Advanced FEA Crack Growth Calculations for Evaluation of PWR Pressurizer Nozzle Dissimilar Metal Weld Circumferential PWSCC

Sponsored by: EPRI Materials Reliability Program

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Presented To:

Expert Review Panel for Advanced FEA Crack Growth Calculations

Presented By:

Glenn White
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Jean Collin
Matthew Klug
Dominion Engineering, Inc.

Tuesday, July 17, 2007
Meeting on Implications of Wolf Creek Dissimilar Metal Weld Inspections
DEI Offices, Reston, Virginia and via Webcast

Agenda

- Introductions / Opening Remarks
- Results Missing from Draft A Report
- New Case S9b to Further Address Effect of Multiple Flaws
- Validation
- Evaluation Criteria
- Final Industry Report
- July 12 NRC Comments
- Remaining Work
- Meeting Summary and Conclusions

Principal Meeting Participants

- EPRI Project Management / Support
  - Craig Harrington, EPRI
  - Christine King, EPRI
  - Tim Gilman, Structural Integrity Associates
- Project Team
  - Glenn White, DEI
  - John Broussard, DEI
  - Jean Collin, DEI
  - Matthew Klug, DEI
- Expert Review Panel
  - Ted Anderson, Quest Reliability, LLC
  - Warren Bamford, Westinghouse
  - David Harris, Structural Integrity Associates
  - Doug Killian, AREVA
  - Pete Riccardella, Structural Integrity Associates
  - Ken Yoon, AREVA
- NRC Participants
  - Al Csontos, NRC Research
  - Tim Lupold, NRC NRR
  - Dave Rudland, EMC2
  - Simon Sheng, NRC NRR
  - Ted Sullivan, NRC NRR

Results Missing from Draft A Report
Summary

- Stable arrest was still be confirmed for 6 matrix cases
  - Now confirmed using FEACrack
- Five matrix cases were still in progress
  - Case 23c multiple repair case: Results on next two slides
  - Case 28b surge nozzle case: Results on next slide
  - Case 36c stress "redistribution" case: Results expected July 17
  - Cases 52 and 53 with nozzle-to-safe-end geometry: Results expected ~July 23
- Leak rate was still to be reported in Table 7-6 for Case 48b at time load margin factor reaches 1.2
  - Missing leak rate is 70.1 gpm
- Leak rate and stability time plots were requested for all cases with a load margin factor of ~1.7 or lower when leak rate is 1 gpm
  - Results not in Draft A are provided below for all cases with factor ≤ 1.75

Results Missing from Draft A Report

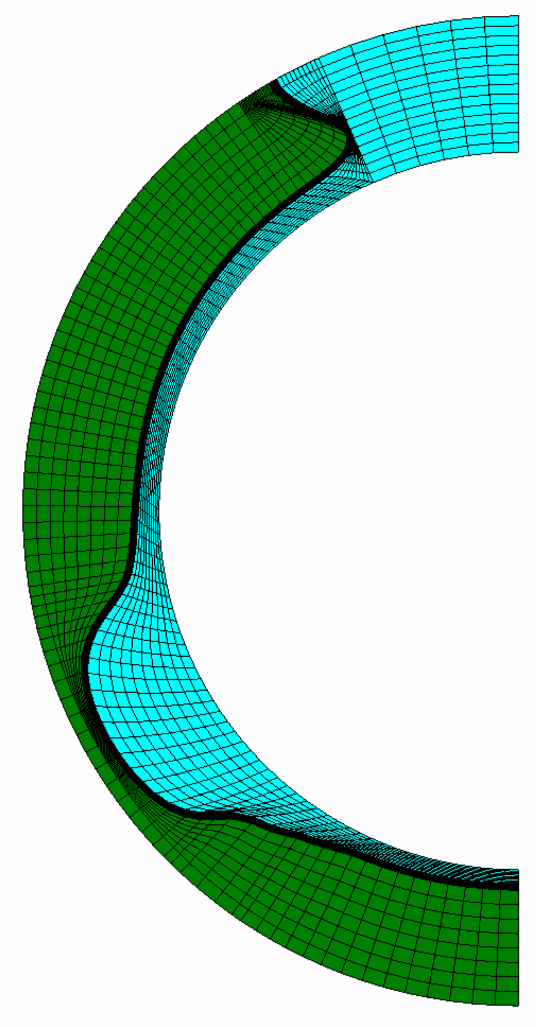
Case 23c and 28b Results

Case #	WRS Subcase	Geometry Case				Surface Crack Stability Results (Press + DW + NT loads and Z-factor for Critical Size)							
		Nozzle Type	Geometry Configuration	R_i (in)	t (in)	Time to TW (yrs)	Fraction Xsection Cracked	Crack Face F (kips)	Max tot Faxial (kips)	Max Pm Based on CF (ksi)	Stability Margin Factor	Support. Pm (ksi)	Support. Pb (thick) (ksi)
23	c	S&R	Config 2a/2b	2.810	1.065	0.5	0.298	14.91	75.33	3.37	3.55	12.0	27.1
28	b	surge	bounding	5.920	1.580	3.4	0.518	77.12	331.23	4.97	1.25	6.2	12.5

