Attachment 2

Responses to Request for Additional Information Questions

Entergy Nuclear Operations, Inc., (ENO) previously submitted the 10 CFR 50 Appendix G equivalent margins analysis (EMA) in Reference A below under 10 CFR 50.4, as discussed in the Detailed Description section in Attachment 1 of this submittal. In Reference B, ENO received a request for additional information (RAI) concerning the EMA submittal that contained six questions. The ENO responses to RAI questions 1, 3, 4, 5, and 6 were provided in Reference C. The ENO response to RAI question 2 was provided in Reference D.

A. Entergy Nuclear Operations, Inc. letter PNP 2013-028, *Palisades Nuclear Plant 10 CFR 50 Appendix G Equivalent Margins Analysis*, dated October 21, 2013 (ADAMS Accession No. ML13295A448).

B. NRC email to Entergy Nuclear Operations, Inc., *Request for Additional Information - Palisades Nuclear Plant 10 CFR 50 Appendix G Equivalent Margin Analysis - MF 2962*, dated May 13, 2014 (ADAMS Accession No. ML14133A684).

C. Entergy Nuclear Operations, Inc. letter PNP 2014-054, *Response to NRC Request for Additional Information - Palisades Nuclear Plant 10 CFR 50 Appendix G Equivalent Margin Analysis – MF 2962*, dated June 12, 2014 (ADAMS Accession No. ML14163A662).

D. Entergy Nuclear Operations, Inc. letter PNP 2014-066, Supplemental Response to NRC Request for Additional Information - Palisades Nuclear Plant 10 CFR 50 Appendix G Equivalent Margin Analysis – MF 2962, dated June 26, 2014 (ADAMS Accession No. ML14177A707).

The ENO responses to the six RAI questions are repeated below.

NRC Request (May 13, 2014)

1. *The EMA is based on American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) Section XI, Appendix K as supplemented by Regulatory Guide (RG) 1.161 "Evaluation of Reactor Pressure Vessels with Charpy Upper-Shelf Energy Less Than 50 Ft-Lb". ASME Code Section XI, Appendix K, Article K-4210 and RG 1.161 both include equations for calculating the stress intensity factor due to radial thermal gradients. In Section 5.1 of the EMA submittal, the licensee discusses through-wall thermal stress and states that typical through-wall stress and stress distribution during a heatup transient are shown in Figures 5-1 and 5-2. But Figures 5-1 and 5-2 of the EMA submittal do not show these stresses as discussed. Provide figures showing typical through-wall stress and stress distributions during a heatup transient to support the discussion in paragraph 5.1 of the EMA submittal.*

ENO Response to RAI-1

Figures detailing typical heatup thermal axial stress and typical through-wall axial stress for the PNP reactor vessel used in the equivalent margins analysis (EMA) submittal are provided below.

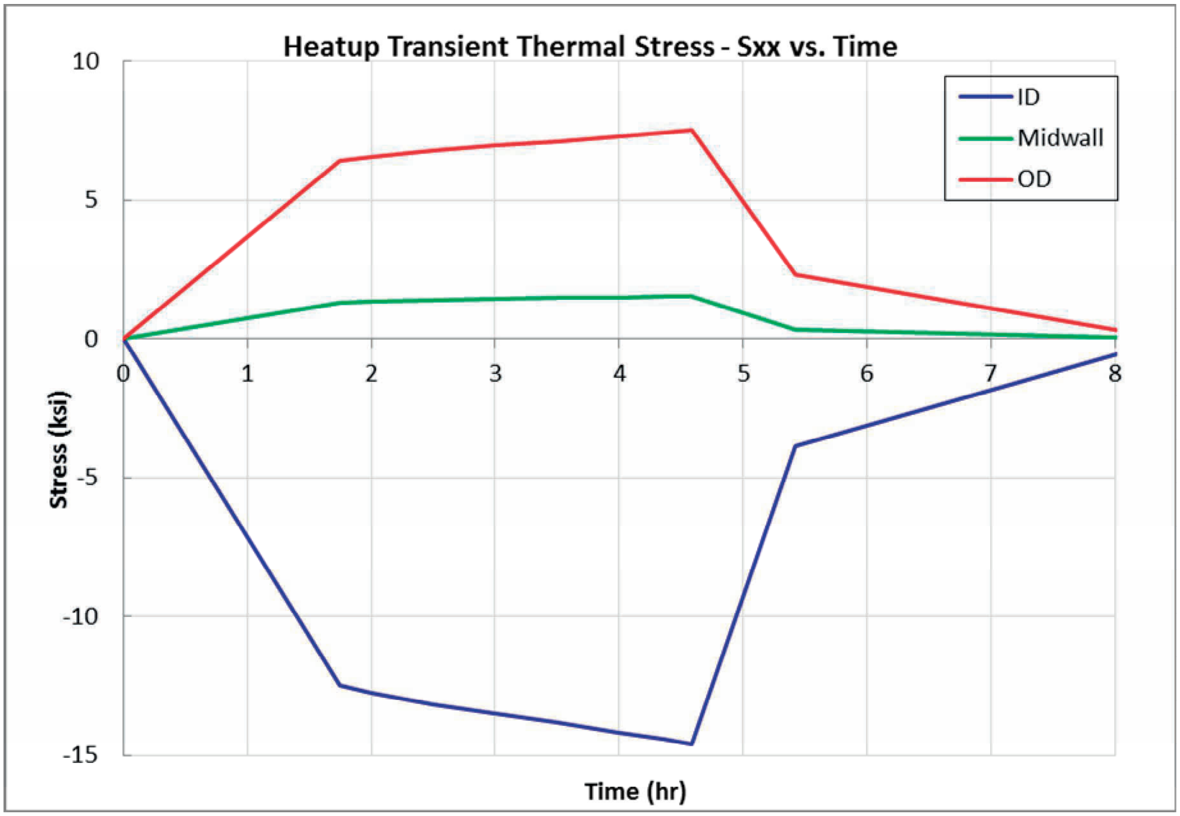


Figure 5-1(a) - PNP Typical Thermal Transient Axial Stress Profile – Stress versus Time

