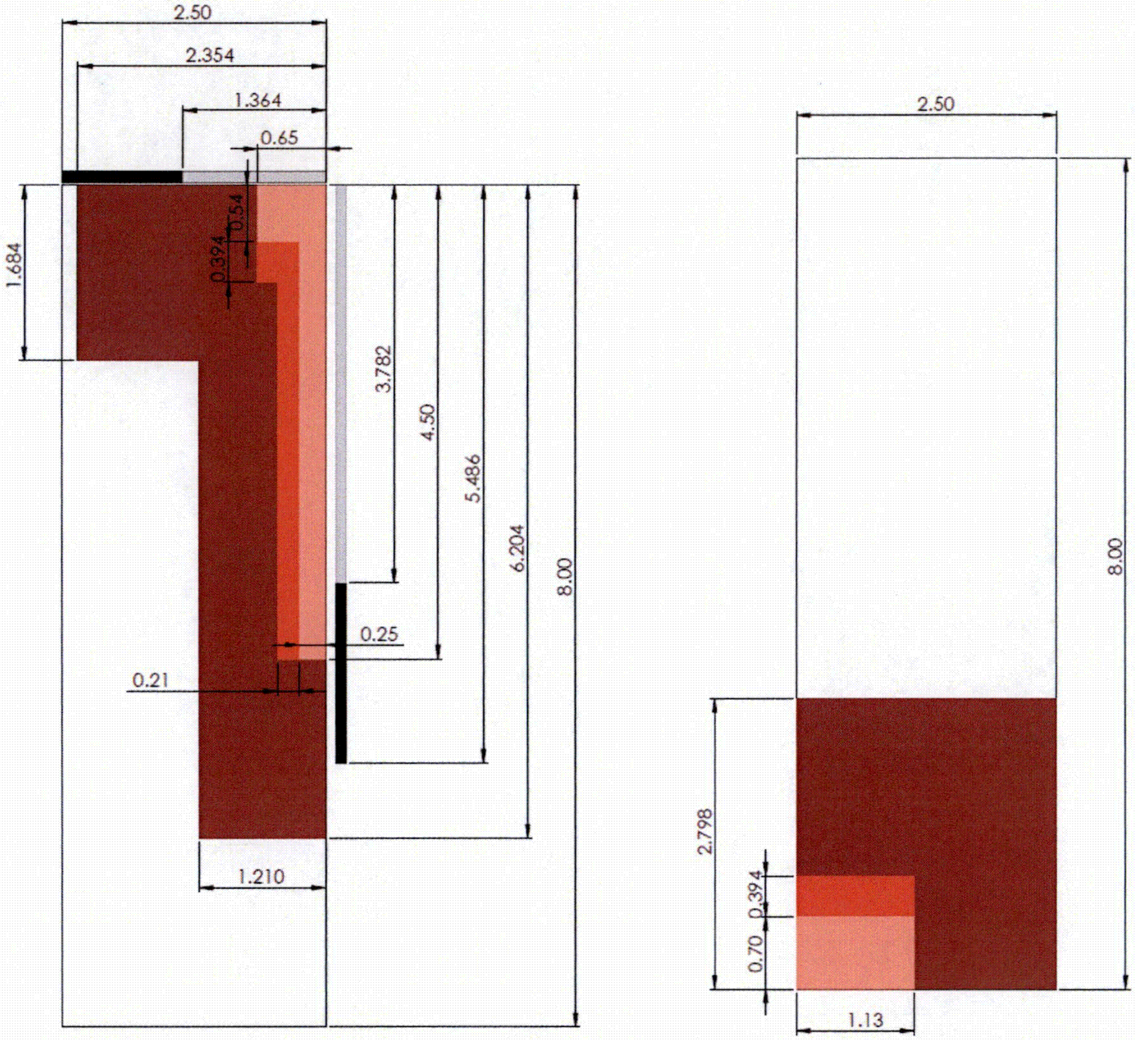


1-587A

1-587B

	UT	EVT-1
Reported		
NDE Uncertainty		
End of Interval Size (SCC only)		

Figure 2a. Overlay of RFO22 Inspection Data with NDE Uncertainty and 2 Cycles of SCC Growth

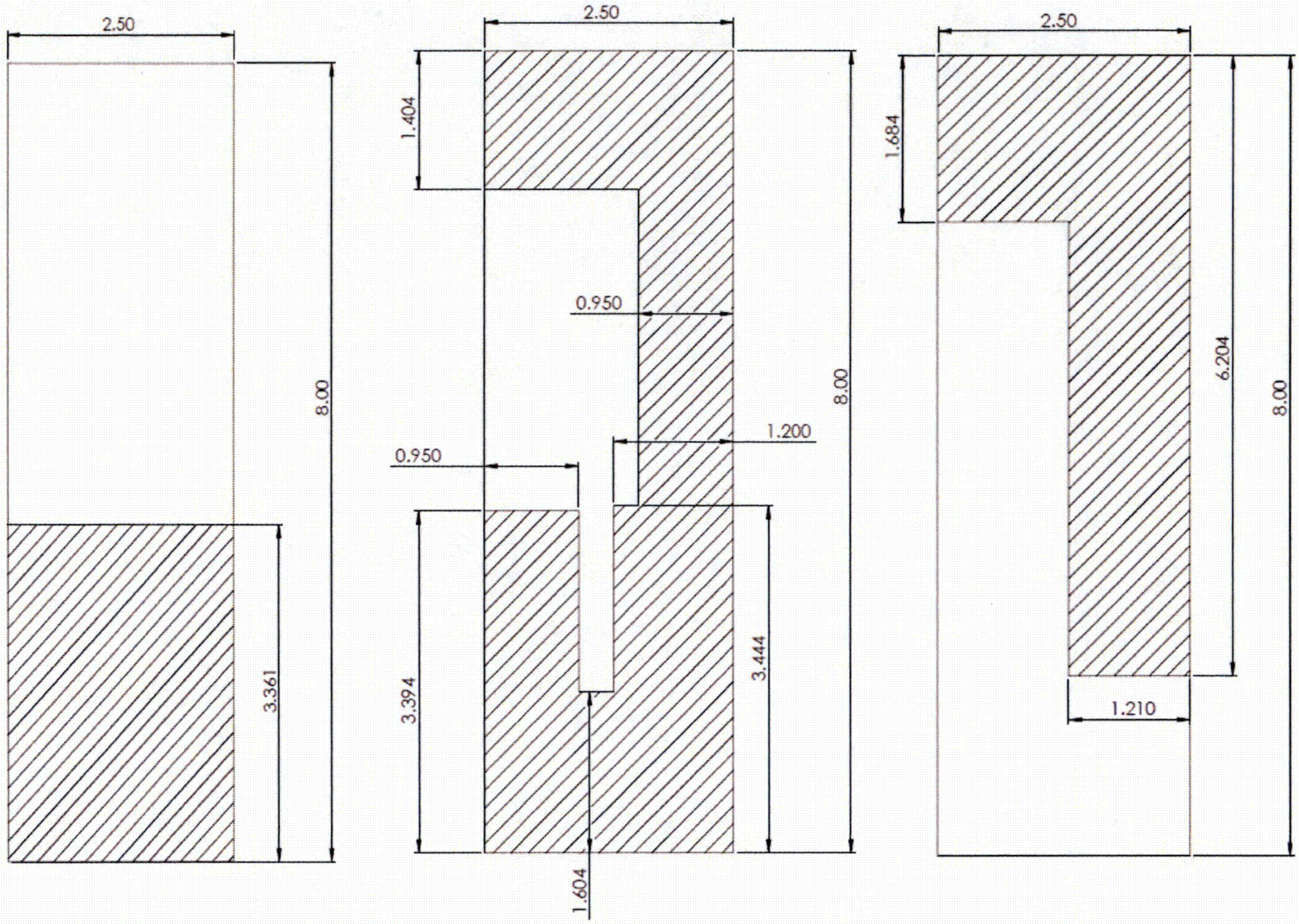


1-587C

1-587D

	UT	EVT-1
Reported		
NDE Uncertainty		
End of Interval Size (SCC only)		

Figure 2b. Overlay of RFO22 Inspection Data with NDE Uncertainty and 2 Cycles of SCC Growth

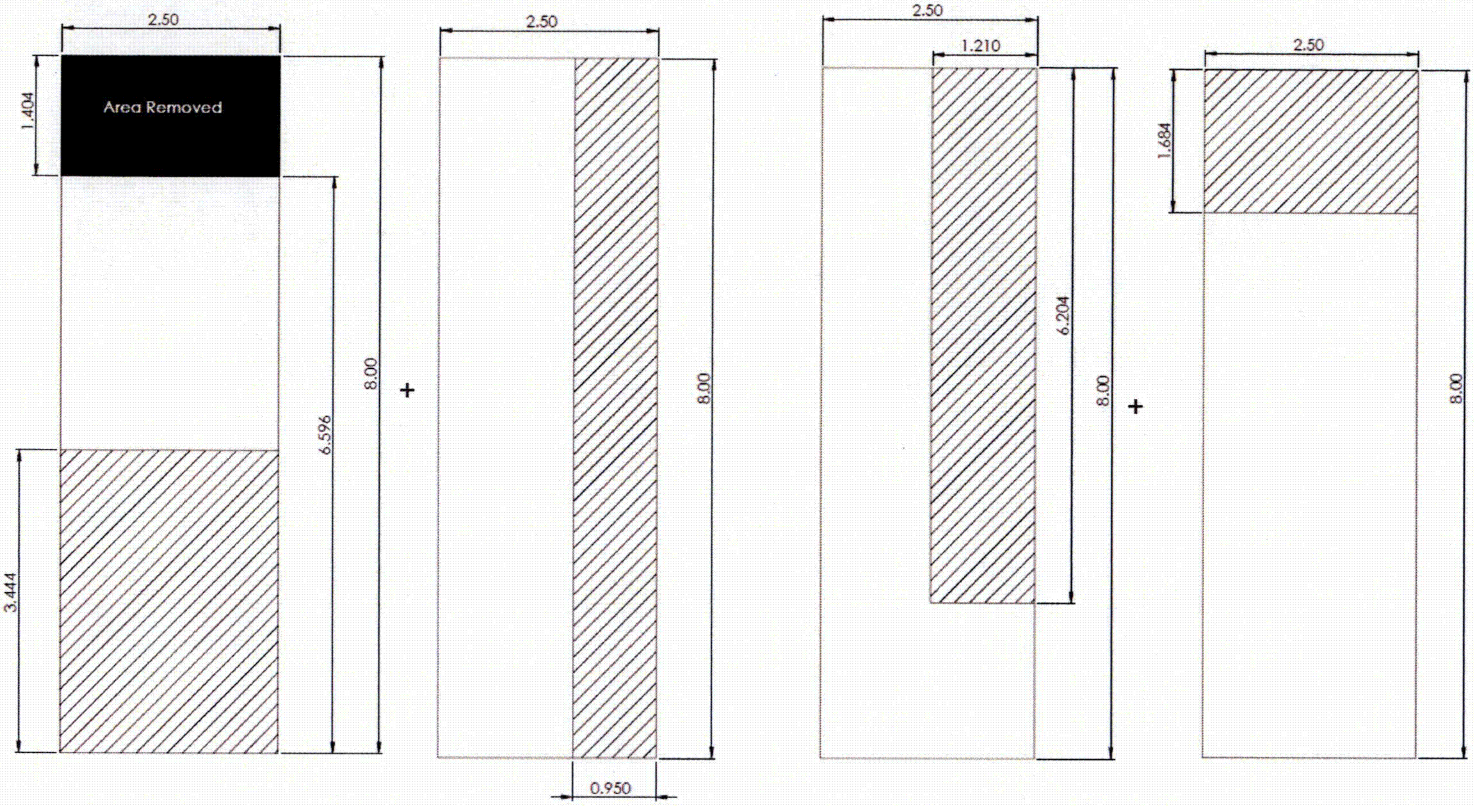


CASE 1
Bracket A
(Bounds Bracket D)

CASE 2
Bracket B

CASE 3
Bracket C

Figure 3: End of Interval Flaw Configurations Considered for Limit Load Evaluation.



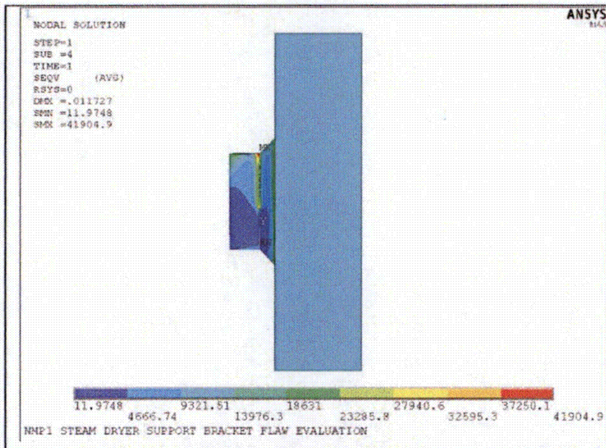
LEFM Crack Case 1 Bounds Brackets A, B and D	LEFM Crack Case 2 Bounds Bracket C

Note: The element size used for the ANSYS analysis is 0.10 inches which results in a nodal dimensional accuracy of +/- 0.05 inches when defining the crack sizes in the FEM.

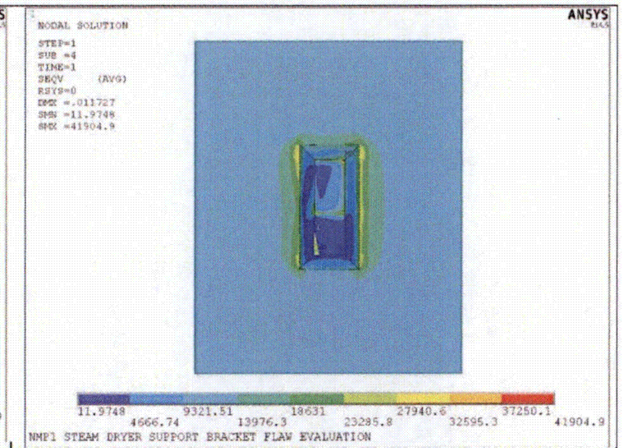
Figure 4: Crack Cases Considered for LEFM Evaluation.