Case and Step	Fraction Xsection Cracked	Crack Face Force (kips)	Max tot Faxial (kips)	Max Pm Based on CF (ksi)	Support. Pm (ksi)	Support. Pb (thick) (ksi)	Stability Margin Factor	Time since TW (hrs)	Time since TW (days)	Leak Rate (gpm @ 70°F)
C23cS16	0.369	18.44	78.87	3.53	10.53	22.76	2.99	1799	75	1.003
C28bS00	0.355	52.84	306.96	4.61	8.49	15.47	1.84	0	0	2.426

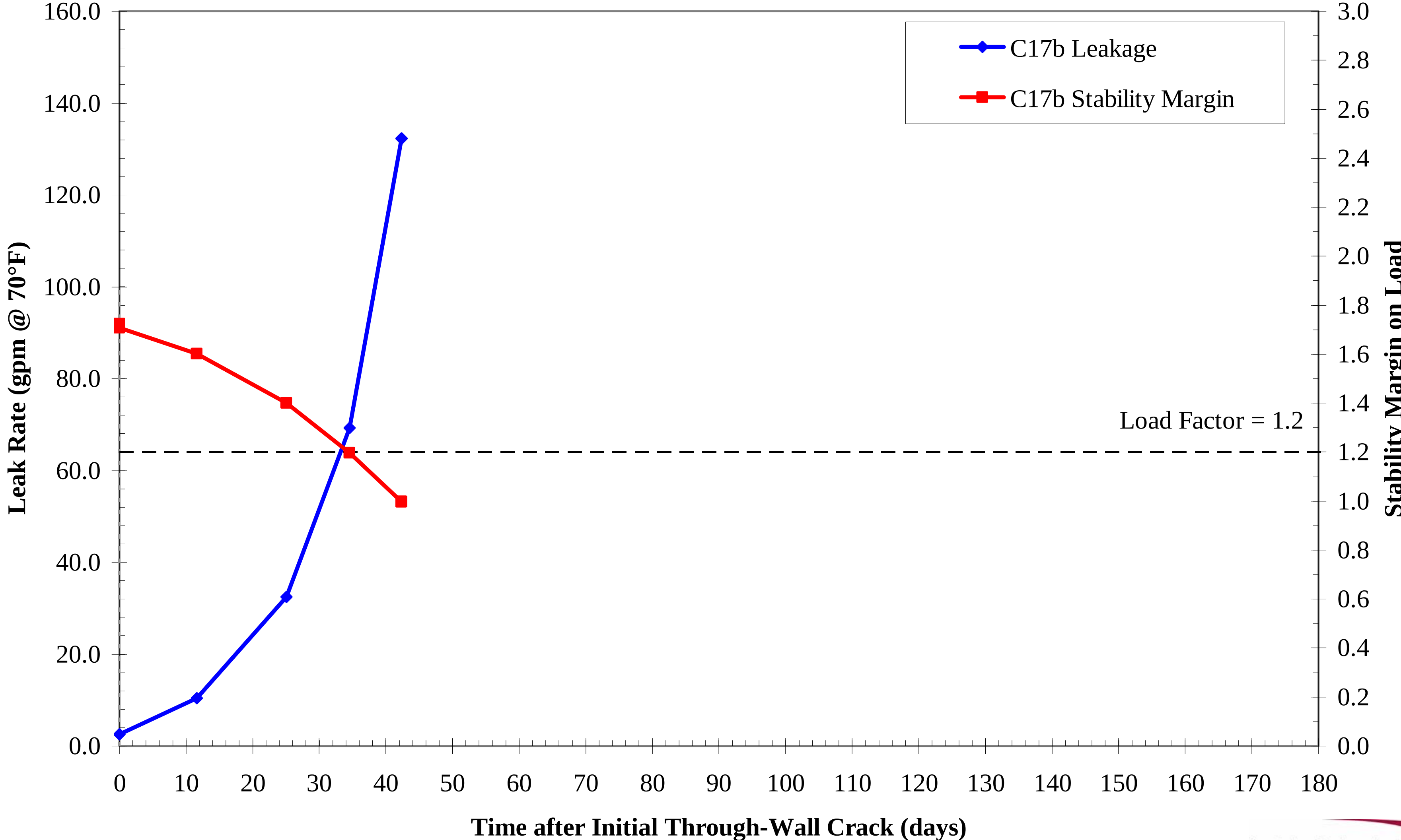
Case and Step	Fraction Xsection Cracked	Crack Face Force (kips)	Max tot Faxial (kips)	Max Pm Based on CF (ksi)	Support. Pm (ksi)	Support. Pb (thick) (ksi)	Stability Margin Factor	Time since TW (hrs)	Time since TW (days)	Time since 1 gpm (hrs)	Time since 1 gpm (days)	Leak Rate (gpm @ 70°F)
C23cS20	0.387	19.34	79.76	3.57	10.08	21.57	**2.83**	2296	96	497	>>21	1.272
C28bS30	0.424	63.08	317.20	4.76	5.71	12.00	1.20	655	27	655	27	28.752