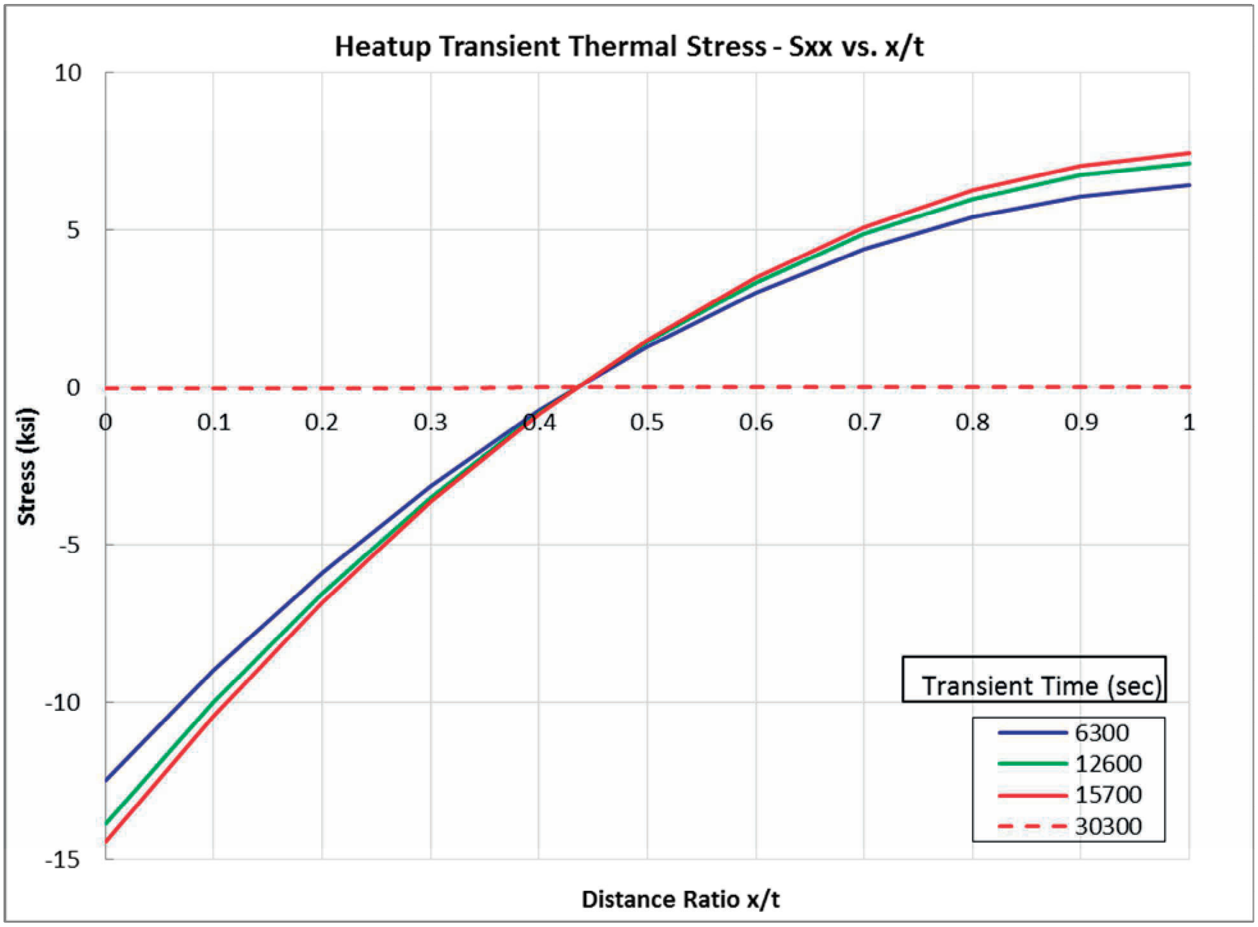


Figure 5-2(a) - PNP Typical Thermal Transient Axial Through-Wall Stress Distribution

NRC Request (May 13, 2014)

2. Section 5.1 states, "Only circumferential base metal flaws are considered in this analysis, because only the "weak" orientation USE is projected to drop below 50 ft-lbs as described below." Please demonstrate that assuming a circumferential flaw in the base metal with the weak Charpy V-Notch (CVN) value in the EMA is more limiting than assuming an axial flaw in the base metal with the strong CVN value. Please note that the significantly greater applied J integral associated with the axial flaw may challenge the fundamental assumption in the EMA submittal.

ENO Response to RAI-2

As documented in WCAP-17651-NP, Revision 0, the PNP reactor vessel plates have sulfur content greater than the 0.018 wt-% value provided in Regulatory Guide 1.161 (Reference 1). Therefore, lower bound high-sulfur fracture toughness data from the V-50 plate included in NUREG/CR-5265 (Reference 7) was located, as documented in the WCAP, to provide justification for use of the J-R model included in Regulatory Guide 1.161.

However, since only transverse (T-L) direction, weak data, was available in this NUREG and since only the T-L upper-shelf energy (USE) dropped below 50 ft-lbs, only circumferential flaws were considered in the original WCAP submittal since there was no longitudinal (L-T) direction, strong data, for which to compare with the axial J-applied values for PNP. The ENO interpretation of Regulatory Guide 1.161 was that this was allowable and axial flaws did not need to be considered since the longitudinal final USE values of the PNP plate materials were over the 50 ft-lb limit of 10 CFR 50, Appendix G at end-of-license- extension (EOLE). However, per discussion during conference call between ENO and the NRC on June 6, 2014, axial flaws should still have been postulated, with longitudinal direction USE considered in the equivalent margins analysis.

Since the V-50 plate does not have L-T strong data reported in NUREG/CR-5265, the T-L data needs to be converted to L-T via an appropriate ratio to approximate the strong direction for direct comparison with axial flaws. The standard ratio is 65% per Regulatory Guide 1.161. Data was located in NUREG/CR-6426 (Reference 6), which had fracture toughness data for both orientations for five of the eight plate codes tested in this report. New Table 5-7 documents the material properties, initial USE values and available fracture toughness data for these materials. The average L-T/T-L fracture toughness conversion was 68% with consideration of all data, and 64% when the Z1/Z2 plate codes were excluded, as they appear to be an outlier compared to the other data points. Either calculated percent conversion supports the generic 65% conversion, which was then selected for use to ratio up the V-50 plate data to L-T orientation for comparison with axial flaw J-Applied values at PNP.

New Table 5-8 details the axial flaw safety factors for all transients, Levels A, B, C and D, with consideration of the Regulatory Guide 1.161 J-R model and limiting EOLE USE equal to 73 ft-lbs per WCAP-17651-NP. New Table 5-9 details the axial flaw safety factors for all transients, Levels A, B, C and D, with consideration of the V-50 plate data adjusted to the L-T orientation. New Figures 5-14 and 5-15 detail the applied J-Integral versus crack extension for axial flaws at 1/4t for Level A and B transients and applied J-Integral versus crack extension for axial flaws at 1/10t for Levels C and D transients, respectively. New Figure 5-16 details the axial flaw J-Integral versus crack extension at 1/4t for Level A and B transients for base metal with Regulatory Guide 1.161 model J-R curves and V-50 plate data included. New Figure 5-17 details the axial flaw J-Integral versus crack extension at 1/4t, pressure = 2.75 ksi, and a 100°F/hr cooldown transient for base metal with Regulatory Guide 1.161 model J-R curves and V-50 plate data included. Lastly, new Figure 5-18 details the axial flaw J-Integral versus crack extension at 1/10t for Levels C and

D transients, for base metal with Regulatory Guide 1.161 model J-R curves and V-50 plate data included.

It should be noted, as discussed in detail in WCAP-17651-NP, that the V-50 plate data has a lower weight percent Ni value (0.23 wt-%), due to being A 302 B steel, and not SA 302 B, Modified, that contribute to the V-50 plate having lower fracture toughness than the PNP-specific plate materials. The PNP plates are SA 302 B, Modified, which means that they have at least 0.4% Ni. Nickel was added to increase toughness. Conservatively, the lowest J-R curve test data reported in NUREG/CR-5265, which is from a 6T size specimen, is used for comparison to the J-Applied values. The 6T data is considerably lower than test data for the 1T J-R data, which is the standard size specimen typically used. Therefore, the V-50 plate 6T J-R data is a conservative lower bound, viewed as the worst possible case, and selected due to being the only available fracture toughness data with high-sulfur content.

The minimum safety factor with consideration of the Regulatory Guide 1.161 J-R model, L-T orientation USE values and the PNP-specific axial flaw J-Applied values is 1.7 while the minimum safety factor with relative to the V-50 plate data and the PNP-specific axial flaw J-applied values is 1.4 at 0.1-inch crack extension. All these cases have their structural factors above the minimum requirement of 1.15 per Regulatory Guide 1.161 and are deemed acceptable. The flaw extension figures demonstrate that the NRC Regulatory Guide 100°F/hr cooldown transient with the accumulation pressure levels governs the Level A and B transients, which is the limiting case. All cases, where the Regulatory Guide 1.161 J-R material correlation is considered with axial flaw J-Applied pressure loadings, are acceptable with the applied J-integral values at 0.1-inch crack extensions below the material J-resistance ($J_{0.1}$) as required by the ASME Code Appendix K. In some instances with consideration of the V-50 plate data adjusted to the L-T orientation, the J-Material curves, adjusted to transient temperature, are either slightly below or just over the J-applied values, specifically for the Regulatory Guide 1.161 100°F/hour cooldown transient. However, as discussed above, the V-50 data is a lower bound high-sulfur data set, that is not fully representative of the PNP actual plate materials, and this result can be considered acceptable with consideration of the associated Regulatory Guide 1.161 model, and the structural factor (SF) calculations shown in Tables 5-8 and 5-9. Finally, as discussed above, the Regulatory Guide 1.161 100°F/hour cooldown transient is more limiting than the PNP-specific transients, as shown in the comparison of J-Applied curves in Figures 5-16 and 5-17. Note that the Regulatory Guide 1.161 100°F/hour cooldown transient with pressure of 2.75 ksi is more conservative than PNP cooldown transient with pressure of 2.13 ksi.