Table 2: LEFM Results for Crack Cases Identified in Figure 4

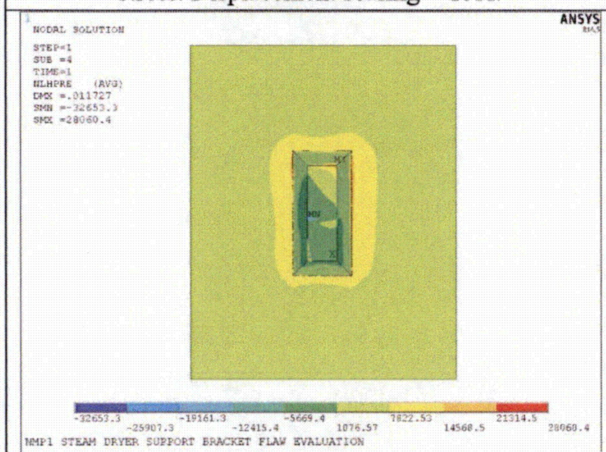
Crack Case	SL	K_{IEQ}, ksi-in$^{0.5}$	$K_{I, Allowable}$, ksi-in$^{0.5}$	Acceptable (Y/N)
3.444" edge crack (with 1.404" removed) with 0.950" edge crack	A	78.28 + 33.00 = 111.28	150	Y
	B	75.74 + 35.79 = 111.53		Y
1.210" x 6.204" (a x c) corner crack combined with 1.684" edge crack	A	4.63 + 33.51 = 38.14		Y
	B	5.53 + 33.25 = 38.78		Y



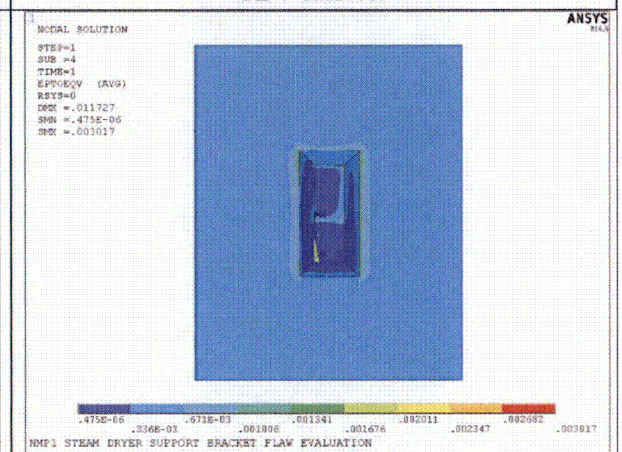
a)Right side view of the FEM showing Von Mises stress. Displacement scaling = 15X.



b)Von Mises stress on crack plane, looking toward RPV surface.



c)Hydrostatic pressure on crack plane, looking toward RPV surface.

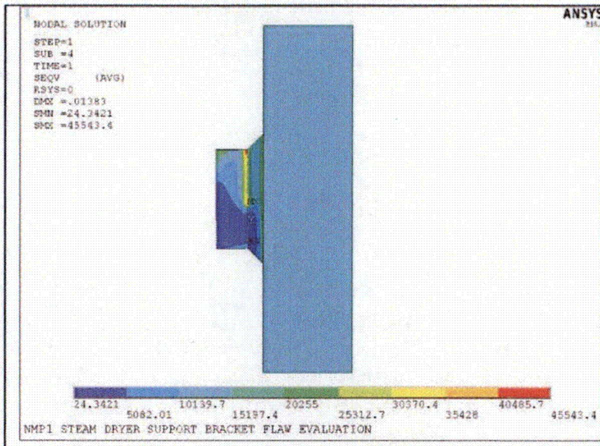


d)Von Mises Strain on crack plane, looking toward RPV surface.

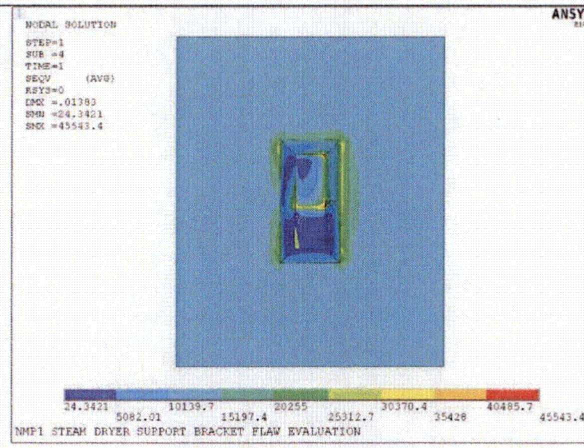
Figure 5: Limit Load Results for Steam Dryer Support Bracket Crack Case 1 –Service Level A – Bounds 1-587A, 1-587D – 2 Cycle SCC Growth.

Table 3: ASME B&PV Code Primary Local Membrane + Bending Stress Check, RPV Shell, Steam Dryer Support Bracket 1-587A, 1-587D, Service Level A.

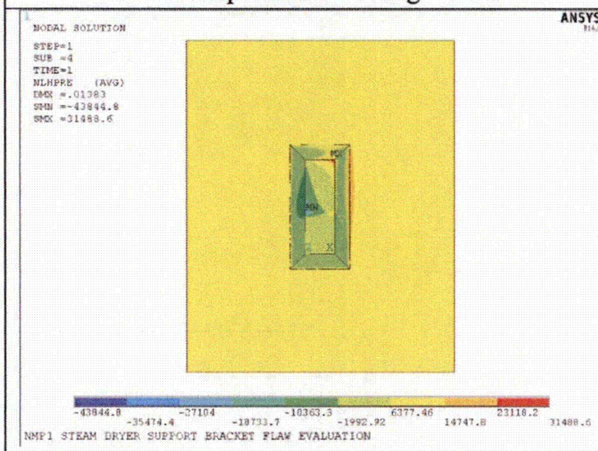
Path	P_m+P_b, psi	Allowable, 1.5S_m, psi
Peak	15,780	40,050



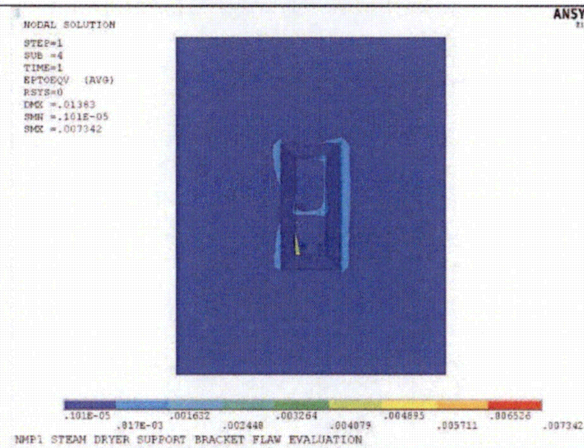
a)Right side view of the FEM showing Von Mises stress. Displacement scaling = 15X.



b)Von Mises stress on crack plane, looking toward RPV surface.



c)Hydrostatic pressure on crack plane, looking toward RPV surface.

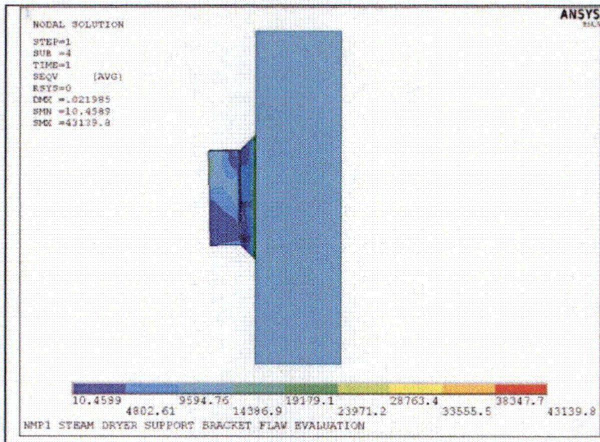


d)Von Mises Strain on crack plane, looking toward RPV surface.

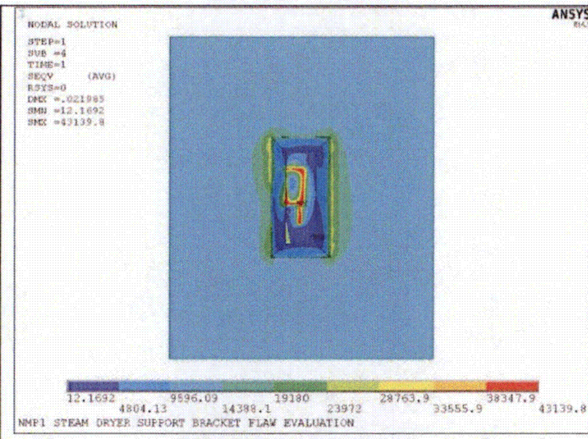
Figure 6: Limit Load Results for Steam Dryer Support Bracket Crack Case 1 –Service Level B – Bounds 1-587A, 1-587D – 2 Cycles SCC Growth.

Table 4: ASME B&PV Code Primary Local Membrane + Bending Stress Check, RPV Shell, Steam Dryer Support Bracket 1-587A, 1-587D, Service Level B.

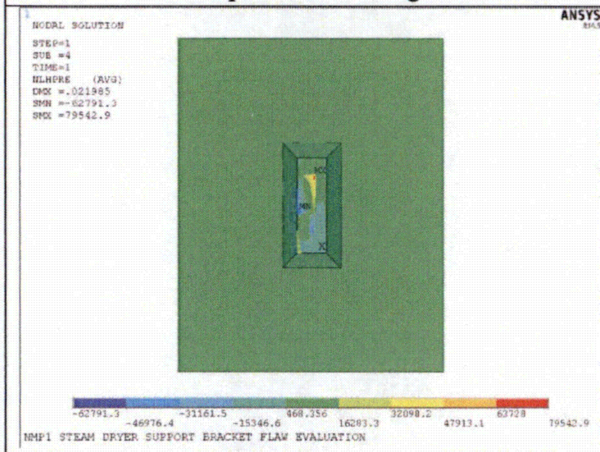
Path	P_m+P_b, psi	Allowable, $1.5S_m$, psi
Peak	16,420	40,050



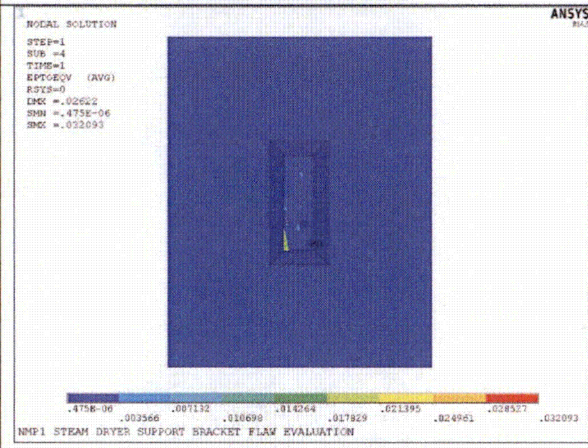
a)Right side view of the FEM showing Von Mises stress. Displacement scaling = 15X.



b)Von Mises stress on crack plane, looking toward RPV surface.



c)Hydrostatic pressure on crack plane, looking toward RPV surface.

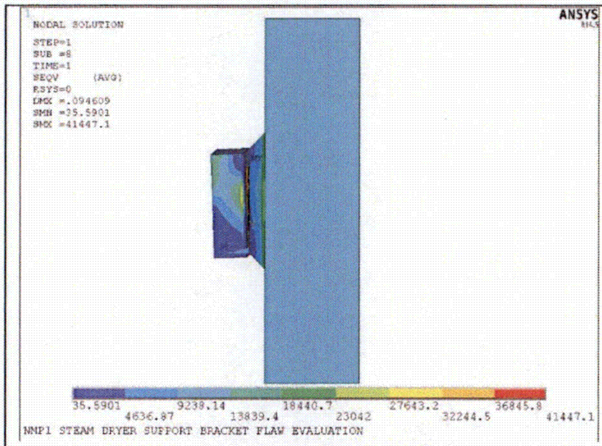


d)Von Mises Strain on crack plane, looking toward RPV surface.

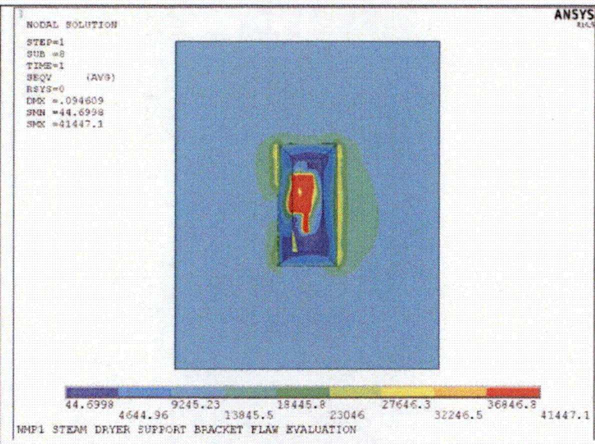
Figure 7: Limit Load Results for Steam Dryer Support Bracket Crack Case 2 –Service Level A – Bounds 1-587B – 2 Cycles SCC Growth.

Table 5: ASME B&PV Code Primary Local Membrane + Bending Stress Check, RPV Shell, Steam Dryer Support Bracket 1-587B, Service Level A.