Results Missing from Draft A Report
Case 23c Crack Mesh for TW Step 20



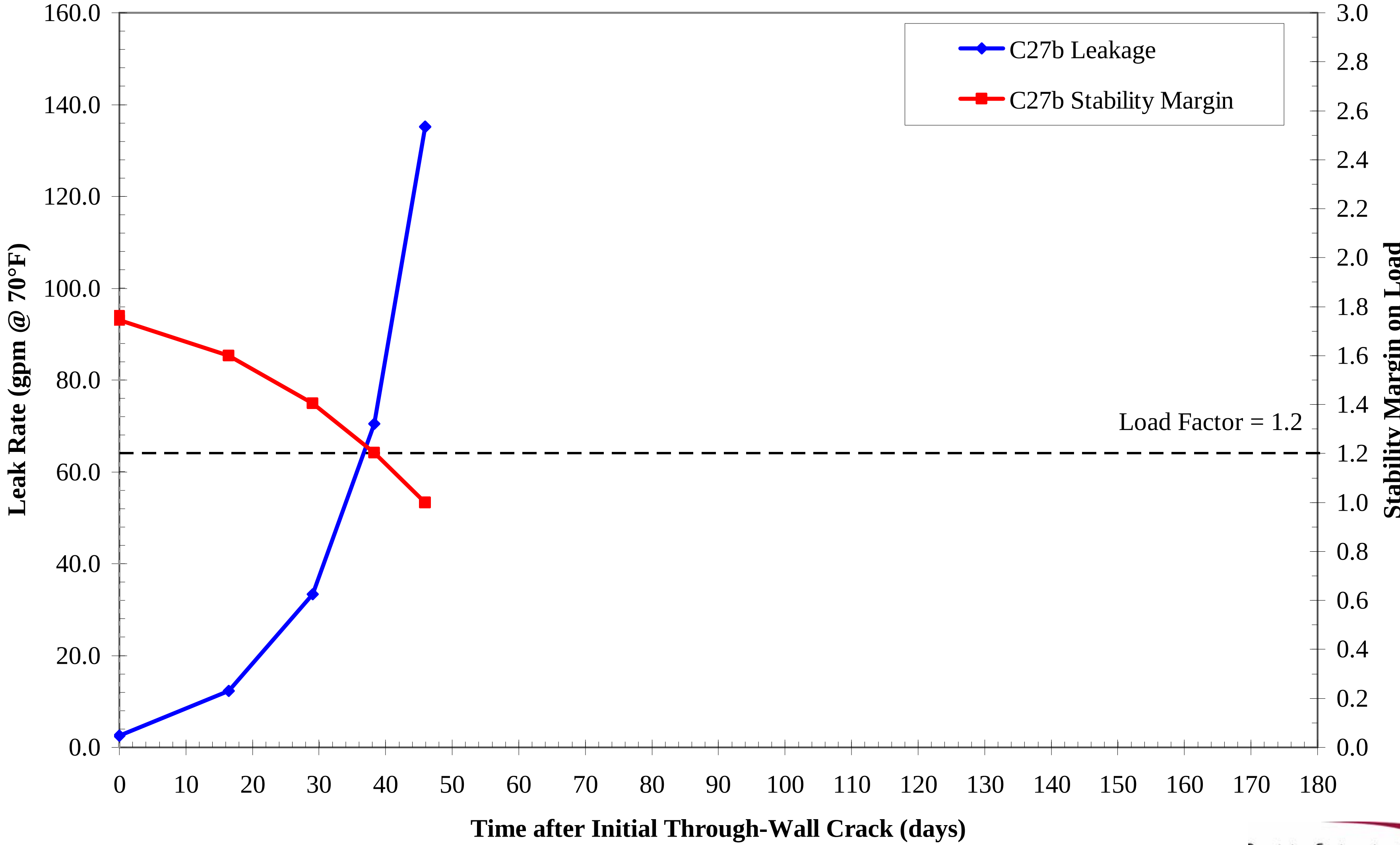
Results Missing from Draft A Report

Leak Rate and Load Margin Factor vs. Time—Case 17b