Table 5-7: NUREG/CR-6426 L-T (Strong) vs. T-L (Weak) Charpy USE and Fracture Toughness Data

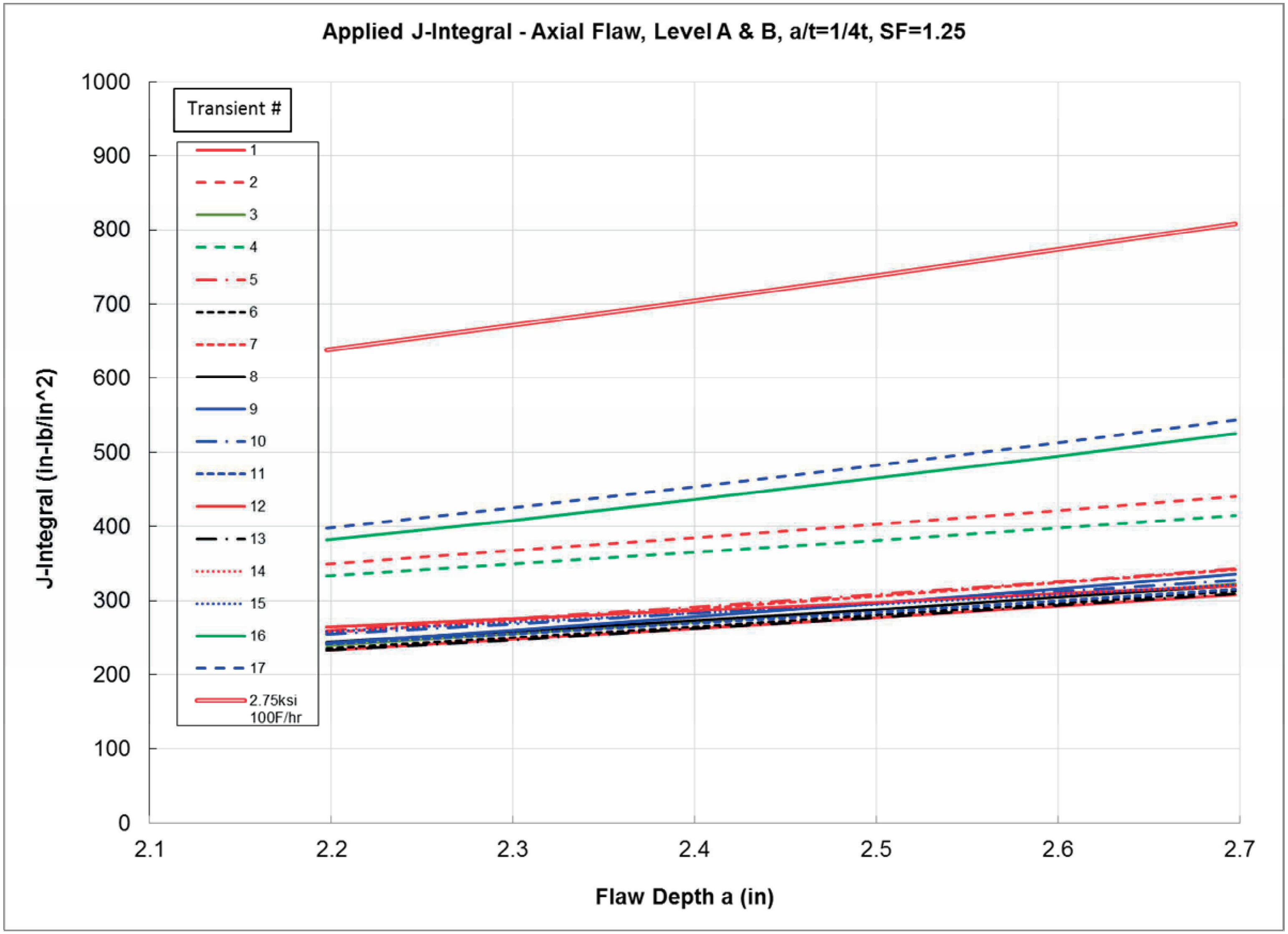
T= 180F	Plate Code	Chemistry			Initial USE (ft-lbs)		USE Ratio	$J_{0.1}$ (in/lb/in^2)		$J_{0.1}$ Ratio
		Cu	Ni	S	Longitudinal	Transverse		Longitudinal	Transverse	
Modified A302B	Z1, Z2	0.17	0.47	0.011	160	126	78.8%	3810	3300	86.6%
	Z5	0.16	0.60	0.016	153	95	62.1%	2640	1630	61.7%
	Z6A	0.18	0.49	0.013	129	113	87.6%	3570	2325	65.1%
	Z6B	0.21	0.51	0.023	117	64	54.7%	2360	1470	62.3%
	Z7	0.16	0.53	0.014	126	96	76.2%	4500	3000	66.7%
						Average (All)	71.9%		Average (All)	68.5%
						Average (Exclude Z1, Z2)	70.1%		Average (Exclude Z1, Z2)	64.0%

Table 5-8: Available Margins on Pressure Load for All Transients, Levels A, B, C and D, Axial Flaws

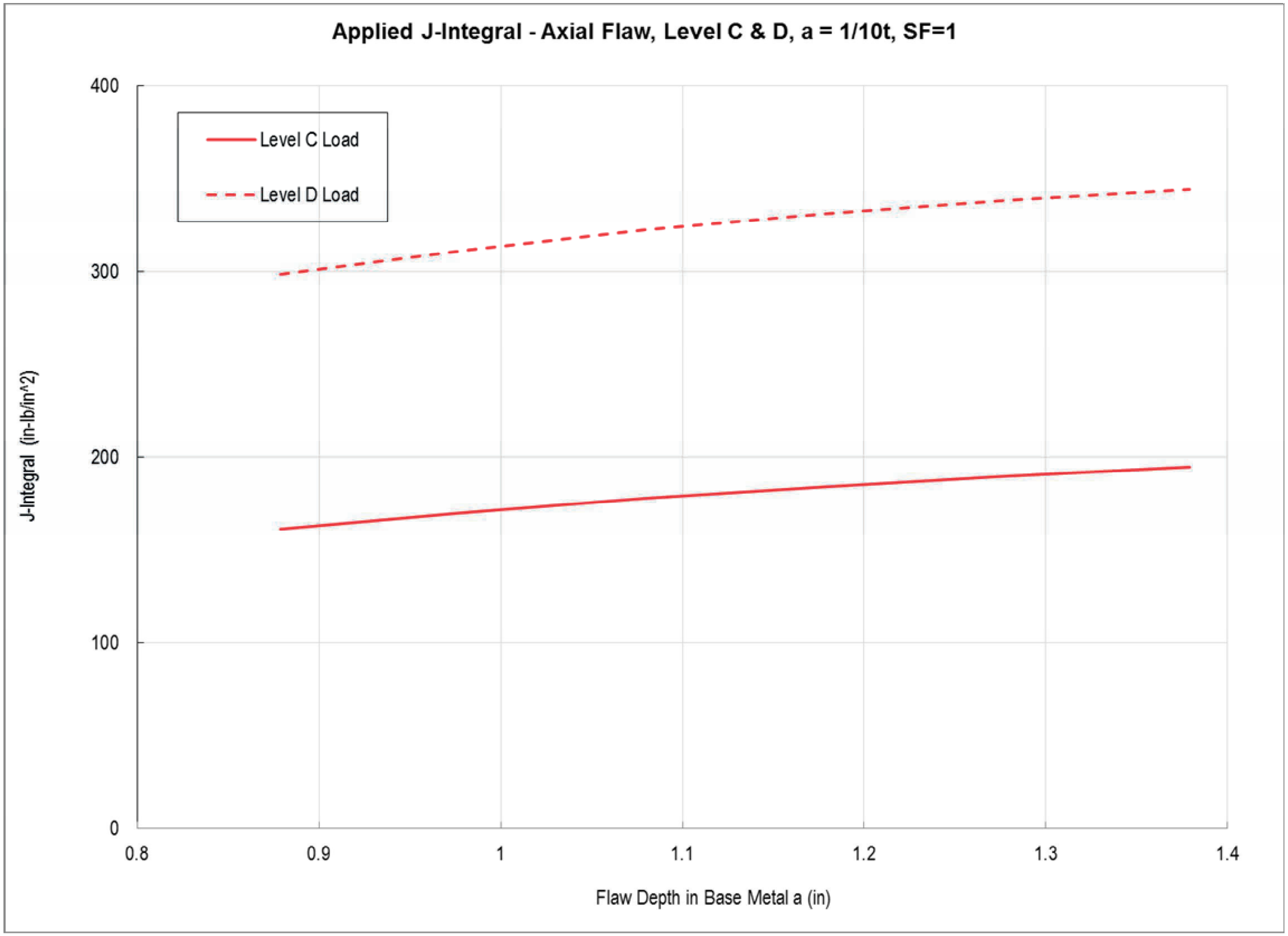
Level A and B	Base Metal – R. G. 1.161			Level C	Base Metal – R. G. 1.161			Level D	Base Metal – R. G. 1.161		
	Axial Flaw		$J_{0.1}$ material (in-lb/in^2)		Axial Flaw		$J_{0.1}$ material (in-lb/in^2)		Axial Flaw		$J_{0.1}$ material (in-lb/in^2)
Time (sec)	SF	J-applied x SF (in-lb/in^2)		Time (sec)	SF	J-applied x SF (in-lb/in^2)		Time (sec)	SF	J-applied x SF (in-lb/in^2)	
0	1.8	985	986	0	3.4	987	986	0	2.9	682	682
2800	1.7	1096	1096	1,197	5.0	1212	1213	798	4.1	831	830
3600	1.7	1138	1139	4,122	5.2	2218	2218	2,748	3.4	1490	1491
5400	1.7	1249	1249								
7200	1.8	1376	1376								
9000	1.9	1518	1518								
10800	18.5	1676	1676								
Minimum SF	**1.7**			Minimum SF	**3.4**			Minimum SF	**2.9**		