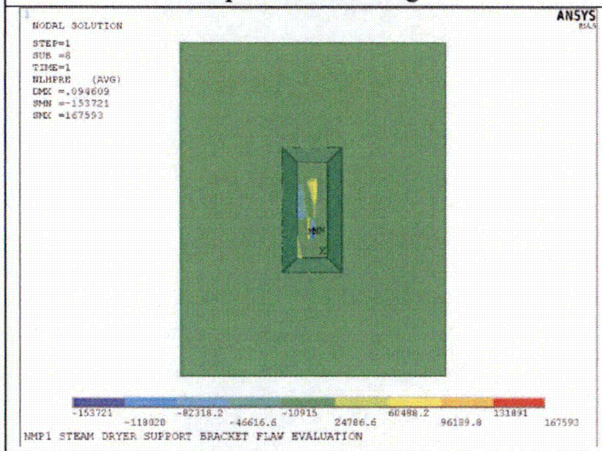
Path	P_m+P_b, psi	Allowable, 1.5S_m, psi
Peak	15,980	40,050



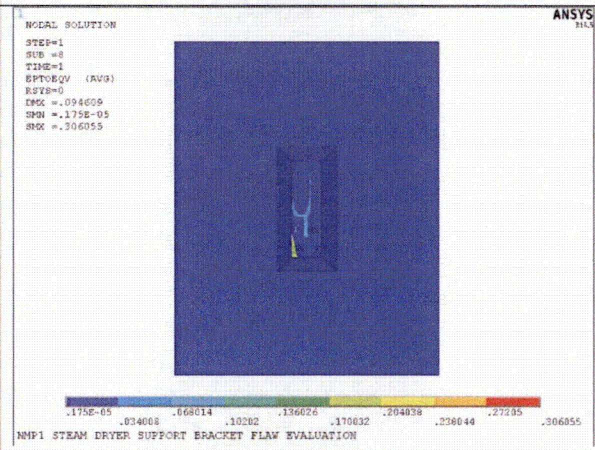
a)Right side view of the FEM showing Von Mises stress. Displacement scaling = 15X.



b)Von Mises stress on crack plane, looking toward RPV surface.



c)Hydrostatic pressure on crack plane, looking toward RPV surface.

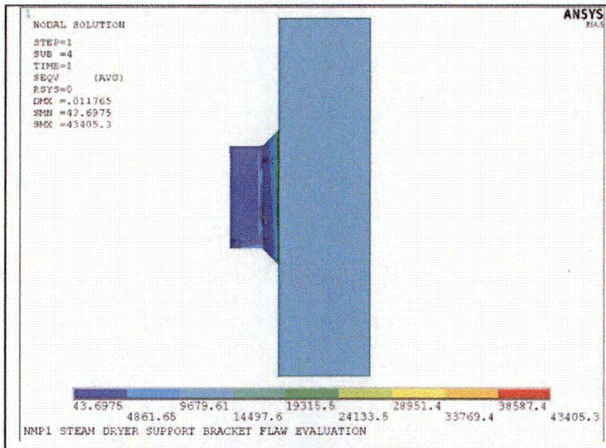


d)Von Mises Strain on crack plane, looking toward RPV surface.

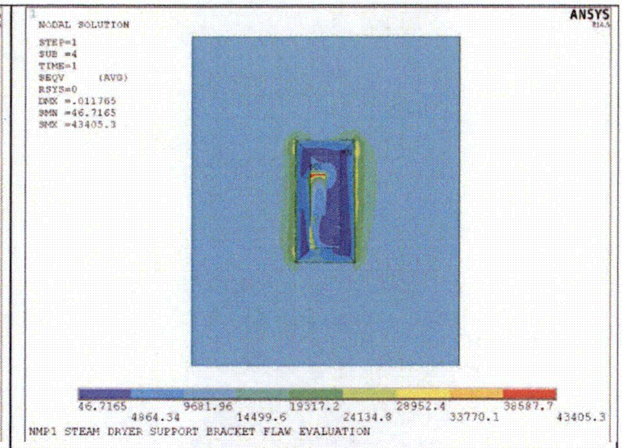
Figure 8: Limit Load Results for Steam Dryer Support Bracket Crack Case 2 –Service Level B – Bounds 1-587B – 2 Cycles SCC Growth.

Table 6: ASME B&PV Code Primary Local Membrane + Bending Stress Check, RPV Shell, Steam Dryer Support Bracket 1-587B, Service Level B.

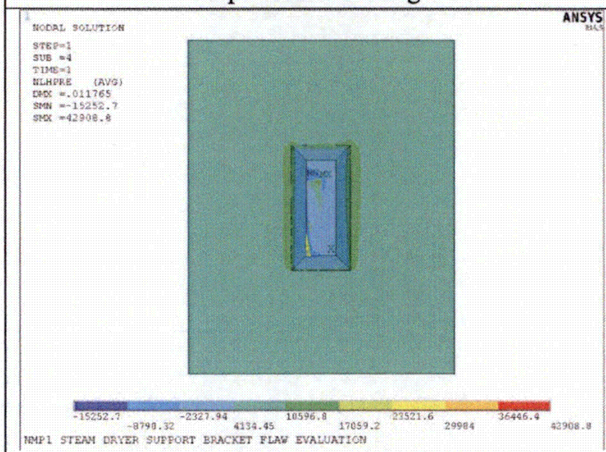
Path	P_m+P_b, psi	Allowable, 1.5S_m, psi
Peak	16,210	40,050



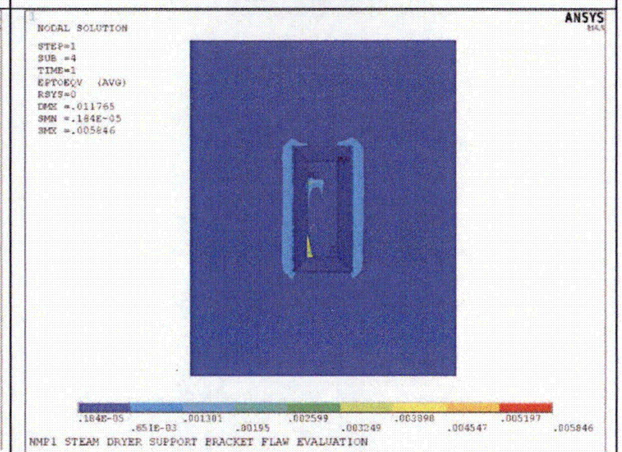
a)Right side view of the FEM showing Von Mises stress. Displacement scaling = 15X.



b)Von Mises stress on crack plane, looking toward RPV surface.



c)Hydrostatic pressure on crack plane, looking toward RPV surface.

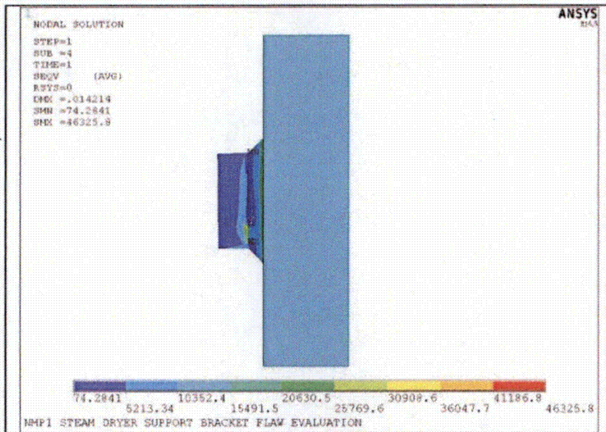


d)Von Mises Strain on crack plane, looking toward RPV surface.

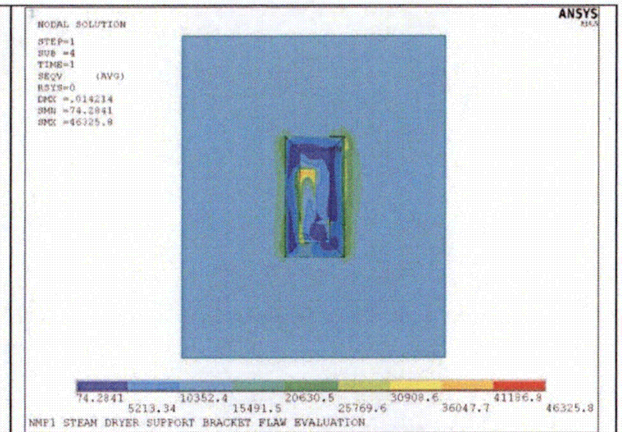
Figure 9: Limit Load Results for Steam Dryer Support Bracket Crack Case 3 –Service Level A – Bounds 1-587C – 2 Cycles SCC Growth.

Table 7: ASME B&PV Code Primary Local Membrane + Bending Stress Check, RPV Shell, Steam Dryer Support Bracket 1-587C, Service Level A.

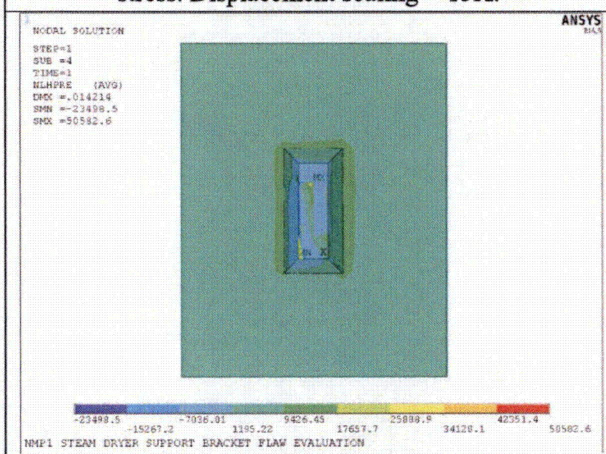
Path	P_m+P_b, psi	Allowable, 1.5S_m, psi
Peak	15,910	40,050



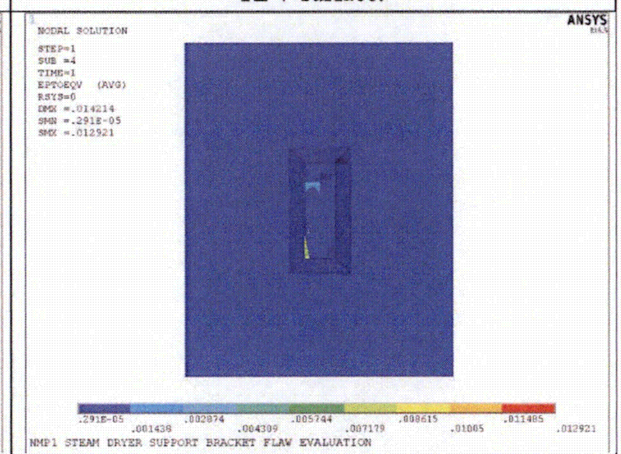
a)Right side view of the FEM showing Von Mises stress. Displacement scaling = 15X.



b)Von Mises stress on crack plane, looking toward RPV surface.



c)Hydrostatic pressure on crack plane, looking toward RPV surface.



d)Von Mises Strain on crack plane, looking toward RPV surface.

Figure 10: Limit Load Results for Steam Dryer Support Bracket Crack Case 3 –Service Level B – Bounds 1-587C – 2 Cycles SCC Growth.

Table 8: ASME B&PV Code Primary Local Membrane + Bending Stress Check, RPV Shell, Steam Dryer Support Bracket 1-587C, Service Level B.