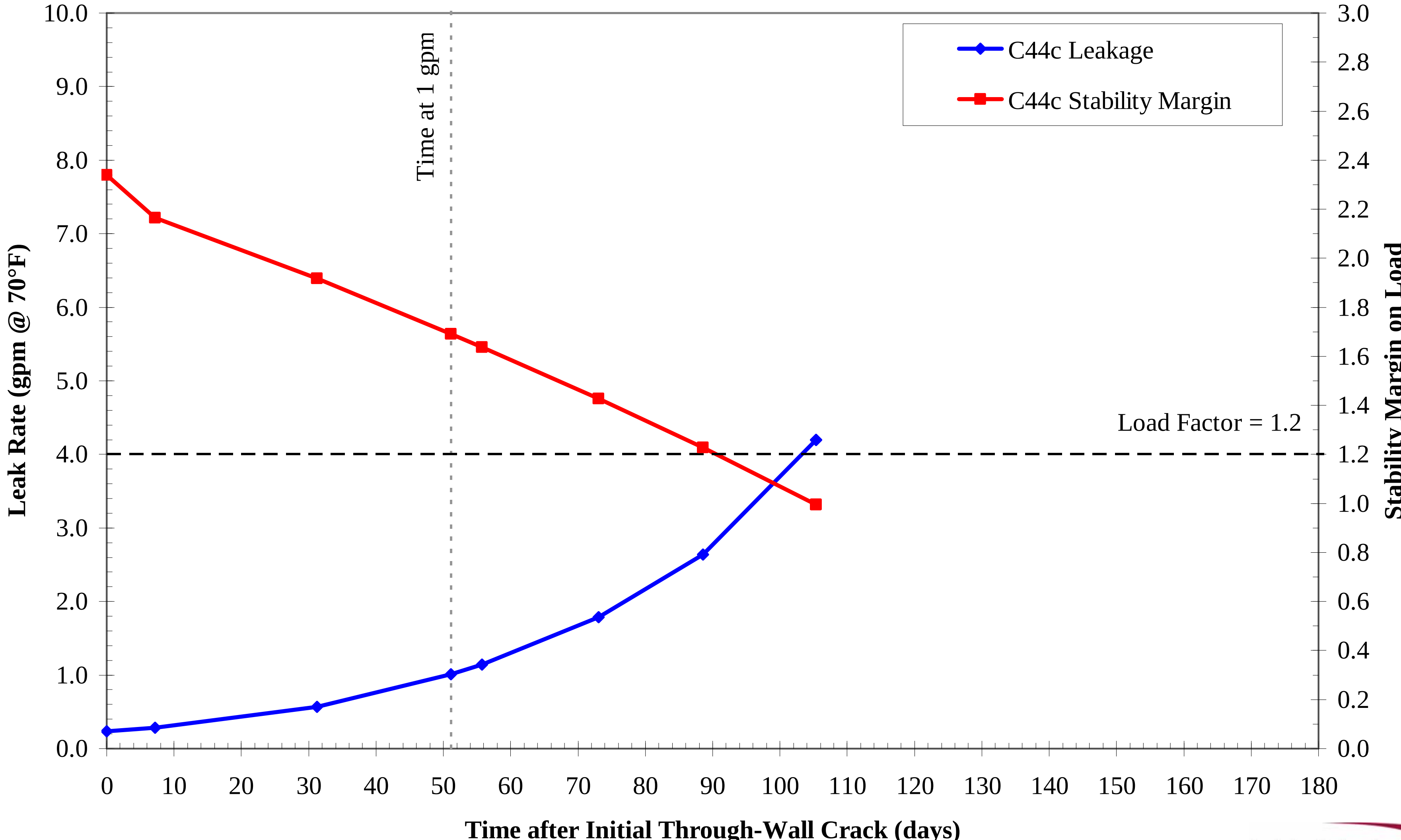
Results Missing from Draft A Report

Leak Rate and Load Margin Factor vs. Time—Case 27b



Results Missing from Draft A Report