Table 5-9: Available Margins on Pressure Load for All Transients, Levels A, B, C and D, with Consideration of V-50 Plate Data and Axial Flaws

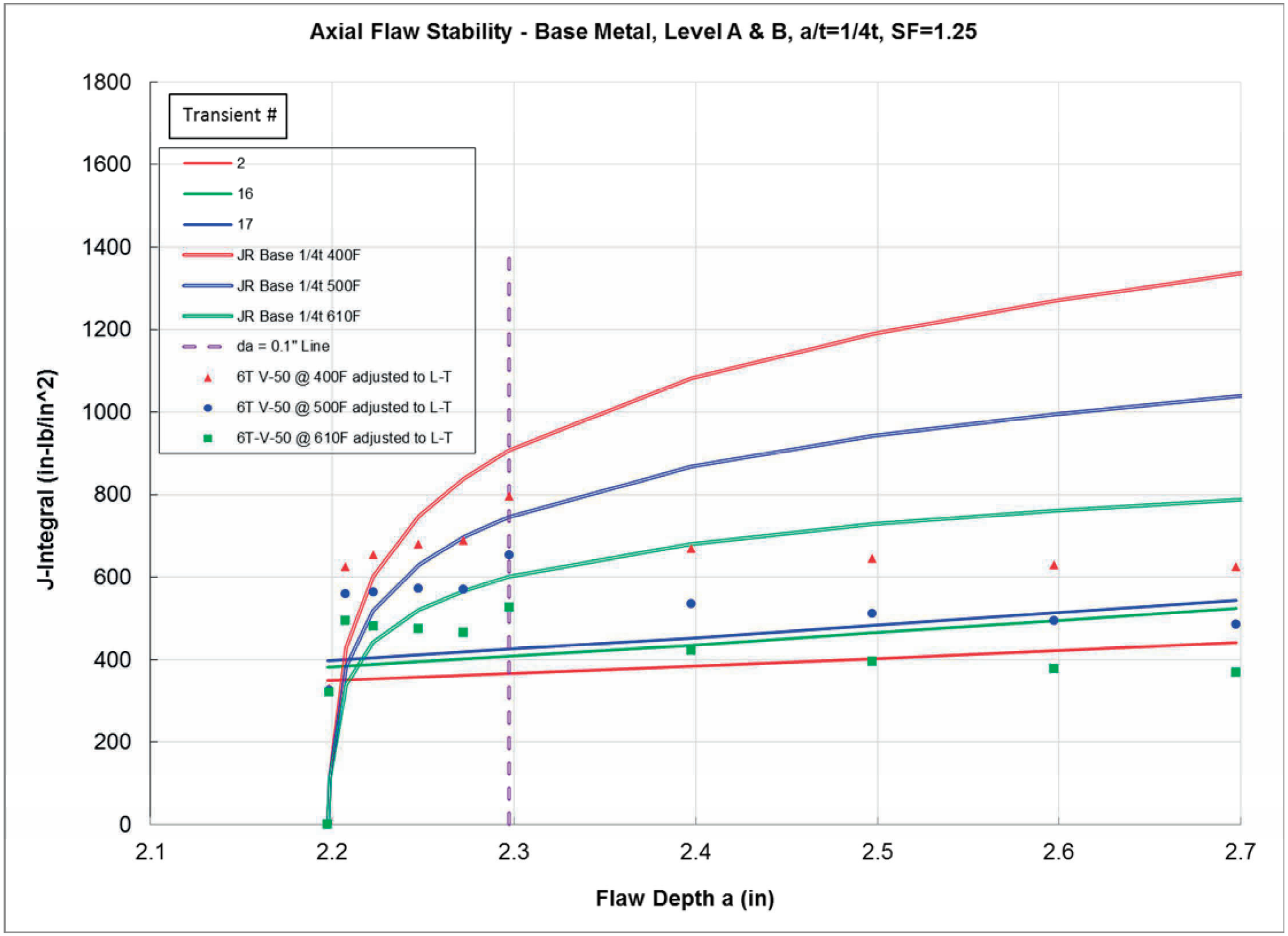
Level A and B	V-50 Plate			Level C	V-50 Plate			Level D	V-50 Plate		
	Axial Flaw		$J_{0.1}$ material ($in\text{-}lb/in^2$)		Axial Flaw		$J_{0.1}$ material ($in\text{-}lb/in^2$)		Axial Flaw		$J_{0.1}$ material ($in\text{-}lb/in^2$)
Time (sec)	SF	J-applied x SF ($in\text{-}lb/in^2$)		Time (sec)	SF	J-applied x SF ($in\text{-}lb/in^2$)		Time (sec)	SF	J-applied x SF ($in\text{-}lb/in^2$)	
0	1.5	611	611	0	2.8	611	611	0	2.8	611	611
2800	1.4	679	679	1,197	4.0	751	751	798	3.9	743	743
3600	1.4	706	706	4,122	4.0	1,374	1,374	2,748	3.1	1335	1,335
5400	1.4	774	774								
7200	1.5	853	853								
9000	1.5	941	941								
10800	15.0	1039	1039								
Minimum SF	**1.4**			Minimum SF	**2.8**			Minimum SF	**2.8**		