Path	P_m+P_b, psi	Allowable, $1.5S_m$, psi
Peak	16,370	40,050

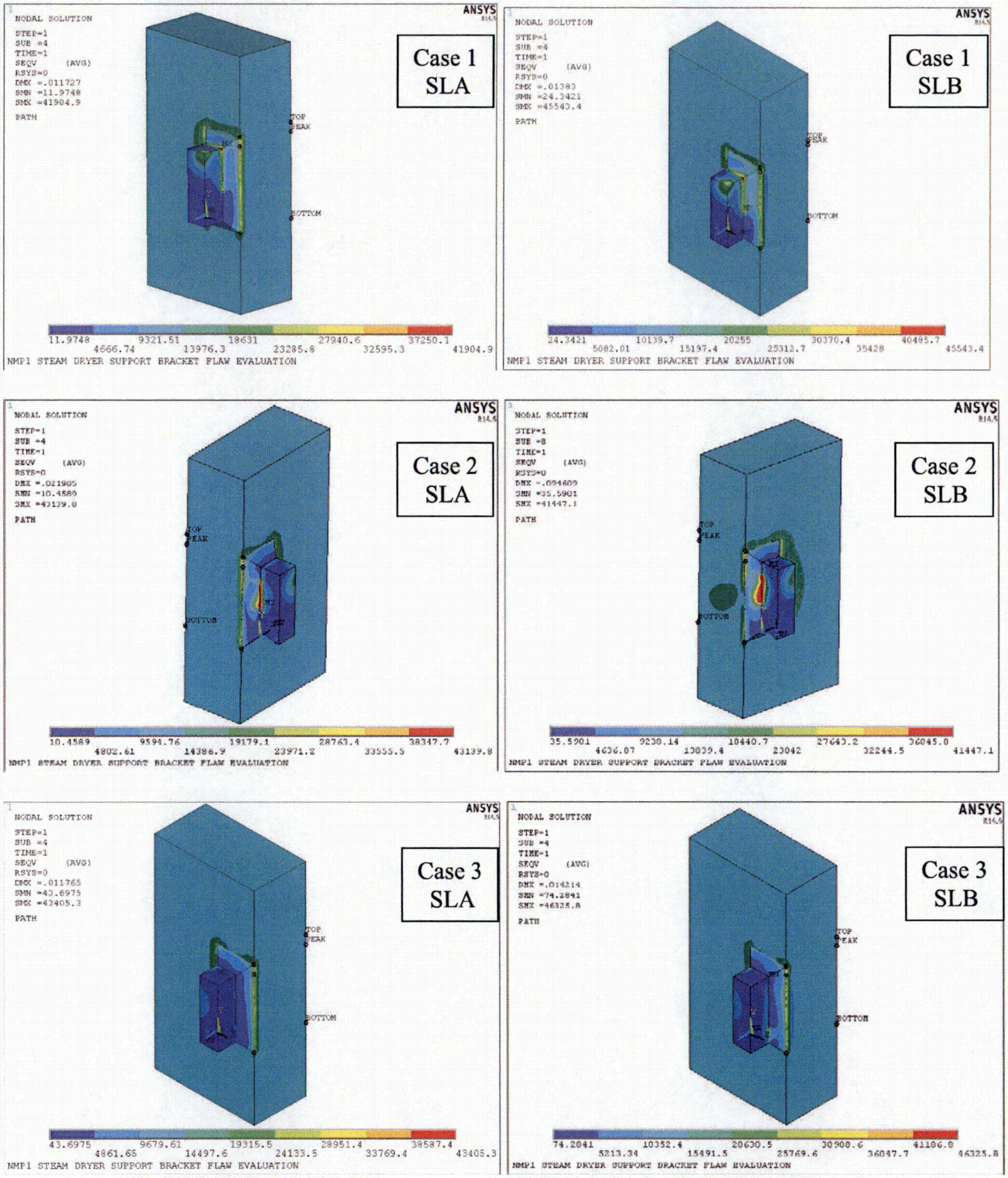
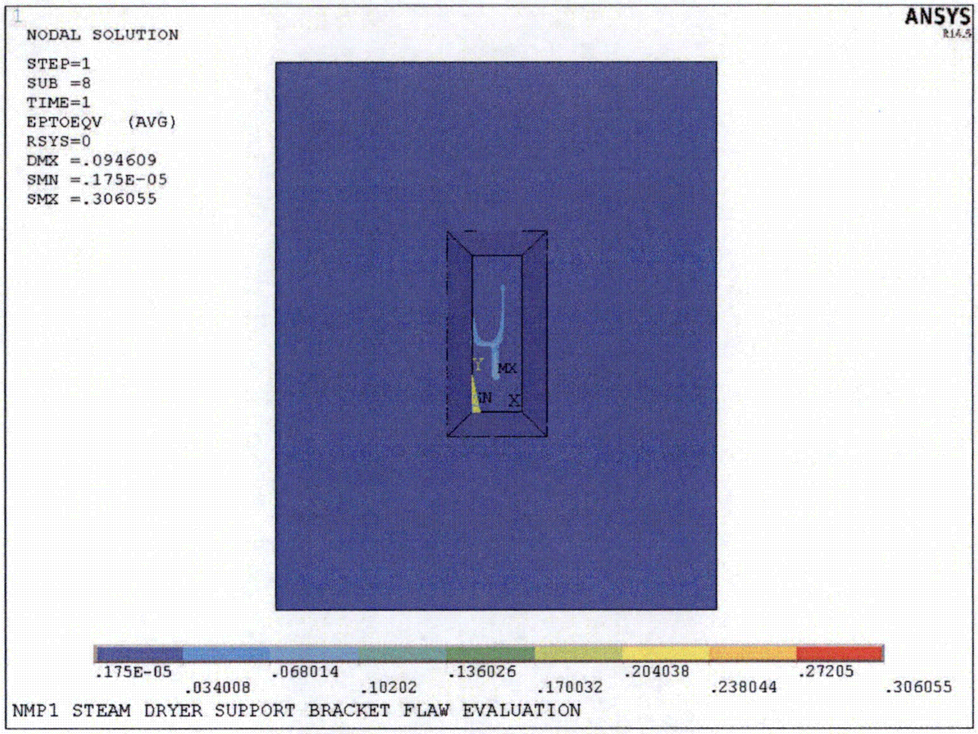
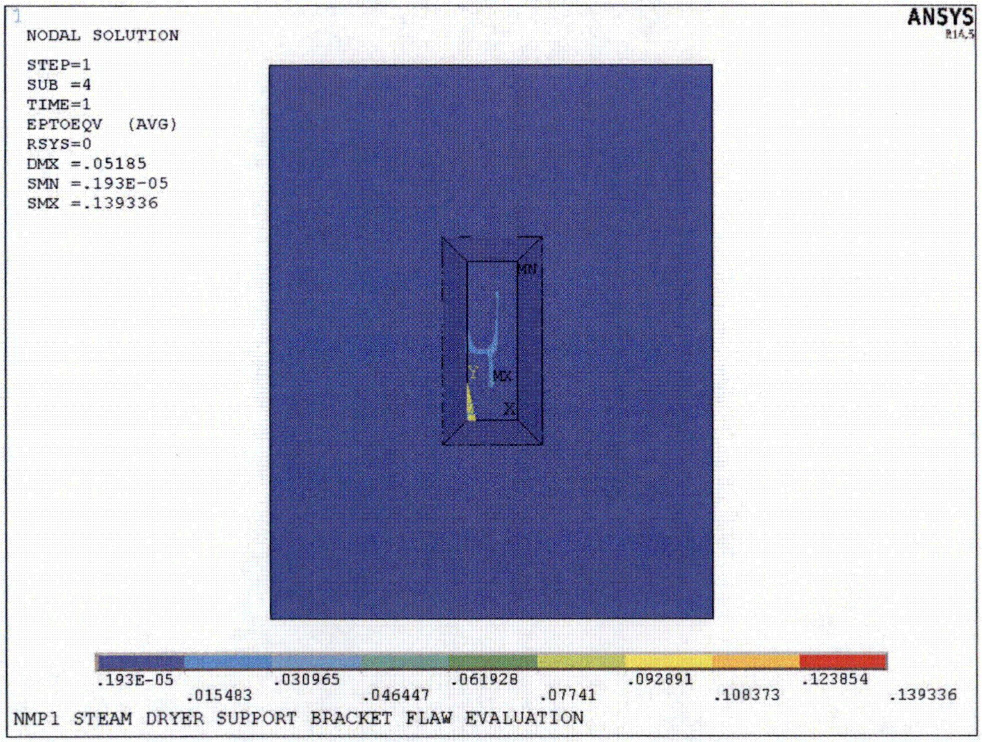


Figure 11: Orientation of Paths to Extract Linearized Stresses in RPV Shell.



Case 2, SLB
Friction = 0.65
Strain = 30.6%



Case 2, SLB
Friction = 0.5
Strain = 13.9%

Figure 12: Comparison of Strain for Crack Case 2, Service Level B

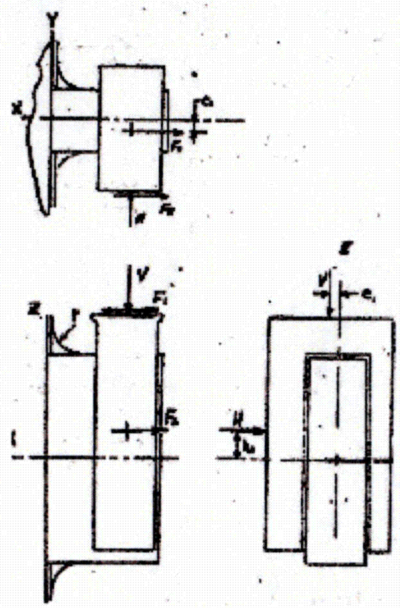
Table 9: Summary of Project Computer Files

Filename	Program	Purpose
LEFM of Bracket-SLA.xmcd	MathCAD	Contains LEFM calculations for bracket flaw stability for service level A loads
LEFM of Bracket-SLB.xmcd	MathCAD	Contains LEFM calculations for bracket flaw stability for service level B loads
NMP1_SB_BracketA-SLA.inp	ANSYS	Input file for limit load analysis of crack case 1 (bracket A), service level A
NMP1_SB_BracketA-SLB.inp	ANSYS	Input file for limit load analysis of crack case 1 (bracket A), service level B
NMP1_SB_BracketB-SLA.inp	ANSYS	Input file for limit load analysis of crack case 2 (bracket B), service level A
NMP1_SB_BracketB-SLB.inp	ANSYS	Input file for limit load analysis of crack case 2 (bracket B), service level B
NMP1_SB_BracketC-SLA.inp	ANSYS	Input file for limit load analysis of crack case 3 (bracket C), service level A
NMP1_SB_BracketC-SLB.inp	ANSYS	Input file for limit load analysis of crack case 3 (bracket C), service level B
NMP1_SB_BracketB-SLB-P5.inp	ANSYS	Input file for limit load analysis of crack case 2 (bracket B), service level B using friction factor of 0.5
Linear_Crack#_SL$.mac	ANSYS	Input file to extract linearized stresses in the vessel wall, where # is crack case 1, 2 or 3 and $ is service level A or B
NMP1-SDBRK-P-Crack#-SL$.lin	ANSYS	output file containing linearized stresses in the vessel wall, where # is crack case 1, 2 or 3 and $ is service level A (1) or B (2)

Appendix A

STEAM DRYER SUPPORT BRACKET LEFM EVALUATION

SERVICE LEVEL A



For the configuration shown above the stress intensity factor at the crack plane is determined by superposition of the following LEFM solutions found in The Stress Analysis of Cracks:

1. Edge cracked finite width plate subjected to in plane and out of plane shear stresses (pg. 73)

2. Semi-infinite 90 degree plate intersection with edge crack at intersection subjected to axial force, moment, and membrane stress (pg. 307).

From pg. 73:

$$KII = \tau \cdot \sqrt{\pi a} \cdot FII$$

$$FII = \frac{1.122 - 0.561 \cdot \left(\frac{a}{b}\right) + 0.085 \cdot \left(\frac{a}{b}\right)^2 + 0.180 \cdot \left(\frac{a}{b}\right)^3}{\sqrt{1 - \frac{a}{b}}}$$

$$KIII = \tau_1 \cdot \sqrt{\pi a} \cdot FIII$$

$$FIII = \sqrt{\frac{2b}{\pi a} \cdot \tan\left(\frac{\pi a}{2b}\right)}$$

$$KI = \sqrt{\pi a}\cdot\left(\sigma\cdot FI\sigma(A) + \frac{P}{W}\cdot FIp(A) + \frac{M}{W^2}\cdot FIm(A)\right)$$

$$KII = \sqrt{\pi a}\cdot\left(\sigma\cdot FII\sigma(A) + \frac{P}{W}\cdot FIIp(A) + \frac{M}{W^2}\cdot FIIm(A)\right)$$

$$A(a,W) = \frac{a}{W}$$

$$FI\sigma(A) = \sqrt{\frac{1-A}{A}}\cdot\left[0.018 + 0.069\cdot e^{-12.5\cdot\left(\frac{A}{1-A}\right)}\right]$$

$$FII\sigma(A) = \sqrt{\frac{1-A}{A}}\cdot\left[0.156 - 0.067\cdot e^{-8.9\cdot\left(\frac{A}{1-A}\right)}\right]$$

$$FIp(A) = \frac{1}{\sqrt{A}\cdot(1-A)^{\frac{3}{2}}}\cdot\left[0.379 + 0.624\cdot A - 0.062\cdot e^{-12\cdot\left(\frac{A}{1-A}\right)}\right]$$

$$FIIp(A) = \frac{1}{\sqrt{A}\cdot(1-A)^{\frac{3}{2}}}\cdot\left[0.126 - 0.24\cdot A - 0.023\cdot(1-A)^5\right]$$

$$FIm(A) = \frac{1}{\sqrt{A}\cdot(1-A)^{\frac{3}{2}}}\cdot\left[2.005 - 0.72\cdot e^{-9\cdot\left(\frac{A}{1-A}\right)}\right]$$

$$FIIm(A) = \frac{1}{\sqrt{A}\cdot(1-A)^{\frac{3}{2}}}\cdot\left[-0.228 + (1-A)^4\cdot\left(0.577 - 0.2A + 0.8A^2\right)\right]$$

For Hoop orientation (i.e. circumferential orientation in RPV)

$i := 0, 1..3$

$$a := \begin{pmatrix} .8 \\ .95 \\ 1.21 \\ 1.25 \end{pmatrix} \text{ in}$$

Range of crack sizes to evaluate.