Leak Rate and Load Margin Factor vs. Time—Case 44c



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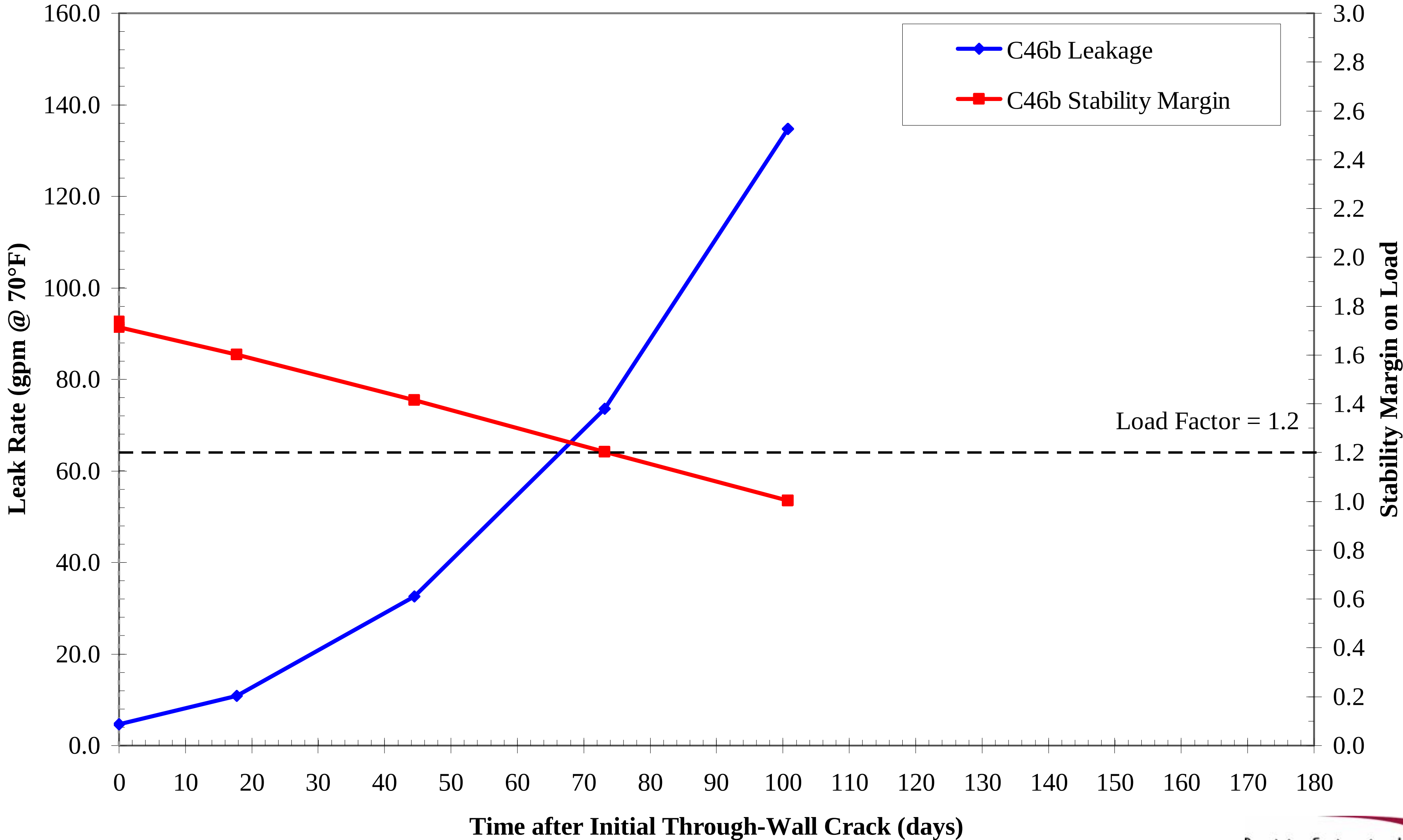
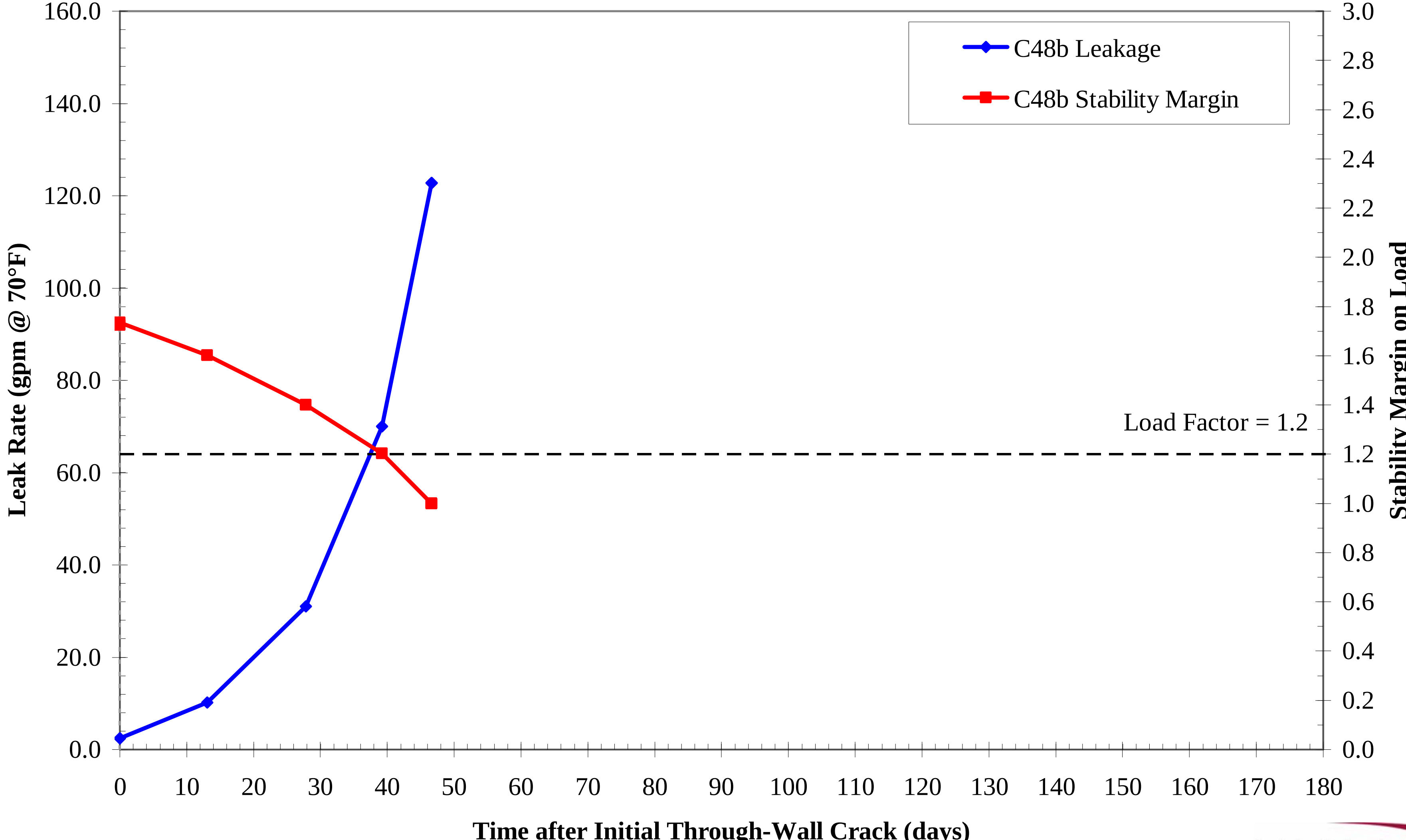
Results Missing from Draft A Report