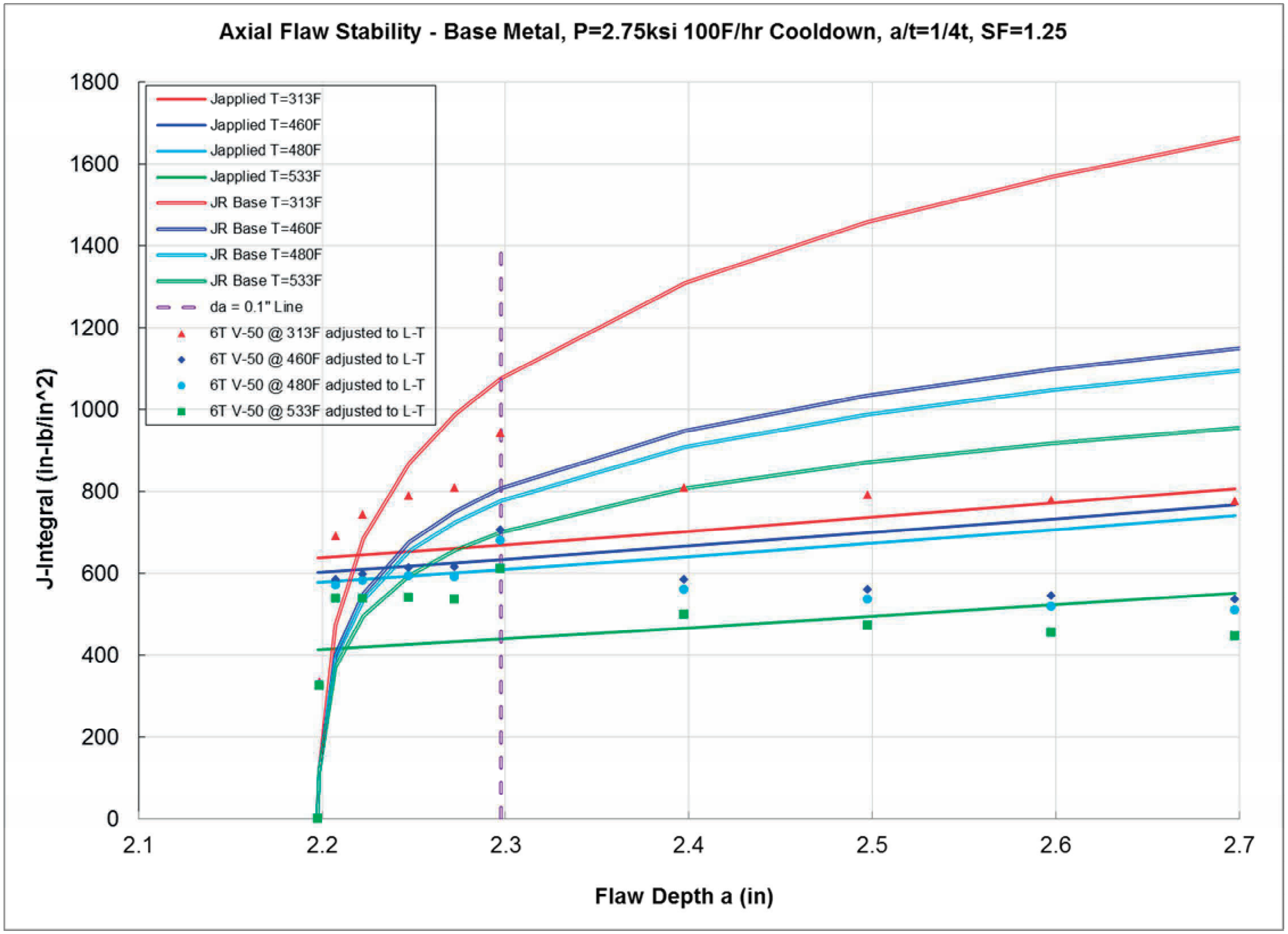
WCAP-17651-NP New Figure 5-14: Applied J-Integral versus Crack Extension for Axial Flaw – 1/4t, Level A and B



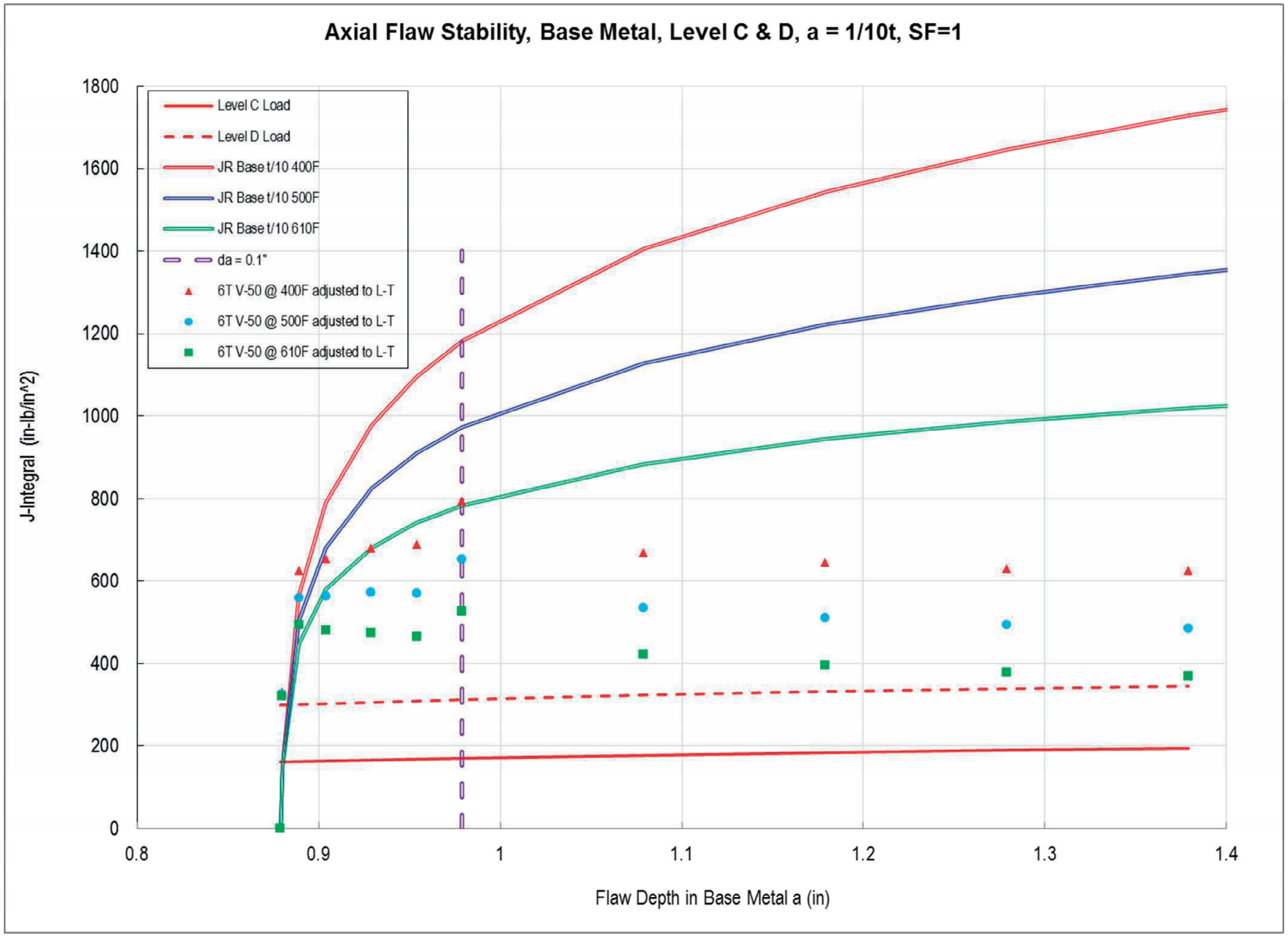
WCAP-17651-NP New Figure 5-15: Applied J-Integral versus Crack Extension for Axial Flaw – 1/10t, Levels C and D



WCAP-17651-NP New Figure 5-16: Axial Flaw J-Integral versus Crack Extension – t/4, Level A and B, Base Metal, with V-50 Plate Data Included



WCAP-17651-NP New Figure 5-17: Axial Flaw J-Integral versus Crack Extension – t/4, P=2.75 ksi, 100°F/hr Cooldown, Base Metal, with V-50 Plate Data Included



WCAP-17651-NP New Figure 5-18: Axial Flaw J-Integral versus Crack Extension – t/10, Levels C and D Loads, Base Metal, with V-50 Plate Data Included

NRC Request (May 13, 2014)

3. *The applied J-integral values for the circumferential flaws for all Level A and B service level conditions are shown in Figure 5-1, and the applied J-integral values for the circumferential flaws for Level C and D service level conditions are shown in Figure 5-2. Since Section 5.1 provides very limited information regarding the applied J-integral calculations, please confirm that the calculations underlying Figures 5-1 and 5-2 are based on the formulas in RG 1.161, "Evaluation of Reactor Pressure Vessels with Charpy Upper-Shelf Energy Less Than 50 FT-LB." If not, please describe, in addition to your response to RAI-1, your plant-specific calculations to support their acceptance in this application.*

ENO Response to RAI-3

Yes, the applied J-integral calculations underlying Figures 5-1 and 5-2 are based on formulas in RG 1.161.