$W := 2.5$ in

$b := W$

$$A_i := \frac{a_i}{W} \qquad A = \begin{pmatrix} 0.32 \\ 0.38 \\ 0.484 \\ 0.5 \end{pmatrix}$$

$$\tau := \frac{15000}{2.5 \cdot 8} \qquad \tau = 750$$

$$\tau 1 := \frac{(5000 \cdot 1 + 15000 \cdot 2.5) \cdot \left(1.25^2 + 4^2\right)^{0.5}}{\frac{1}{12} \cdot \left(8 \cdot 2.5^3 + 2.5 \cdot 8^3\right)} \qquad \tau 1 = 1521$$

$$FII_i := \frac{1.122 - 0.561 \cdot \left(\frac{a_i}{b}\right) + 0.085 \cdot \left(\frac{a_i}{b}\right)^2 + 0.180 \cdot \left(\frac{a_i}{b}\right)^3}{\sqrt{1 - \frac{a_i}{b}}} \qquad FII = \begin{pmatrix} 1.161 \\ 1.182 \\ 1.24 \\ 1.252 \end{pmatrix}$$

$$KII\_1_i := 2.7\tau \cdot \sqrt{\pi\, a_i} \cdot FII_i \qquad KII\_1 = \begin{pmatrix} 3726 \\ 4136.2 \\ 4896.1 \\ 5023.8 \end{pmatrix}$$

$$FIII_i := \sqrt{\frac{2 \cdot b}{\pi\, a_i} \cdot \tan\left(\frac{\pi\, a_i}{2 \cdot b}\right)} \qquad FIII = \begin{pmatrix} 1.046 \\ 1.067 \\ 1.118 \\ 1.128 \end{pmatrix}$$

$$KIII_i := 2.7\tau 1\cdot\sqrt{\pi\, a_i}\cdot FIII_i$$ $$KIII = \begin{pmatrix} 6810 \\ 7571 \\ 8956 \\ 9184 \end{pmatrix}$$

$$\sigma := \frac{1000\cdot\frac{213.44}{2}}{7.125}$$ (Pressure stress) $\sigma = 14978$ psi

$$P := \frac{10000}{8}$$ (Force per unit thickness) $P = 1250$ $\frac{lb}{in}$

$$M := \frac{3250\cdot 2.5 + 5000\cdot 1.25 + 9750\cdot 2.5}{8}$$ (Moment per unit thickness) $M = 4844$ $\frac{lb - in}{in}$

$$FI\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.018 + 0.069\cdot e^{-12.5\cdot\left(\frac{A_i}{1-A_i}\right)}\right]$$ $$FI\sigma = \begin{pmatrix} 0.027 \\ 0.023 \\ 0.019 \\ 0.018 \end{pmatrix}$$

$$FII\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.156 - 0.067\cdot e^{-8.9\cdot\left(\frac{A_i}{1-A_i}\right)}\right]$$ $$FII\sigma = \begin{pmatrix} 0.226 \\ 0.199 \\ 0.161 \\ 0.156 \end{pmatrix}$$

$$FIp_i := \frac{1}{\sqrt{A_i}\cdot(1 - A_i)^{\frac{3}{2}}}\cdot\left[0.379 + 0.624\cdot A_i - 0.062\cdot e^{-12\cdot\left(\frac{A_i}{1-A_i}\right)}\right]$$ $$FIp = \begin{pmatrix} 1.824 \\ 2.047 \\ 2.641 \\ 2.764 \end{pmatrix}$$

$$FIIp_i := \frac{1}{\sqrt{A_i}\cdot(1 - A_i)^{\frac{3}{2}}}\cdot\left[0.126 - 0.24\cdot A_i - 0.023\cdot(1 - A_i)^5\right]$$ $$FIIp = \begin{pmatrix} 0.145 \\ 0.109 \\ 0.035 \\ 0.021 \end{pmatrix}$$

$$FIm_i := \frac{1}{\sqrt{A_i}\cdot\left(1-A_i\right)^{\frac{3}{2}}}\cdot\left[2.005 - 0.72\cdot e^{-9\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIm = \begin{pmatrix} 6.288 \\ 6.653 \\ 7.775 \\ 8.02 \end{pmatrix}$$

$$FIIm_i := \frac{1}{\sqrt{A_i}\cdot\left(1-A_i\right)^{\frac{3}{2}}}\cdot\left[-0.228 + \left(1-A_i\right)^4\cdot\left[0.577 - 0.2A_i + 0.8\left(A_i\right)^2\right]\right] \qquad FIIm = \begin{pmatrix} -0.318 \\ -0.455 \\ -0.701 \\ -0.743 \end{pmatrix}$$

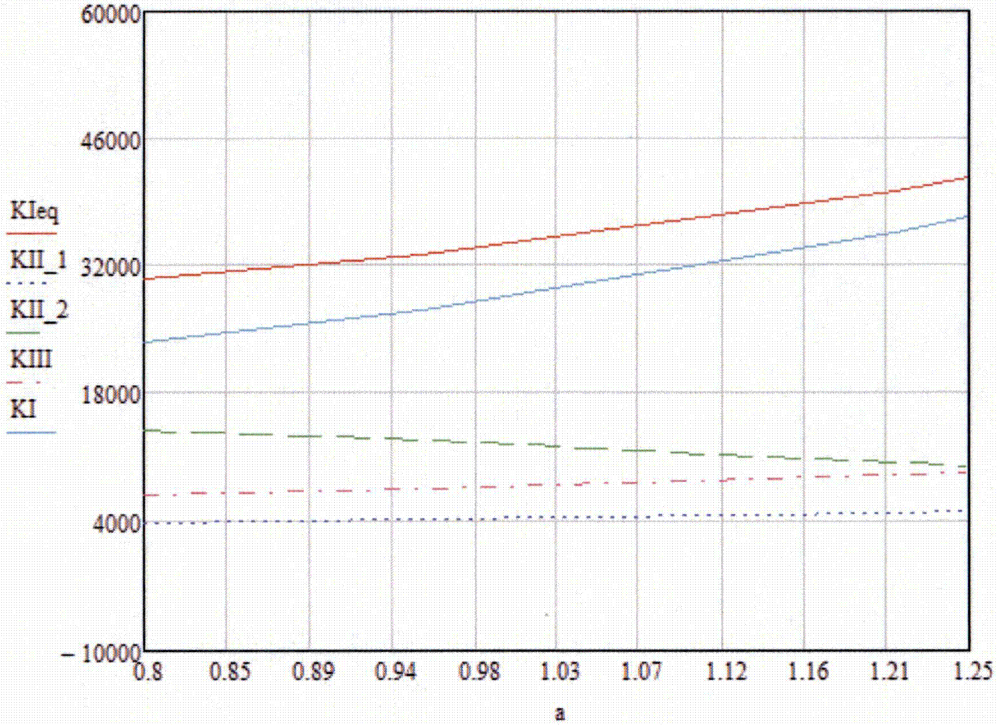
$$KI_i := \sqrt{\pi\cdot a_i}\cdot\left(2.7\sigma\cdot FI\sigma_i + \frac{2.7P}{W}\cdot FIp_i + \frac{2.3M}{W^2}\cdot FIm_i\right) \qquad KI = \begin{pmatrix} 23372 \\ 26871 \\ 35436 \\ 37165 \end{pmatrix} \quad psi\cdot\sqrt{in}$$

$$KII\_2_i := \sqrt{\pi\cdot a_i}\cdot\left(2.7\sigma\cdot FII\sigma_i + \frac{2.7P}{W}\cdot FIIp_i + \frac{2.3M}{W^2}\cdot FIIm_i\right) \qquad KII\_2 = \begin{pmatrix} 13896 \\ 12749 \\ 10356 \\ 9934 \end{pmatrix} \quad psi\cdot\sqrt{in}$$

An equivalent KI may be given by:

$$\upsilon := 0.3$$

$$KIeq_i := \left[\left(KI_i\right)^2 + \left(KII\_1_i + KII\_2_i\right)^2 + \frac{1}{1-\upsilon}\cdot\left(KIII_i\right)^2\right]^{0.5} \qquad KIeq = \begin{pmatrix} 30382 \\ 33000 \\ 40037 \\ 41539 \end{pmatrix} \quad psi\cdot\sqrt{in}$$



Using a solution for a quarter elliptical crack in a finite body subjected to remote tension and bending loads (Raju and Newman):

$$K = (St + H \cdot Sb) \cdot 2.7 \sqrt{\pi \cdot \frac{a}{Q}} \cdot Fc\left(\frac{a}{c}, \frac{a}{t}, \frac{c}{b}, \phi\right)$$

$a := 1.210 \cdot in$

$c := 6.204 \cdot in$

$\frac{a}{c} = 0.195$ $\quad\quad$ $\frac{c}{8 \cdot in} = 0.775$ $\quad\quad$ $\frac{a}{2.5 \cdot in} = 0.484$

Using the a/c=0.2 graph in Figure 7 of NASA Technical Memorandum 85793 gives a maximum Fc at the deepest point. This value is approximately 1.7. At the surface Fc would be approximately 0.8. From Figure 8, using the same crude interpolation gives a FcHc=~0.7 at the surface and ~0.75 at the deepest point.

$Q := 1 + 1.464 \cdot \left(\frac{a}{c}\right)^{1.65}$ $\quad\quad$ $Q = 1.099$

Remote bending stress is given as: $Sb = \frac{6 \cdot M}{b \cdot t^2} \cdot psi$ $Sb := \frac{6 \cdot M}{4 \cdot 2.5^2} \cdot \frac{lb}{in^2}$ $Sb = 1163 \cdot \frac{lb}{in^2}$

Remote tension stress is given as: $St = \frac{P}{2 \cdot b \cdot t}$ $St := \frac{P}{2.5 \cdot 8} \cdot \frac{lb}{in^2}$ $St = 62.5 \cdot \frac{lb}{in^2}$

$Ksurface := (St \cdot 0.8 + 0.75 \cdot Sb) \cdot 2.7 \sqrt{\pi \cdot \frac{a}{Q}}$ $Ksurface = 4630 \cdot \frac{lb}{in^2} \cdot in^{0.5}$

$Kdeep := (St \cdot 1.7 + 0.7 \cdot Sb) \cdot 2.7 \sqrt{\pi \cdot \frac{a}{Q}}$ $Kdeep = 4620 \cdot \frac{lb}{in^2} \cdot in^{0.5}$

Note that the corner crack case gives a KI that is ~10 smaller than the edge crack (5 versus 50). This solution does not consider torsional loading or shear and may be at the edges of the applicability of c/b; however, it gives an estimate of the benefit of more accurately treating the corner crack configuration.

For Axial orientation (i.e. longitudinal axis of RPV)

$a := \begin{pmatrix} 1 \\ 1.684 \\ 2.5 \\ 3.444 \end{pmatrix} in$ Range of crack sizes evaluated

$W := 8$ in

$b := W$

$A := \frac{a}{W}$ $A = \begin{pmatrix} 0.125 \\ 0.211 \\ 0.313 \\ 0.43 \end{pmatrix}$

$\tau := \frac{15000}{2.5 \cdot 8}$ $\tau = 750$

$\tau 1 := \frac{(5000 \cdot 1 + 15000 \cdot 2.5) \cdot \left(1.25^2 + 4^2\right)^{0.5}}{\frac{1}{12} \cdot \left(8 \cdot 2.5^3 + 2.5 \cdot 8^3\right)}$ $\tau 1 = 1521$

$$FII_i := \frac{1.122 - 0.561\cdot\left(\frac{a_i}{b}\right) + 0.085\cdot\left(\frac{a_i}{b}\right)^2 + 0.180\cdot\left(\frac{a_i}{b}\right)^3}{\sqrt{1 - \frac{a_i}{b}}} \qquad FII = \begin{pmatrix} 1.126 \\ 1.136 \\ 1.158 \\ 1.207 \end{pmatrix}$$

$$KII\_1_i := 2.7\tau\cdot\sqrt{\pi\, a_i}\cdot FII_i \qquad KII\_1 = \begin{pmatrix} 4043 \\ 5291 \\ 6574 \\ 8037 \end{pmatrix}$$

$$FIII_i := \sqrt{\frac{2\cdot b}{\pi\, a_i}\cdot\tan\left(\frac{\pi\, a_i}{2\cdot b}\right)} \qquad FIII = \begin{pmatrix} 1.007 \\ 1.019 \\ 1.044 \\ 1.089 \end{pmatrix}$$

$$KIII_i := 2.7\tau 1\cdot\sqrt{\pi\, a_i}\cdot FIII_i \qquad KIII = \begin{pmatrix} 7327 \\ 9625 \\ 12011 \\ 14717 \end{pmatrix}$$

$$\sigma := \frac{1000\cdot\frac{213.44}{2}}{2\cdot 7.125}$$ (Pressure stress) $\sigma = 7489$ psi

$$P := \frac{10000}{2.5}$$ (Force per unit thickness) $P = 4000$ $\frac{lb}{in}$

$$M := \frac{9750\cdot 5.5 + 15000\cdot 2.25 + 3250\cdot 1}{2.5}$$ (Moment per unit thickness) $M = 36250$ $\frac{lb - in}{in}$

$$FI\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.018 + 0.069\cdot e^{-12.5\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FI\sigma = \begin{pmatrix} 0.078 \\ 0.04 \\ 0.027 \\ 0.021 \end{pmatrix}$$

$$FII\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.156 - 0.067\cdot e^{-8.9\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FII\sigma = \begin{pmatrix} 0.363 \\ 0.29 \\ 0.23 \\ 0.179 \end{pmatrix}$$

$$FIp_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[0.379 + 0.624\cdot A_i - 0.062\cdot e^{-12\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIp = \begin{pmatrix}1.541\\1.578\\1.8\\2.297\end{pmatrix}$$

$$FIIp_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[0.126 - 0.24\cdot A_i - 0.023\cdot(1-A_i)^5\right] \qquad FIIp = \begin{pmatrix}0.291\\0.213\\0.149\\0.076\end{pmatrix}$$

$$FIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[2.005 - 0.72\cdot e^{-9\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIm = \begin{pmatrix}6.241\\6.027\\6.254\\7.107\end{pmatrix}$$

$$FIIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[-0.228 + (1-A_i)^4\cdot\left[0.577 - 0.2\,A_i + 0.8\left(A_i\right)^2\right]\right] \qquad FIIm = \begin{pmatrix}0.356\\-0.02\\-0.3\\-0.57\end{pmatrix}$$