Leak Rate and Load Margin Factor vs. Time—Case 46b



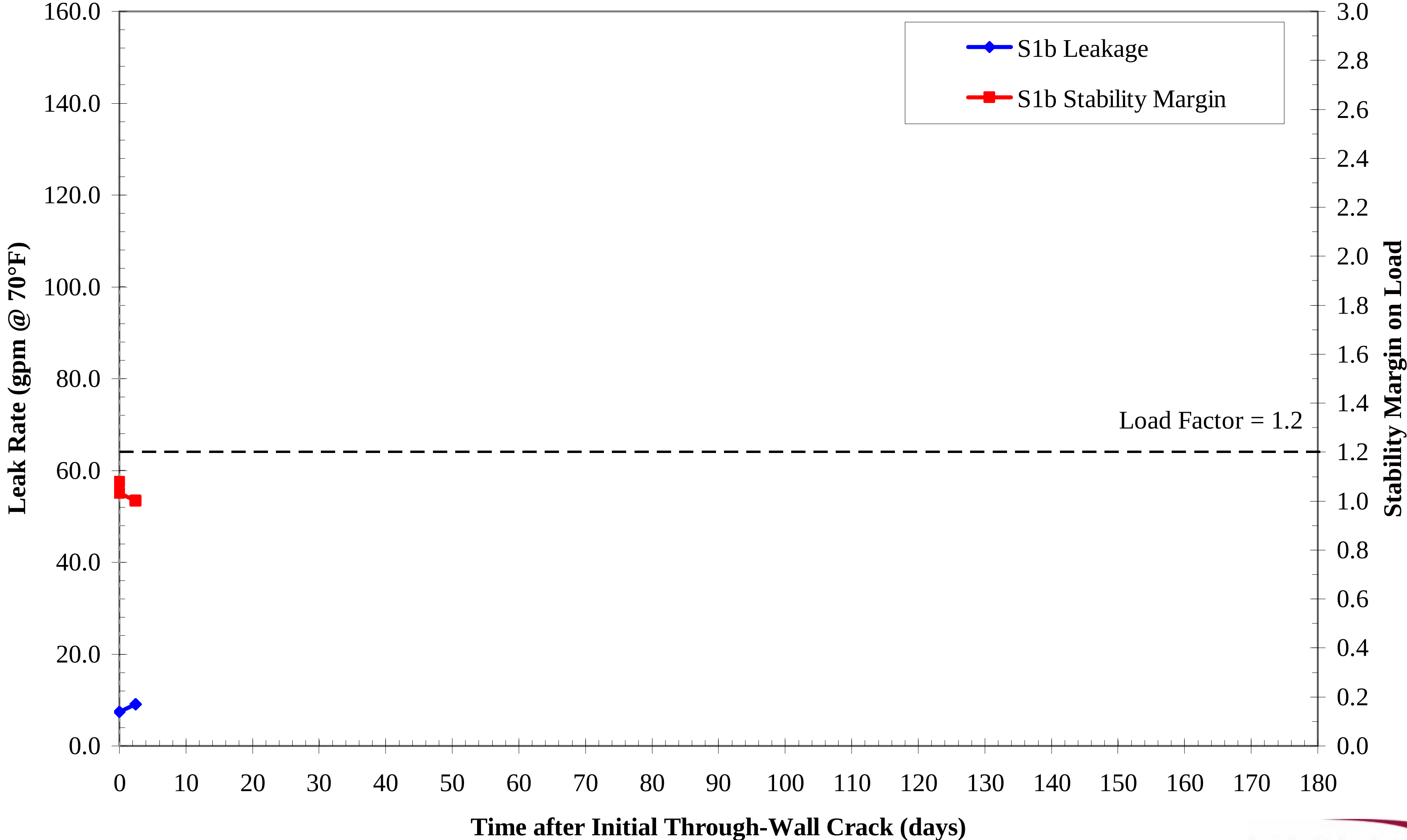
Results Missing from Draft A Report

Leak Rate and Load Margin Factor vs. Time—Case 48b