NRC Request (May 13, 2014)

4. *Table 4-4 was presented but without being mentioned in Section 4 regarding how it was used in the EMA analysis. Therefore, please confirm that the calculated available margins presented in Table 5-3 for various time during cooldown are results, using the relevant J-R curves adjusted by the material margin factors of Table 4-4.*

ENO Response to RAI-4

As discussed in Section 2.2 of WCAP-17651-NP, "Palisades Nuclear Power Plant Reactor Vessel Equivalent Margins Analysis," Revision 0, RG 1.161 material margin factors (MF) in Table 4-4 were used for the J-R curves.

NRC Request (May 13, 2014)

5. *Section 5.2 provides justification for using the high-toughness/low-sulfur model from RG 1.161 in the proposed EMA for the high-sulfur plates, and Section 5.3 provides the corresponding EMA results. When the high-sulfur model (e.g., for the 6T specimen) of NUREG/CR-5265, "Size Effects on J-R Curves for A 302-B Plate," is used, please demonstrate that*

    - *The updated safety factors (see Table 5-3), after adjusting for temperature, will still be greater than 1.15.*

- *The updated applied J/J-R curves (see figures 5-8, 5-9, and 5-12), after adjusting for temperature, will still show that $dJ_{applied}/d_{\mathbf{a}} < dJ_{material}/d_{\mathbf{a}}$ at $J_{applied} = J_{material}$.*

If the above cannot be demonstrated, perform a sensitivity study, showing at what percentage of the proposed J-R curve (e.g., 90%), your EMA calculation results will meet the criteria on both crack extension and stability.

6. *Section 6 presents conclusions of this submittal. For Service Level C condition with 400°F/hr cooldown, it is concluded that, "The equivalent margins analyses for the plate materials are acceptable and bounded by the conservative test data reported in NUREG/CR-5265 in all cases for the Level C transient." This conclusion was repeated later for Service Level D condition with 600°F/hr cooldown, with "C" in the quote replaced by "D." Plot the relevant NUREG/CR 5265 6T data in Figure 5-12 and provide sufficient justification to support your conclusions.*

ENO Responses to RAI-5 and RAI-6

Updated Figures 5-9 and 5-12 with the V-50 plate data are provided below, along with added Tables 5-4 and 5-5 showing the Level C and D safety factors, respectively. Table 5-6 was added, which demonstrates the available margins on pressure loading with the V-50 plate data, adjusted for temperature, with consideration of all service loadings, Level A, B, C and D. The minimum safety factor (SF) with consideration of the V-50 plate data and the PNP-specific J-applied values is 1.5, which is above the minimum required SF of 1.15 per RG 1.161.

Figure 5-8 from WCAP-17651-NP, Revision 0, along with the updated Figures 5-9 and 5-12 below, all demonstrate that at $J_{applied} = J_{material}$, $dJ_{applied}/d_{\mathbf{a}} < dJ_{material}/d_{\mathbf{a}}$, is satisfied for all three cases (i.e., the slope of the $J_{applied}$ is smaller than the $J_{material}$ at the point of intersection).

Therefore, as demonstrated below and in WCAP-17651-NP, the equivalent margins of safety per ASME Code Section XI (References 4 and 5) are found to be acceptable for the PNP reactor vessel beltline and extended beltline regions with predicted Charpy upper-shelf energy levels falling below the 50 ft-lb 10 CFR 50, Appendix G requirements at end-of-license-extension.

Westinghouse discovered during the development of this RAI response that the Level C and D loading J-applied curves plotted in WCAP-17651-NP, Figure 5-12, were not the most limiting case. This error also propagated onto Figures 5-2 and 5-13 in the WCAP. This has been updated in the attached figures as part of this RAI response. Note that the conclusions to the report, including the safety factor determination, are unchanged; only the figures were in error. This has been documented in the Westinghouse corrective action system, and will be corrected when the WCAP is revised to incorporate these RAI changes.

Lastly, note that the Level C and D margin tables (Tables 5-4 and 5-5 below) were originally omitted from WCAP-17651-NP because Service Level A and B, as discussed in Section 5.3 of WCAP-17651-NP, are the governing transients.

Table 5-4 Available Margins on Pressure Load for Level C, 400°F/hr Cooldown

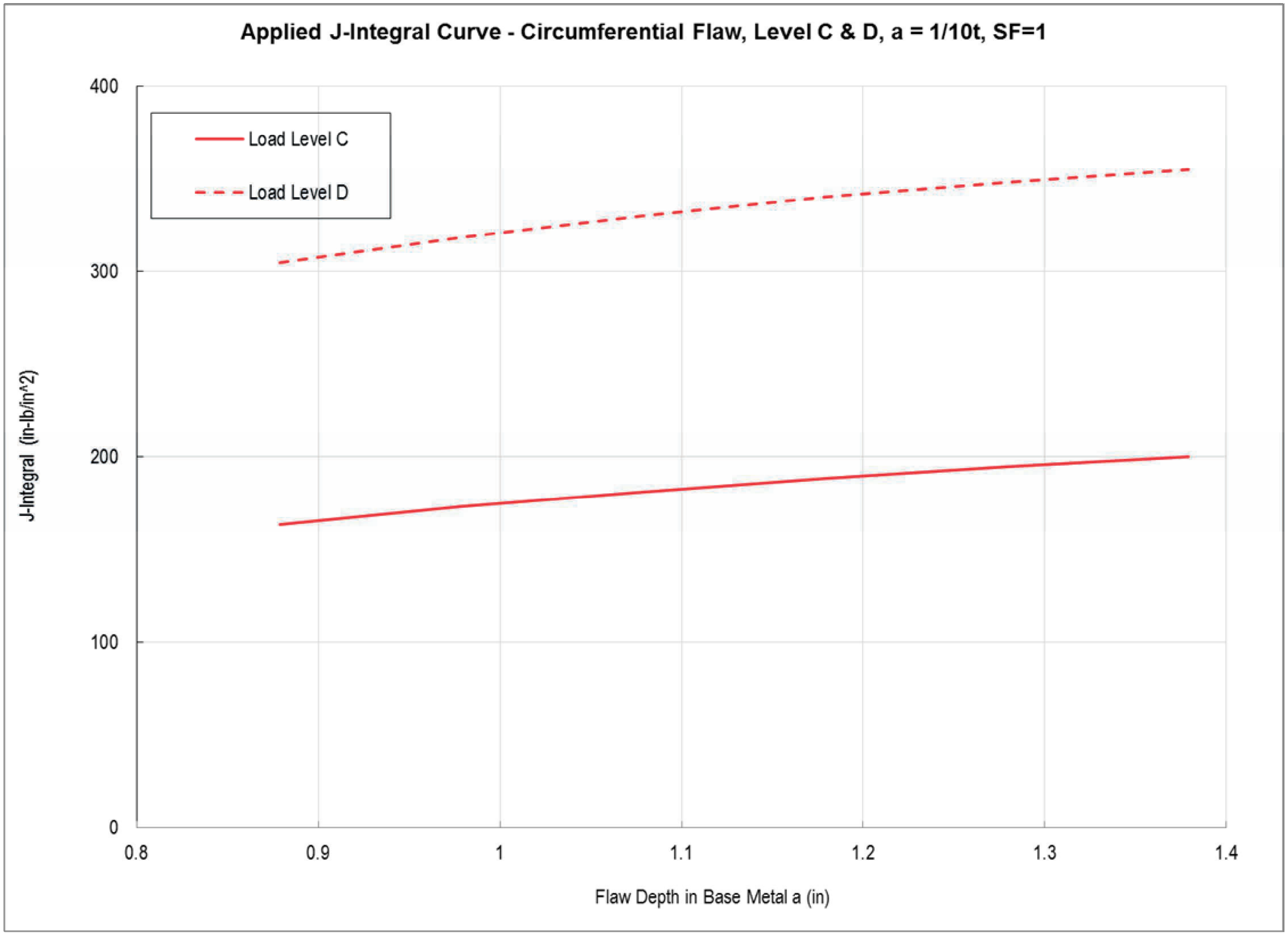
	Base Material			Weld Material		
	Circumferential Flaw			Circumferential Flaw		
Time (sec)	SF	J-applied x SF (in-lb/in^2)	$J_{0.1}$ material (in-lb/in^2)	SF	J-applied x SF (in-lb/in^2)	$J_{0.1}$ material (in-lb/in^2)
0	5.8	682	682	5.2	511	510
1,197	8.6	885	839	7.1	613	613
4,122	8.9	1,535	1,534	7.1	1,050	1,050
Minimum SF	**5.8**			**5.2**		