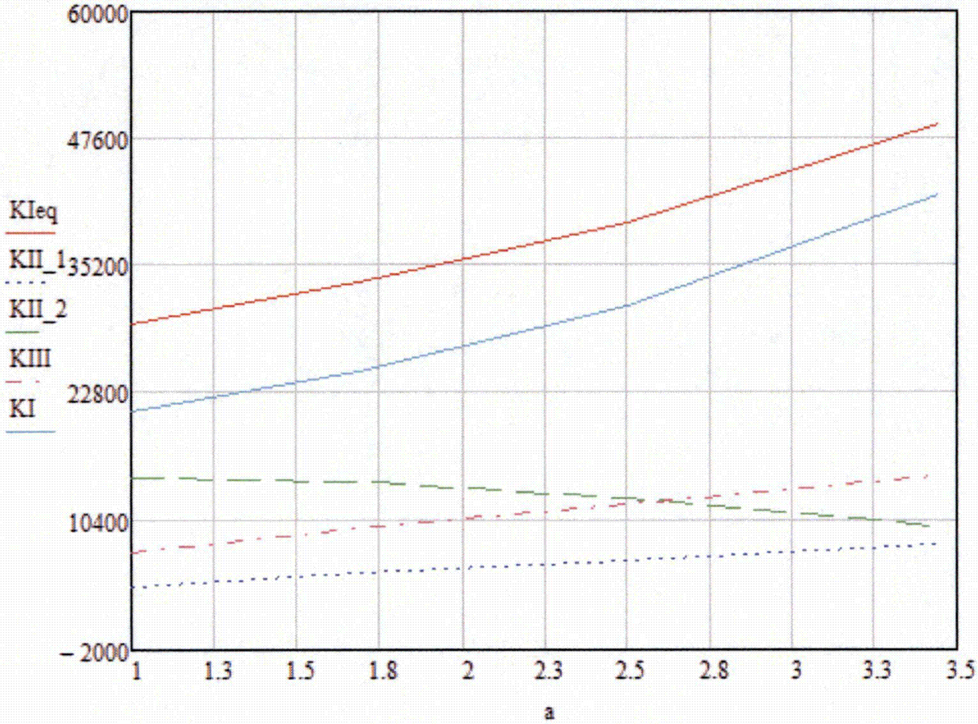
$$KI_i := \sqrt{\pi\cdot a_i}\cdot\left(2.7\sigma\cdot FI\sigma_i + \frac{2.7P}{W}\cdot FIp_i + \frac{2.3M}{W^2}\cdot FIm_i\right) \qquad KI = \begin{pmatrix}20901\\24801\\31178\\42032\end{pmatrix} \ psi\cdot\sqrt{in}$$

$$KII\_2_i := \sqrt{\pi\cdot a_i}\cdot\left(2.7\sigma\cdot FII\sigma_i + \frac{2.7P}{W}\cdot FIIp_i + \frac{2.3M}{W^2}\cdot FIIm_i\right) \qquad KII\_2 = \begin{pmatrix}14528\\14089\\12482\\9820\end{pmatrix} \ psi\cdot\sqrt{in}$$

An equivalent KI may be given by:

$\upsilon := 0.3$

$$KIeq_i := \left[(KI_i)^2 + (KII\_1_i + KII\_2_i)^2 + \frac{1}{1-\upsilon}\cdot(KIII_i)^2\right]^{0.5} \qquad KIeq = \begin{pmatrix}29299\\33511\\39259\\48939\end{pmatrix} \ psi\cdot\sqrt{in}$$



Since Bracket B has through wall flaws on top and bottom, assume top flaw area is removed for shear stress calculation.

$W := 6.596$ in

$b := W$

$A := \frac{a}{W}$ $\qquad A = \begin{pmatrix} 0.152 \\ 0.255 \\ 0.379 \\ 0.522 \end{pmatrix}$

$\tau := \frac{15000}{2.5 \cdot 6.596}$ $\qquad \tau = 909.642$

$\tau 1 := \frac{(5000 \cdot 1 + 15000 \cdot 2.5) \cdot \left(1.25^2 + 4^2\right)^{0.5}}{\frac{1}{12} \cdot \left(6.596 \cdot 2.5^3 + 2.5 \cdot 6.596^3\right)}$ $\qquad \tau 1 = 2605$

$$FII_i := \frac{1.122 - 0.561\cdot\left(\frac{a_i}{b}\right) + 0.085\cdot\left(\frac{a_i}{b}\right)^2 + 0.180\cdot\left(\frac{a_i}{b}\right)^3}{\sqrt{1 - \frac{a_i}{b}}} \qquad FII = \begin{pmatrix} 1.129 \\ 1.144 \\ 1.182 \\ 1.27 \end{pmatrix}$$

$$KII\_1_i := 2.7\tau\cdot\sqrt{\pi\, a_i}\cdot FII_i \qquad KII\_1 = \begin{pmatrix} 4913 \\ 6463 \\ 8135 \\ 10259 \end{pmatrix}$$

$$FIII_i := \sqrt{\frac{2\cdot b}{\pi\, a_i}\cdot \tan\left(\frac{\pi\, a_i}{2\cdot b}\right)} \qquad FIII = \begin{pmatrix} 1.01 \\ 1.028 \\ 1.067 \\ 1.143 \end{pmatrix}$$

$$KIII_i := 2.7\tau 1\cdot\sqrt{\pi\, a_i}\cdot FIII_i \qquad KIII = \begin{pmatrix} 12586 \\ 16634 \\ 21024 \\ 26450 \end{pmatrix}$$

$$\sigma := \frac{1000\cdot\frac{213.44}{2}}{2\cdot 7.125}$$ (Pressure stress) $\sigma = 7489$ psi

$$P := \frac{10000}{2.5}$$ (Force per unit thickness) $P = 4000$ $\frac{lb}{in}$

$$M := \frac{9750\cdot 5.5 + 15000\cdot 2.25 + 3250\cdot 1}{2.5}$$ (Moment per unit thickness) $M = 36250$ $\frac{lb - in}{in}$

$$FI\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.018 + 0.069\cdot e^{-12.5\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FI\sigma = \begin{pmatrix} 0.06 \\ 0.032 \\ 0.023 \\ 0.017 \end{pmatrix}$$

$$FII\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.156 - 0.067\cdot e^{-8.9\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FII\sigma = \begin{pmatrix} 0.337 \\ 0.261 \\ 0.199 \\ 0.149 \end{pmatrix}$$

$$FIp_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[0.379 + 0.624\cdot A_i - 0.062\cdot e^{-12\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIp = \begin{pmatrix}1.533\\1.655\\2.043\\2.953\end{pmatrix}$$

$$FIIp_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[0.126 - 0.24\cdot A_i - 0.023\cdot(1-A_i)^5\right] \qquad FIIp = \begin{pmatrix}0.261\\0.183\\0.109\\4.799\times 10^{-4}\end{pmatrix}$$

$$FIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[2.005 - 0.72\cdot e^{-9\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIm = \begin{pmatrix}6.116\\6.073\\6.645\\8.4\end{pmatrix}$$

$$FIIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[-0.228 + (1-A_i)^4\cdot\left[0.577 - 0.2A_i + 0.8(A_i)^2\right]\right] \qquad FIIm = \begin{pmatrix}0.213\\-0.155\\-0.453\\-0.804\end{pmatrix}$$

$$KI_i := \sqrt{\pi\cdot a_i}\cdot\left(2.7\sigma\cdot FI\sigma_i + \frac{2.7P}{W}\cdot FIp_i + \frac{2.3M}{W^2}\cdot FIm_i\right) \qquad KI = \begin{pmatrix}27374\\34507\\46372\\69995\end{pmatrix}\ psi\cdot\sqrt{in}$$

$$KII\_2_i := \sqrt{\pi\cdot a_i}\cdot\left(2.7\sigma\cdot FII\sigma_i + \frac{2.7P}{W}\cdot FIIp_i + \frac{2.3M}{W^2}\cdot FIIm_i\right) \qquad KII\_2 = \begin{pmatrix}13549\\12148\\9364\\4859\end{pmatrix}\ psi\cdot\sqrt{in}$$

An equivalent KI may be given by:

$\upsilon := 0.3$

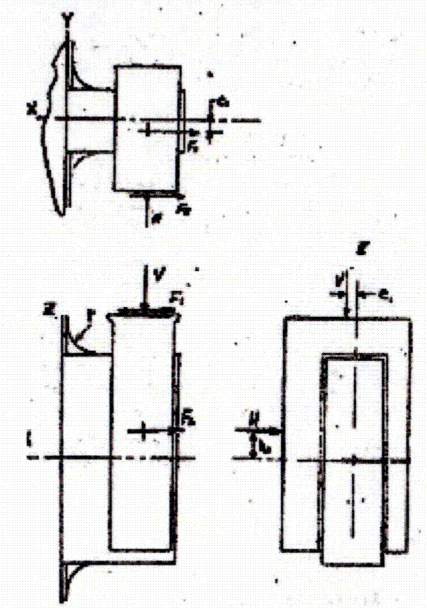
$$KIeq_i := \left[(KI_i)^2 + (KII\_1_i + KII\_2_i)^2 + \frac{1}{1-\upsilon}\cdot(KIII_i)^2\right]^{0.5} \qquad KIeq = \begin{pmatrix}36283\\43959\\55570\\78276\end{pmatrix}\ psi\cdot\sqrt{in}$$

The static fracture toughness for unirradiated stainless steel is taken from BWRVIP-76 as 150 ksi-in^0.5. The required structural factors for Level A/B conditions have already been accounted for in the equations above. Therefore, the allowable fracture toughness for stainless steel is given as:

$$KI\_allowable := 150 \quad ksi \cdot in^{0.5}$$

Considering a flaw oriented on either axis of the support bracket the applied stress intensity factor is less than the allowable fracture toughness.

SERVICE LEVEL B



For the configuration shown above the stress intensity factor at the crack plane is determined by superposition of the following LEFM solutions found in The Stress Analysis of Cracks:

1. Edge cracked finite width plate subjected to in plane and out of plane shear stresses (pg. 73)

2. Semi-infinite 90 degree plate intersection with edge crack at intersection subjected to axial force, moment, and membrane stress (pg. 307).

From pg. 73:

$$KII = \tau \cdot \sqrt{\pi a} \cdot FII$$

$$FII = \frac{1.122 - 0.561 \cdot \left(\frac{a}{b}\right) + 0.085 \cdot \left(\frac{a}{b}\right)^2 + 0.180 \cdot \left(\frac{a}{b}\right)^3}{\sqrt{1 - \frac{a}{b}}}$$

$$KIII = \tau_1 \cdot \sqrt{\pi a} \cdot FIII$$

$$FIII = \sqrt{\frac{2b}{\pi a} \cdot \tan\left(\frac{\pi a}{2b}\right)}$$

$$KI = \sqrt{\pi a} \cdot \left(\sigma \cdot FI\sigma(A) + \frac{P}{W} \cdot FIp(A) + \frac{M}{W^2} \cdot FIm(A) \right)$$

$$KII = \sqrt{\pi a} \cdot \left(\sigma \cdot FII\sigma(A) + \frac{P}{W} \cdot FIIp(A) + \frac{M}{W^2} \cdot FIIm(A) \right)$$

$$A(a, W) = \frac{a}{W}$$

$$FI\sigma(A) = \sqrt{\frac{1-A}{A}} \cdot \left[0.018 + 0.069 \cdot e^{-12.5 \cdot \left(\frac{A}{1-A} \right)} \right]$$

$$FII\sigma(A) = \sqrt{\frac{1-A}{A}} \cdot \left[0.156 - 0.067 \cdot e^{-8.9 \cdot \left(\frac{A}{1-A} \right)} \right]$$

$$FIp(A) = \frac{1}{\sqrt{A} \cdot (1-A)^{\frac{3}{2}}} \cdot \left[0.379 + 0.624 \cdot A - 0.062 \cdot e^{-12 \cdot \left(\frac{A}{1-A} \right)} \right]$$

$$FIIp(A) = \frac{1}{\sqrt{A} \cdot (1-A)^{\frac{3}{2}}} \cdot \left[0.126 - 0.24 \cdot A - 0.023 \cdot (1-A)^5 \right]$$

$$FIm(A) = \frac{1}{\sqrt{A} \cdot (1-A)^{\frac{3}{2}}} \cdot \left[2.005 - 0.72 \cdot e^{-9 \cdot \left(\frac{A}{1-A} \right)} \right]$$

$$FIIm(A) = \frac{1}{\sqrt{A} \cdot (1-A)^{\frac{3}{2}}} \cdot \left[-0.228 + (1-A)^4 \cdot \left(0.577 - 0.2A + 0.8A^2 \right) \right]$$

For Hoop orientation (i.e. circumferential orientation in RPV)

$i := 0, 1 .. 3$

$$a := \begin{pmatrix} .8 \\ .95 \\ 1.21 \\ 1.25 \end{pmatrix} \text{ in}$$

Range of crack sizes to evaluate.

$W := 2.5$ in

$b := W$

$$A_i := \frac{a_i}{W} \qquad A = \begin{pmatrix} 0.32 \\ 0.38 \\ 0.484 \\ 0.5 \end{pmatrix}$$

$$\tau := \frac{18750}{2.5 \cdot 8} \qquad \tau = 937.5$$

$$\tau 1 := \frac{(16250 \cdot 1 + 18750 \cdot 2.5) \cdot \left(1.25^2 + 4^2\right)^{0.5}}{\frac{1}{12} \cdot \left(8 \cdot 2.5^3 + 2.5 \cdot 8^3\right)} \qquad \tau 1 = 2259$$

$$FII_i := \frac{1.122 - 0.561 \cdot \left(\frac{a_i}{b}\right) + 0.085 \cdot \left(\frac{a_i}{b}\right)^2 + 0.180 \cdot \left(\frac{a_i}{b}\right)^3}{\sqrt{1 - \frac{a_i}{b}}} \qquad FII = \begin{pmatrix} 1.161 \\ 1.182 \\ 1.24 \\ 1.252 \end{pmatrix}$$

$$KII\_1_i := 2.4 \tau \cdot \sqrt{\pi\, a_i} \cdot FII_i \qquad KII\_1 = \begin{pmatrix} 4140 \\ 4595.8 \\ 5440.1 \\ 5582 \end{pmatrix}$$

$$FIII_i := \sqrt{\frac{2 \cdot b}{\pi\, a_i} \cdot \tan\left(\frac{\pi\, a_i}{2 \cdot b}\right)} \qquad FIII = \begin{pmatrix} 1.046 \\ 1.067 \\ 1.118 \\ 1.128 \end{pmatrix}$$

$KIII_i := 2.4\tau 1 \cdot \sqrt{\pi\, a_i} \cdot FIII_i$ $\qquad KIII = \begin{pmatrix} 8990 \\ 9996 \\ 11824 \\ 12125 \end{pmatrix}$

$\sigma := \dfrac{1000 \cdot \dfrac{213.44}{2}}{7.125}$ (Pressure stress) $\qquad \sigma = 14978$ psi

$P := \dfrac{10000}{8}$ (Force per unit thickness) $\qquad P = 1250 \ \dfrac{lb}{in}$