Results Missing from Draft A Report

Leak Rate and Load Margin Factor vs. Time—Case S1b



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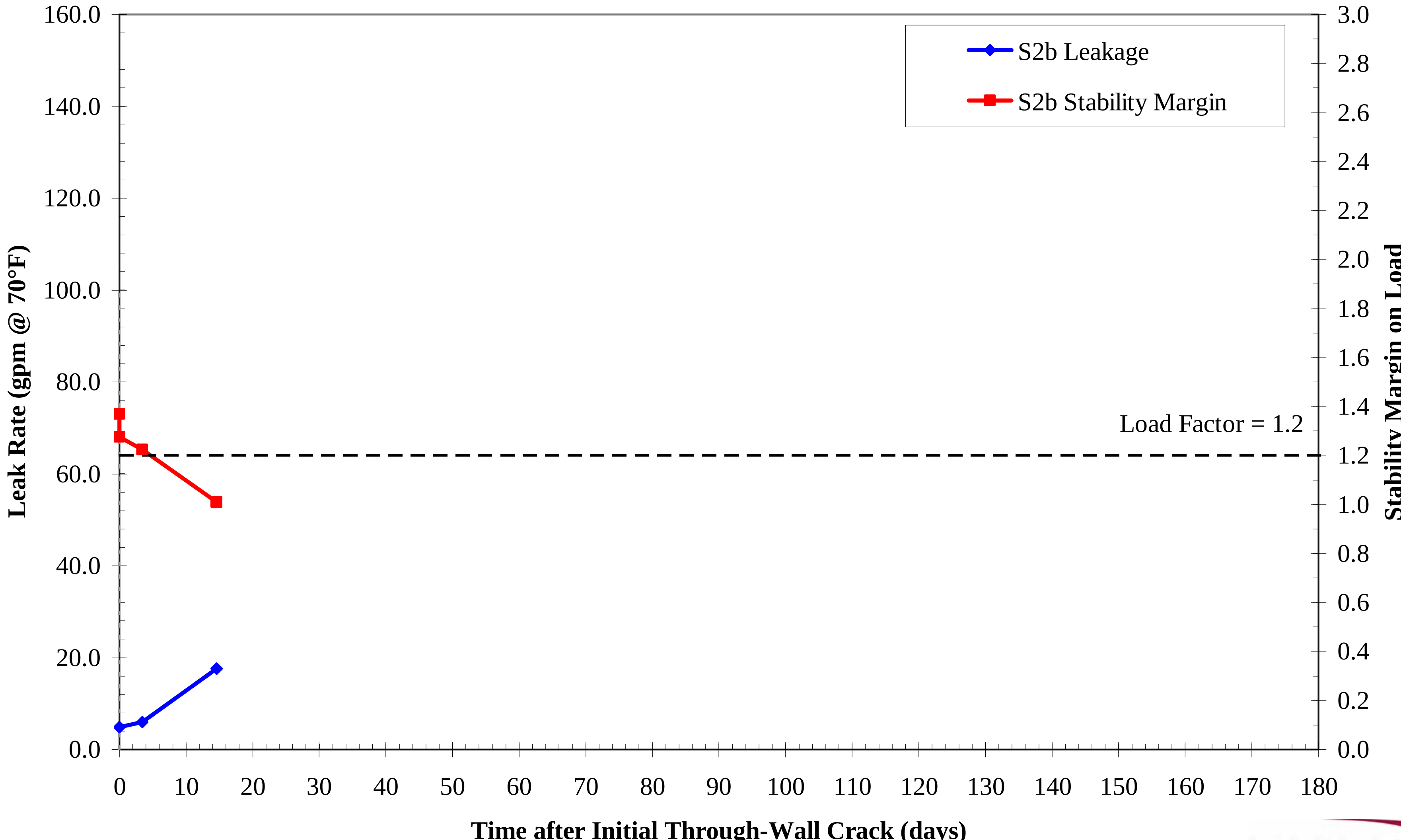
Results Missing from Draft A Report