Table 5-5 Available Margins on Pressure Load for Level D, 600°F/hr Cooldown

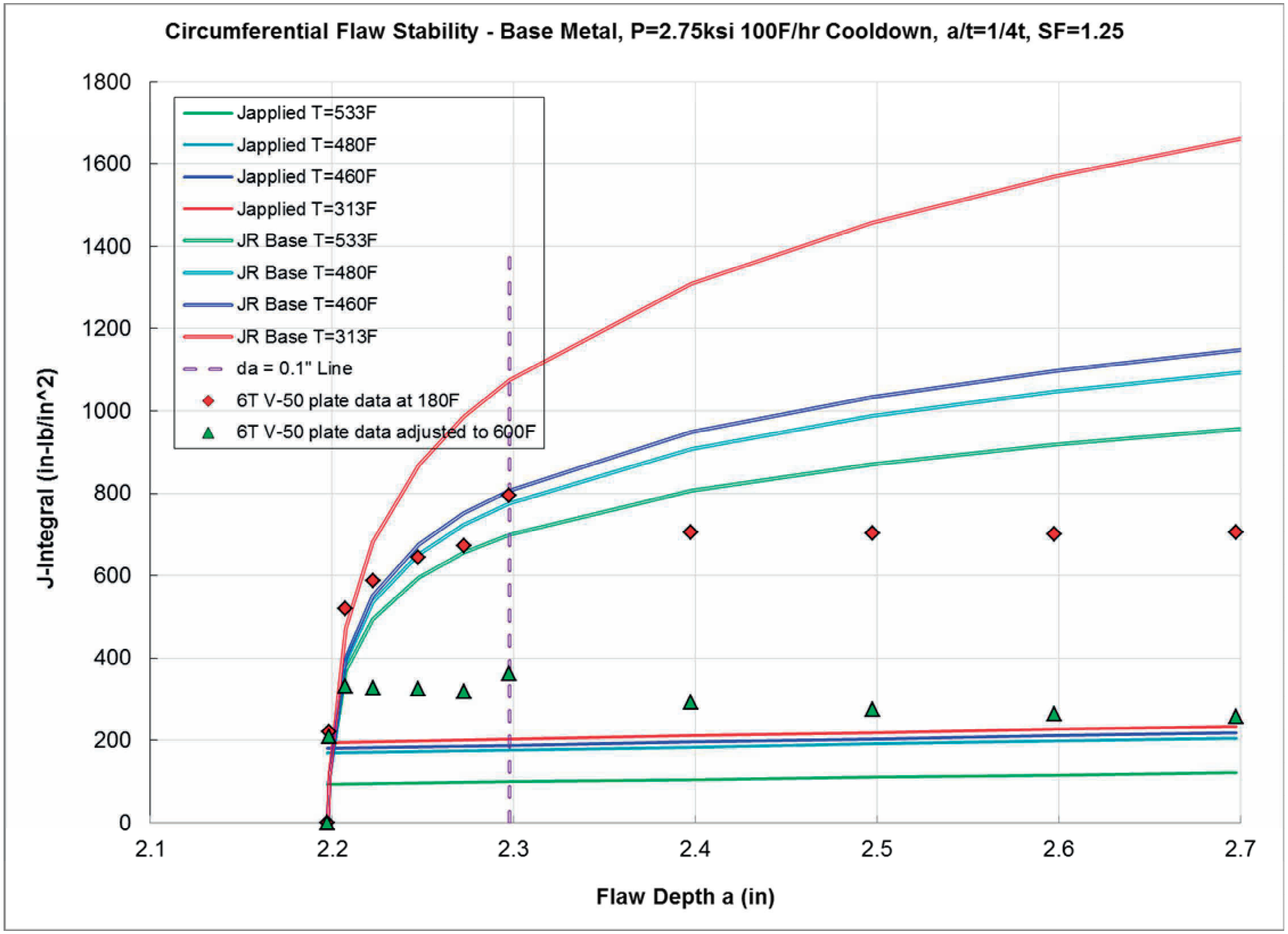
	Base Material			Weld Material		
	Circumferential Flaw			Circumferential Flaw		
Time (sec)	SF	J-applied x SF (in-lb/in^2)	$J_{0.1}$ material (in-lb/in^2)	SF	J-applied x SF (in-lb/in^2)	$J_{0.1}$ material (in-lb/in^2)
0	5.8	682	682	5.2	510	510
798	8.1	830	830	6.9	607	607
2,748	7.0	1,491	1,491	5.2	1,023	1,023
Minimum SF	**5.8**			**5.2**		

Table 5-6: Available Margins on Pressure Load for All Transients, Levels A, B, C and D, with Consideration of V-50 Plate Data

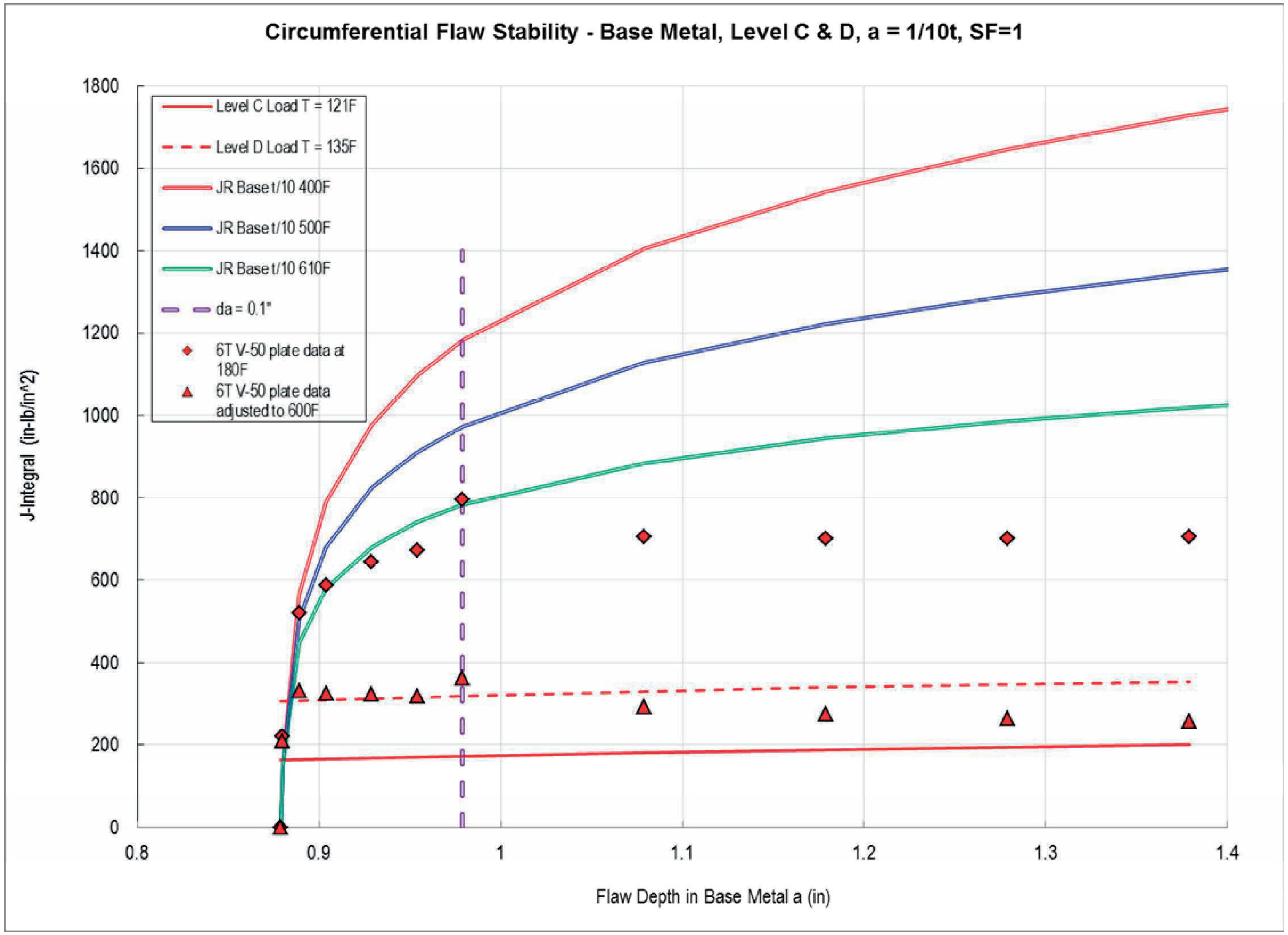
Level A and B	V-50 Plate			Level C	V-50 Plate			Level D	V-50 Plate		
	Circumferential Flaw		$J_{0.1}$ material ($in\text{-}lb/in^2$)		Circumferential Flaw		$J_{0.1}$ material ($in\text{-}lb/in^2$)		Circumferential Flaw		$J_{0.1}$ material ($in\text{-}lb/in^2$)
Time (sec)	SF	J-applied x SF ($in\text{-}lb/in^2$)		Time (sec)	SF	J-applied x SF ($in\text{-}lb/in^2$)		Time (sec)	SF	J-applied x SF ($in\text{-}lb/in^2$)	
0	**1.8**	397	397	0	3.4	397	397	0	3.4	397	397
2800	**1.6**	441	441	1,197	4.7	488	488	798	4.7	483	483
3600	**1.6**	459	459	4,122	1.9	893	893	2,748	1.5	868	868
5400	**1.7**	503	503								
7200	**1.8**	554	554								
9000	**1.9**	611	611								
10800	**18.0**	675	675								
Minimum SF	**1.6**			Minimum SF	**1.9**			Minimum SF	**1.5**		