$M := \dfrac{3250 \cdot 2.5 + 16250 \cdot 1.25 + 9750 \cdot 2.5}{8}$ (Moment per unit thickness) $\qquad M = 6602 \ \dfrac{lb - in}{in}$

$$FI\sigma_i := \sqrt{\frac{1 - A_i}{A_i}} \cdot \left[0.018 + 0.069 \cdot e^{-12.5 \cdot \left(\frac{A_i}{1 - A_i}\right)} \right] \qquad FI\sigma = \begin{pmatrix} 0.027 \\ 0.023 \\ 0.019 \\ 0.018 \end{pmatrix}$$

$$FII\sigma_i := \sqrt{\frac{1 - A_i}{A_i}} \cdot \left[0.156 - 0.067 \cdot e^{-8.9 \cdot \left(\frac{A_i}{1 - A_i}\right)} \right] \qquad FII\sigma = \begin{pmatrix} 0.226 \\ 0.199 \\ 0.161 \\ 0.156 \end{pmatrix}$$

$$FIp_i := \frac{1}{\sqrt{A_i} \cdot (1 - A_i)^{\frac{3}{2}}} \cdot \left[0.379 + 0.624 \cdot A_i - 0.062 \cdot e^{-12 \cdot \left(\frac{A_i}{1 - A_i}\right)} \right] \qquad FIp = \begin{pmatrix} 1.824 \\ 2.047 \\ 2.641 \\ 2.764 \end{pmatrix}$$

$$FIIp_i := \frac{1}{\sqrt{A_i} \cdot (1 - A_i)^{\frac{3}{2}}} \cdot \left[0.126 - 0.24 \cdot A_i - 0.023 \cdot (1 - A_i)^5 \right] \qquad FIIp = \begin{pmatrix} 0.145 \\ 0.109 \\ 0.035 \\ 0.021 \end{pmatrix}$$

$$FIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[2.005 - 0.72\cdot e^{-9\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIm = \begin{pmatrix}6.288\\6.653\\7.775\\8.02\end{pmatrix}$$

$$FIIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[-0.228 + (1-A_i)^4\cdot\left[0.577 - 0.2A_i + 0.8(A_i)^2\right]\right] \qquad FIIm = \begin{pmatrix}-0.318\\-0.455\\-0.701\\-0.743\end{pmatrix}$$

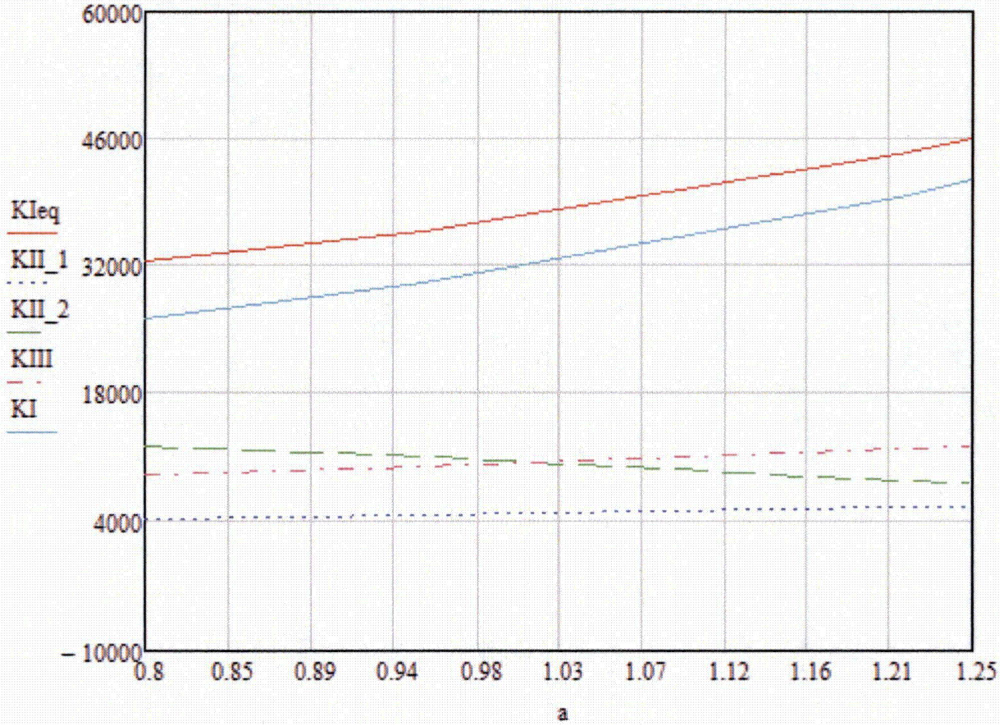
$$KI_i := \sqrt{\pi\cdot a_i}\cdot\left(2.4\sigma\cdot FI\sigma_i + \frac{2.4P}{W}\cdot FIp_i + \frac{2.0M}{W^2}\cdot FIm_i\right) \qquad KI = \begin{pmatrix}26039\\29954\\39503\\41427\end{pmatrix} \ psi\cdot\sqrt{in}$$

$$KII\_2_i := \sqrt{\pi\cdot a_i}\cdot\left(2.4\sigma\cdot FII\sigma_i + \frac{2.4P}{W}\cdot FIIp_i + \frac{2.0M}{W^2}\cdot FIIm_i\right) \qquad KII\_2 = \begin{pmatrix}12086\\10917\\8484\\8053\end{pmatrix} \ psi\cdot\sqrt{in}$$

An equivalent KI may be given by:

$\upsilon := 0.3$

$$KIeq_i := \left[(KI_i)^2 + (KII\_1_i + KII\_2_i)^2 + \frac{1}{1-\upsilon}\cdot(KIII_i)^2\right]^{0.5} \qquad KIeq = \begin{pmatrix}32508\\35786\\44206\\45958\end{pmatrix} \ psi\cdot\sqrt{in}$$



Using a solution for a quarter elliptical crack in a finite body subjected to remote tension and bending loads (Raju and Newman):

$$K = (St + H \cdot Sb) \cdot 2.4 \sqrt{\pi \cdot \frac{a}{Q}} \cdot Fc\left(\frac{a}{c}, \frac{a}{t}, \frac{c}{b}, \phi\right)$$

$a := 1.210 \cdot in$

$c := 6.204 \cdot in$

$\frac{a}{c} = 0.195$ $\qquad \frac{c}{8 \cdot in} = 0.775$ $\qquad \frac{a}{2.5 \cdot in} = 0.484$

Using the a/c=0.2 graph in Figure 7 of NASA Technical Memorandum 85793 gives a maximum Fc at the deepest point. This value is approximately 1.7. At the surface Fc would be approximately 0.8. From Figure 8, using the same crude interpolation gives a FcHc=~0.7 at the surface and ~0.75 at the deepest point.

$Q := 1 + 1.464 \cdot \left(\frac{a}{c}\right)^{1.65}$ $\qquad Q = 1.099$

Remote bending stress is given as: $Sb = \frac{6 \cdot M}{b \cdot t^2} \cdot psi$ $Sb := \frac{6 \cdot M}{4 \cdot 2.5^2} \cdot \frac{lb}{in^2}$ $Sb = 1584 \cdot \frac{lb}{in^2}$

Remote tension stress is given as: $St = \frac{P}{2 \cdot b \cdot t}$ $St := \frac{P}{2.5 \cdot 8} \cdot \frac{lb}{in^2}$ $St = 62.5 \cdot \frac{lb}{in^2}$

$Ksurface := (St \cdot 0.8 + 0.75 \cdot Sb) \cdot 2.4 \sqrt{\pi \cdot \frac{a}{Q}}$ $Ksurface = 5528 \cdot \frac{lb}{in^2} \cdot in^{0.5}$

$Kdeep := (St \cdot 1.7 + 0.7 \cdot Sb) \cdot 2.4 \sqrt{\pi \cdot \frac{a}{Q}}$ $Kdeep = 5425 \cdot \frac{lb}{in^2} \cdot in^{0.5}$

Note that the corner crack case gives a KI that is ~10 smaller than the edge crack (5 versus 50). This solution does not consider torsional loading or shear and may be at the edges of the applicability of c/b; however, it gives an estimate of the benefit of more accurately treating the corner crack configuration.

For Axial orientation (i.e. longitudinal axis of RPV)

$a := \begin{pmatrix} 1 \\ 1.684 \\ 2.5 \\ 3.444 \end{pmatrix}$ in Range of crack sizes evaluated

$W := 8$ in

$b := W$

$A := \frac{a}{W}$ $A = \begin{pmatrix} 0.125 \\ 0.211 \\ 0.313 \\ 0.43 \end{pmatrix}$

$\tau := \frac{18750}{2.5 \cdot 8}$ $\tau = 937.5$

$\tau 1 := \frac{(16250 \cdot 1 + 18750 \cdot 2.5) \cdot \left(1.25^2 + 4^2\right)^{0.5}}{\frac{1}{12} \cdot \left(8 \cdot 2.5^3 + 2.5 \cdot 8^3\right)}$ $\tau 1 = 2259$

$$FII_i := \frac{1.122 - 0.561\cdot\left(\frac{a_i}{b}\right) + 0.085\cdot\left(\frac{a_i}{b}\right)^2 + 0.180\cdot\left(\frac{a_i}{b}\right)^3}{\sqrt{1 - \frac{a_i}{b}}}$$

$$FII = \begin{pmatrix} 1.126 \\ 1.136 \\ 1.158 \\ 1.207 \end{pmatrix}$$

$$KII\_1_i := 2.4\tau\cdot\sqrt{\pi\, a_i}\cdot FII_i$$

$$KII\_1 = \begin{pmatrix} 4492 \\ 5879 \\ 7304 \\ 8930 \end{pmatrix}$$

$$FIII_i := \sqrt{\frac{2\cdot b}{\pi\, a_i}\cdot \tan\left(\frac{\pi\, a_i}{2\cdot b}\right)}$$

$$FIII = \begin{pmatrix} 1.007 \\ 1.019 \\ 1.044 \\ 1.089 \end{pmatrix}$$

$$KIII_i := 2.4\tau 1\cdot\sqrt{\pi\, a_i}\cdot FIII_i$$

$$KIII = \begin{pmatrix} 9674 \\ 12708 \\ 15858 \\ 19430 \end{pmatrix}$$

$$\sigma := \frac{1000\cdot\frac{213.44}{2}}{2\cdot 7.125}$$ (Pressure stress) $\sigma = 7489$ psi

$$P := \frac{10000}{2.5}$$ (Force per unit thickness) $P = 4000$ $\frac{lb}{in}$

$$M := \frac{9750\cdot 5.5 + 18750\cdot 2.25 + 3250\cdot 1}{2.5}$$ (Moment per unit thickness) $M = 39625$ $\frac{lb - in}{in}$

$$FI\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.018 + 0.069\cdot e^{-12.5\cdot\left(\frac{A_i}{1-A_i}\right)}\right]$$

$$FI\sigma = \begin{pmatrix} 0.078 \\ 0.04 \\ 0.027 \\ 0.021 \end{pmatrix}$$

$$FII\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.156 - 0.067\cdot e^{-8.9\cdot\left(\frac{A_i}{1-A_i}\right)}\right]$$

$$FII\sigma = \begin{pmatrix} 0.363 \\ 0.29 \\ 0.23 \\ 0.179 \end{pmatrix}$$

$$FIp_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[0.379 + 0.624\cdot A_i - 0.062\cdot e^{-12\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIp = \begin{pmatrix} 1.541 \\ 1.578 \\ 1.8 \\ 2.297 \end{pmatrix}$$

$$FIIp_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[0.126 - 0.24\cdot A_i - 0.023\cdot(1-A_i)^5\right] \qquad FIIp = \begin{pmatrix} 0.291 \\ 0.213 \\ 0.149 \\ 0.076 \end{pmatrix}$$

$$FIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[2.005 - 0.72\cdot e^{-9\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIm = \begin{pmatrix} 6.241 \\ 6.027 \\ 6.254 \\ 7.107 \end{pmatrix}$$

$$FIIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[-0.228 + (1-A_i)^4\cdot\left[0.577 - 0.2A_i + 0.8(A_i)^2\right]\right] \qquad FIIm = \begin{pmatrix} 0.356 \\ -0.02 \\ -0.3 \\ -0.57 \end{pmatrix}$$

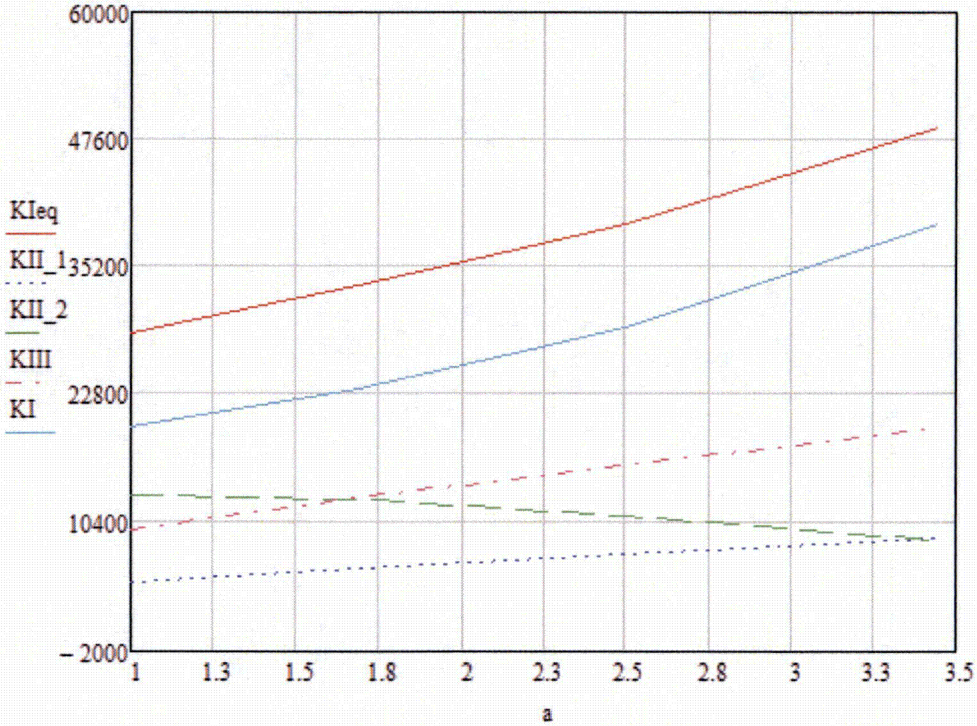
$$KI_i := \sqrt{\pi\cdot a_i}\cdot\left(2.4\sigma\cdot FI\sigma_i + \frac{2.4P}{W}\cdot FIp_i + \frac{2.0M}{W^2}\cdot FIm_i\right) \qquad KI = \begin{pmatrix} 19467 \\ 23158 \\ 29121 \\ 39239 \end{pmatrix} \ psi\cdot\sqrt{in}$$

$$KII\_2_i := \sqrt{\pi\cdot a_i}\cdot\left(2.4\sigma\cdot FII\sigma_i + \frac{2.4P}{W}\cdot FIIp_i + \frac{2.0M}{W^2}\cdot FIIm_i\right) \qquad KII\_2 = \begin{pmatrix} 12965 \\ 12520 \\ 11027 \\ 8579 \end{pmatrix} \ psi\cdot\sqrt{in}$$

An equivalent KI may be given by:

$\upsilon := 0.3$

$$KIeq_i := \left[(KI_i)^2 + (KII\_1_i + KII\_2_i)^2 + \frac{1}{1-\upsilon}\cdot(KIII_i)^2\right]^{0.5} \qquad KIeq = \begin{pmatrix} 28590 \\ 33249 \\ 39285 \\ 48843 \end{pmatrix} \ psi\cdot\sqrt{in}$$



Since Bracket B has through wall flaws on top and bottom, assume top flaw area is removed for shear stress calculation.

$W := 6.596$ in

$b := W$

$A := \frac{a}{W}$ $\qquad A = \begin{pmatrix} 0.152 \\ 0.255 \\ 0.379 \\ 0.522 \end{pmatrix}$

$\tau := \frac{18750}{2.5 \cdot 6.596}$ $\qquad \tau = 1.137 \times 10^3$

$\tau 1 := \frac{(16250 \cdot 1 + 18750 \cdot 2.5) \cdot \left(1.25^2 + 4^2\right)^{0.5}}{\frac{1}{12} \cdot \left(6.596 \cdot 2.5^3 + 2.5 \cdot 6.596^3\right)}$ $\qquad \tau 1 = 3869$

$$FII_i := \frac{1.122 - 0.561\cdot\left(\frac{a_i}{b}\right) + 0.085\cdot\left(\frac{a_i}{b}\right)^2 + 0.180\cdot\left(\frac{a_i}{b}\right)^3}{\sqrt{1 - \frac{a_i}{b}}} \qquad FII = \begin{pmatrix}1.129\\1.144\\1.182\\1.27\end{pmatrix}$$

$$KII\_1_i := 2.4\tau\cdot\sqrt{\pi\, a_i}\cdot FII_i \qquad KII\_1 = \begin{pmatrix}5459\\7181\\9039\\11399\end{pmatrix}$$

$$FIII_i := \sqrt{\frac{2\cdot b}{\pi\, a_i}\cdot\tan\left(\frac{\pi\, a_i}{2\cdot b}\right)} \qquad FIII = \begin{pmatrix}1.01\\1.028\\1.067\\1.143\end{pmatrix}$$

$$KIII_i := 2.4\tau 1\cdot\sqrt{\pi\, a_i}\cdot FIII_i \qquad KIII = \begin{pmatrix}16617\\21961\\27757\\34920\end{pmatrix}$$

$$\sigma := \frac{1000\cdot\frac{213.44}{2}}{2\cdot 7.125}$$ (Pressure stress) $\sigma = 7489$ psi

$$P := \frac{10000}{2.5}$$ (Force per unit thickness) $P = 4000$ $\frac{lb}{in}$

$$M := \frac{9750\cdot 5.5 + 15000\cdot 2.25 + 3250\cdot 1}{2.5}$$ (Moment per unit thickness) $M = 36250$ $\frac{lb - in}{in}$

$$FI\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.018 + 0.069\cdot e^{-12.5\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FI\sigma = \begin{pmatrix}0.06\\0.032\\0.023\\0.017\end{pmatrix}$$

$$FII\sigma_i := \sqrt{\frac{1 - A_i}{A_i}}\cdot\left[0.156 - 0.067\cdot e^{-8.9\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FII\sigma = \begin{pmatrix}0.337\\0.261\\0.199\\0.149\end{pmatrix}$$

$$FIp_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[0.379 + 0.624\cdot A_i - 0.062\cdot e^{-12\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIp = \begin{pmatrix}1.533\\1.655\\2.043\\2.953\end{pmatrix}$$

$$FIIp_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[0.126 - 0.24\cdot A_i - 0.023\cdot(1-A_i)^5\right] \qquad FIIp = \begin{pmatrix}0.261\\0.183\\0.109\\4.799\times10^{-4}\end{pmatrix}$$

$$FIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[2.005 - 0.72\cdot e^{-9\cdot\left(\frac{A_i}{1-A_i}\right)}\right] \qquad FIm = \begin{pmatrix}6.116\\6.073\\6.645\\8.4\end{pmatrix}$$

$$FIIm_i := \frac{1}{\sqrt{A_i}\cdot(1-A_i)^{\frac{3}{2}}}\cdot\left[-0.228 + (1-A_i)^4\cdot\left[0.577 - 0.2A_i + 0.8(A_i)^2\right]\right] \qquad FIIm = \begin{pmatrix}0.213\\-0.155\\-0.453\\-0.804\end{pmatrix}$$

$$KI_i := \sqrt{\pi\cdot a_i}\cdot\left(2.4\sigma\cdot FI\sigma_i + \frac{2.4P}{W}\cdot FIp_i + \frac{2.0M}{W^2}\cdot FIm_i\right) \qquad KI = \begin{pmatrix}23931\\30156\\40530\\61194\end{pmatrix}\ psi\cdot\sqrt{in}$$

$$KII\_2_i := \sqrt{\pi\cdot a_i}\cdot\left(2.4\sigma\cdot FII\sigma_i + \frac{2.4P}{W}\cdot FIIp_i + \frac{2.0M}{W^2}\cdot FIIm_i\right) \qquad KII\_2 = \begin{pmatrix}12030\\10811\\8371\\4417\end{pmatrix}\ psi\cdot\sqrt{in}$$

An equivalent KI may be given by:

$$\upsilon := 0.3$$

$$KIeq_i := \left[(KI_i)^2 + (KII\_1_i + KII\_2_i)^2 + \frac{1}{1-\upsilon}\cdot(KIII_i)^2\right]^{0.5} \qquad KIeq = \begin{pmatrix}35679\\43842\\55194\\75743\end{pmatrix}\ psi\cdot\sqrt{in}$$

The static fracture toughness for unirradiated stainless steel is taken from BWRVIP-76 as 150 ksi-in^0.5. The required structural factors for Level A/B conditions have already been accounted for in the equations above. Therefore, the allowable fracture toughness for stainless steel is given as:

$$KI\_allowable := 150 \quad ksi \cdot in^{0.5}$$

Considering a flaw oriented on either axis of the support bracket the applied stress intensity factor is less than the allowable fracture toughness.

Attachment 3

EPRI affidavit to request withholding of proprietary information contained in "Nine Mile Point Unit 1 Steam Dryer Support Bracket Flaw Evaluation – 2014"

Attachment 1

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

NEIL WILMSHURST
Vice President and
Chief Nuclear Officer

Ref. EPRI Project Number 669

May 19, 2015

Document Control Desk
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Request for Withholding of the following Proprietary Information Included in:

"Nine Mile Point Unit 1 Steam Dryer Support Bracket Flaw Evaluation-2014" included in Structural Integrity Associates, Inc. Report on Project "NMP1 Steam Dryer Support Bracket Flaw Evaluation" for Plant Nine Mile Point Nuclear Station, Unit 1. File No: 1400734.301

To Whom It May Concern:

This is a request under 10 C.F.R. §2.390(a)(4) that the U.S. Nuclear Regulatory Commission ("NRC") withhold from public disclosure the report identified in the enclosed Affidavit consisting of the proprietary information owned by Electric Power Research Institute, Inc. ("EPRI") identified in the attached report. Proprietary and non-proprietary versions of the Report and the Affidavit in support of this request are enclosed.

EPRI desires to disclose the Proprietary Information in confidence to assist the NRC review of the enclosed submittal to the NRC by Exelon. The Proprietary Information is not to be divulged to anyone outside of the NRC or to any of its contractors, nor shall any copies be made of the Proprietary Information provided herein. EPRI welcomes any discussions and/or questions relating to the information enclosed.

If you have any questions about the legal aspects of this request for withholding, please do not hesitate to contact me at (704) 595-2732. Questions on the content of the Report should be directed to Andy McGehee of EPRI at (704) 502-6440.

Sincerely,

Attachment(s)
c: Sheldon Stuchell, NRC (sheldon.stuchell@nrc.gov)

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

AFFIDAVIT

RE: Request for Withholding of the Following Proprietary Information Included In:

"Nine Mile Point Unit 1 Steam Dryer Support Bracket Flaw Evaluation-2014" included in Structural Integrity Associates, Inc. Report on Project "NMP1 Steam Dryer Support Bracket Flaw Evaluation" for Plant Nine Mile Point Nuclear Station, Unit 1. File No: 1400734.301

I, Neil Wilmshurst, being duly sworn, depose and state as follows:

I am the Vice President and Chief Nuclear Officer at Electric Power Research Institute, Inc. whose principal office is located at 1300 W WT Harris Blvd, Charlotte, NC. ("EPRI") and I have been specifically delegated responsibility for the above-listed report that contains EPRI Proprietary Information that is sought under this Affidavit to be withheld "Proprietary Information". I am authorized to apply to the U.S. Nuclear Regulatory Commission ("NRC") for the withholding of the Proprietary Information on behalf of EPRI.

EPRI Proprietary Information is identified in the above referenced report by double brackets. An example of such identification is as follows:

{{This sentence is an example.{E}}}

Tables containing EPRI Proprietary Information are identified with double brackets before and after the object. In each case, the superscript notation {E} refers to this affidavit as the basis for the proprietary determination.

EPRI requests that the Proprietary Information be withheld from the public on the following bases:

Withholding Based Upon Privileged And Confidential Trade Secrets Or Commercial Or Financial Information (see e.g., 10 C.F.R. § 2.390(a)(4):

a. The Proprietary Information is owned by EPRI and has been held in confidence by EPRI. All entities accepting copies of the Proprietary Information do so subject to written agreements imposing an obligation upon the recipient to maintain the confidentiality of the Proprietary Information. The Proprietary Information is disclosed only to parties who agree, in writing, to preserve the confidentiality thereof.

b. EPRI considers the Proprietary Information contained therein to constitute trade secrets of EPRI. As such, EPRI holds the Information in confidence and disclosure thereof is strictly limited to individuals and entities who have agreed, in writing, to maintain the confidentiality of the Information.

c. The information sought to be withheld is considered to be proprietary for the following reasons. EPRI made a substantial economic investment to develop the Proprietary Information and, by prohibiting public disclosure, EPRI derives an economic benefit in the form of licensing royalties and other additional fees from the confidential nature of the Proprietary Information. If the Proprietary Information were publicly available to consultants and/or other businesses providing services in the electric and/or nuclear power industry, they would be able to use the Proprietary Information for their own commercial benefit and profit and without expending the substantial economic resources required of EPRI to develop the Proprietary Information.

d. EPRI's classification of the Proprietary Information as trade secrets is justified by the Uniform Trade Secrets Act which California adopted in 1984 and a version of which has been adopted by over

forty states. The California Uniform Trade Secrets Act, California Civil Code §§3426 – 3426.11, defines a "trade secret" as follows:

> "'Trade secret' means information, including a formula, pattern, compilation, program device, method, technique, or process, that:
>
> (1) Derives independent economic value, actual or potential, from not being generally known to the public or to other persons who can obtain economic value from its disclosure or use; and
>
> (2) Is the subject of efforts that are reasonable under the circumstances to maintain its secrecy."

e. The Proprietary Information contained therein are not generally known or available to the public. EPRI developed the Information only after making a determination that the Proprietary Information was not available from public sources. EPRI made a substantial investment of both money and employee hours in the development of the Proprietary Information. EPRI was required to devote these resources and effort to derive the Proprietary Information. As a result of such effort and cost, both in terms of dollars spent and dedicated employee time, the Proprietary Information is highly valuable to EPRI.

f. A public disclosure of the Proprietary Information would be highly likely to cause substantial harm to EPRI's competitive position and the ability of EPRI to license the Proprietary Information both domestically and internationally. The Proprietary Information can only be acquired and/or duplicated by others using an equivalent investment of time and effort.

I have read the foregoing and the matters stated herein are true and correct to the best of my knowledge, information and belief. I make this affidavit under penalty of perjury under the laws of the United States of America and under the laws of the State of North Carolina.

Executed at 1300 W WT Harris Blvd being the premises and place of business of Electric Power Research Institute, Inc.

Date: 5-19-2015

[signature]

Neil Wilmshurst

(State of North Carolina)
(County of Mecklenburg)

Subscribed and sworn to (or affirmed) before me on this 19th day of May, 2015 by Neil Wilmshurst, proved to me on the basis of satisfactory evidence to be the person(s) who appeared before me.

Signature Deborah A. Rouse (Seal)

My Commission Expires 2nd day of April, 2016