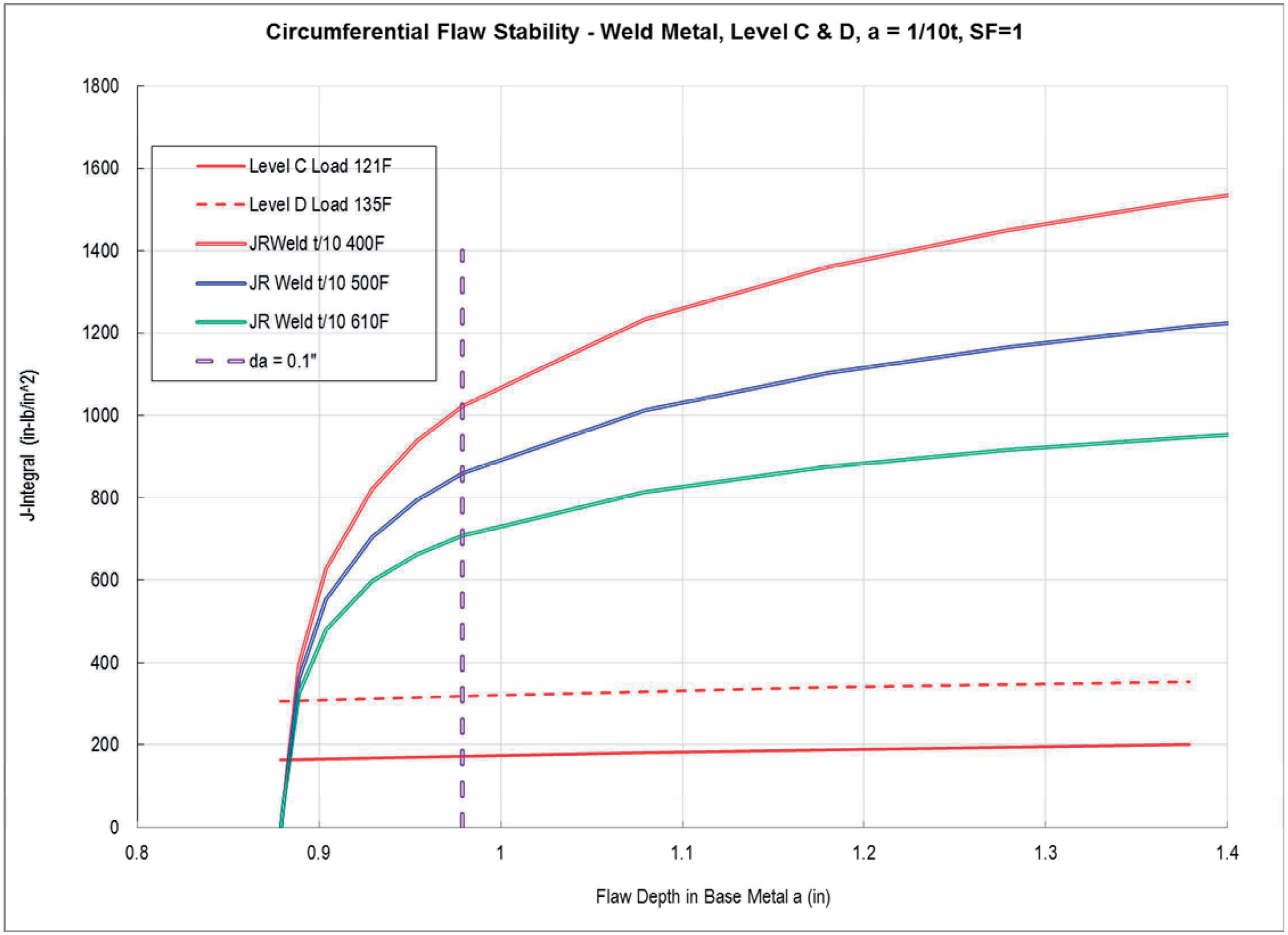
WCAP-17651-NP, Revision 0, Updated Figure 5-2 with Corrected, Limiting, Level C and D Transients



WCAP-17651-NP, Revision 0, Updated Figure 5-9 with V-50 Plate Data Included



WCAP-17651-NP, Revision 0, Updated Figure 5-12 with V-50 Plate Data Included and Corrected, Limiting, Level C and D Transients



WCAP-17651-NP, Revision 0, Updated Figure 5-13 with Corrected, Limiting, Level C and D Transients

RAI Response References

1. Regulatory Guide 1.161, “Evaluation of Reactor Pressure Vessels with Charpy Upper-Shelf Energy Less than 50 Ft-Lb,” U. S. Nuclear Regulatory Commission, June 1995.
2. Westinghouse Report WCAP-17651-NP, Revision 0, “Palisades Nuclear Power Plant Reactor Vessel Equivalent Margins Analysis,” February 2013 (ADAMS Accession No. ML13295A451).
3. Code of Federal Regulations, 10 CFR Part 50, Appendix G, “Fracture Toughness Requirements,” U.S. Nuclear Regulatory Commission, Washington, D.C., Federal Register, Volume 60, No. 243, dated December 19, 1995.
4. ASME Boiler and Pressure Vessel (B&PV) Code, Section XI, Division 1, Appendix K, “Assessment of Reactor Vessels with Low Upper Shelf Charpy Impact Energy Levels,” 2007 Edition up to and including 2008 Addenda.
5. ASME B&PV Code, Section XI, Division 1, Appendix G, “Fracture Toughness Criteria for Protection Against Failure,” 1998 Edition up to and including 2000 Addenda.
6. NUREG/CR-6426, Volumes 1 and 2, “Ductile Fracture Toughness of Modified A 302 Grade B Plate Materials, Data Analysis,” U.S. Nuclear Regulatory Commission, January and February 1997.
7. NUREG/CR-5265, “Size Effects on J-R Curves for A 302-B Plate,” U.S. Nuclear Regulatory Commission, January 1989.