Leak Rate and Load Margin Factor vs. Time—Case S2b



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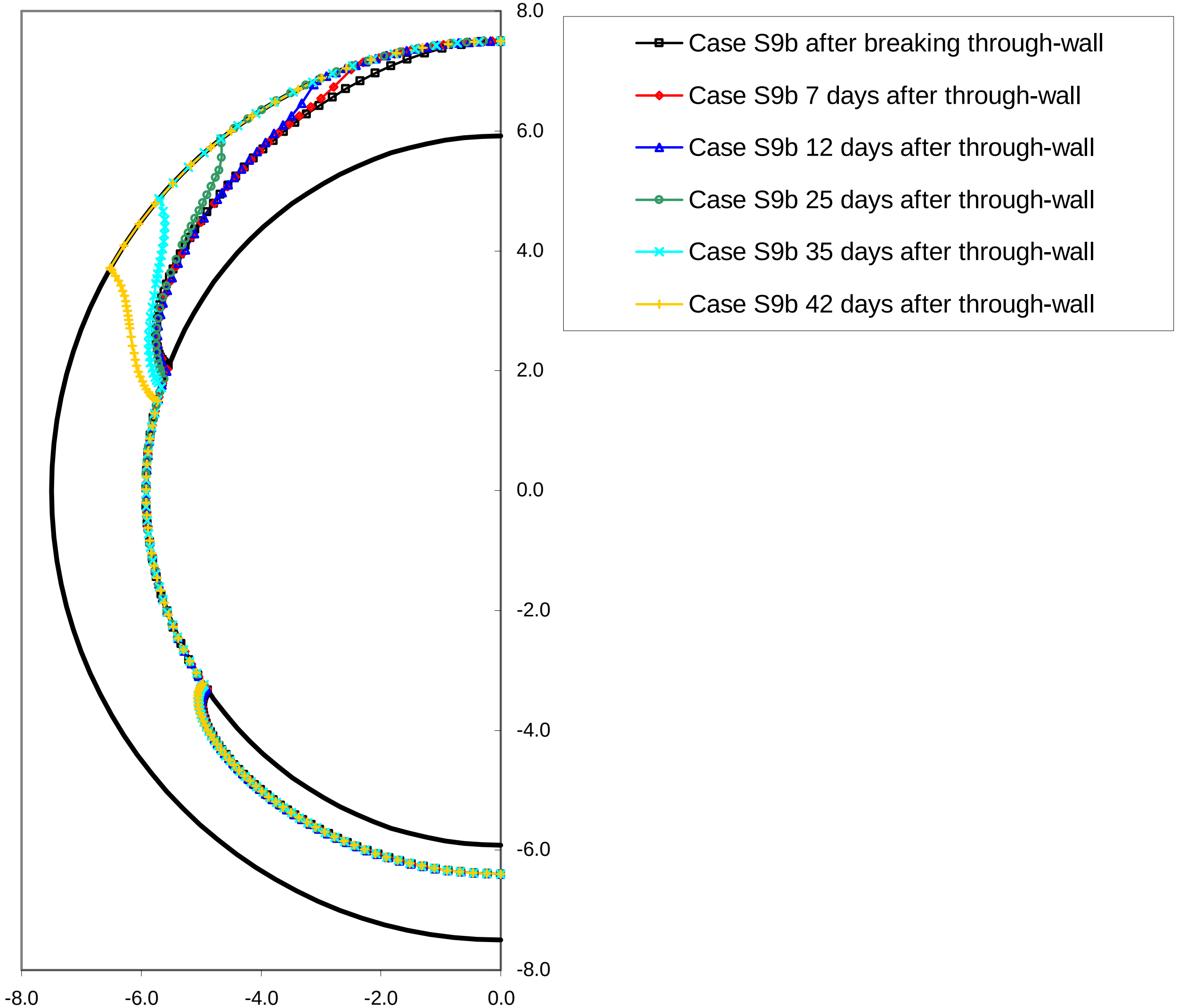
Evaluation Case Matrix
Effect of Multiple Crack Initiation Sites

- Sensitivity cases investigate the effect of multiple crack initiation (e.g., Wolf Creek surge nozzle NDE results)
  - Enveloping of multiple initial flaws with one modeled flaw
  - Modeling of a part-depth 360° flaw
  - Growing multiple individual flaws and then combining on a single weld cross section for stability calculation

New Case S9b
Further Addresses Effect of Multiple Flaws

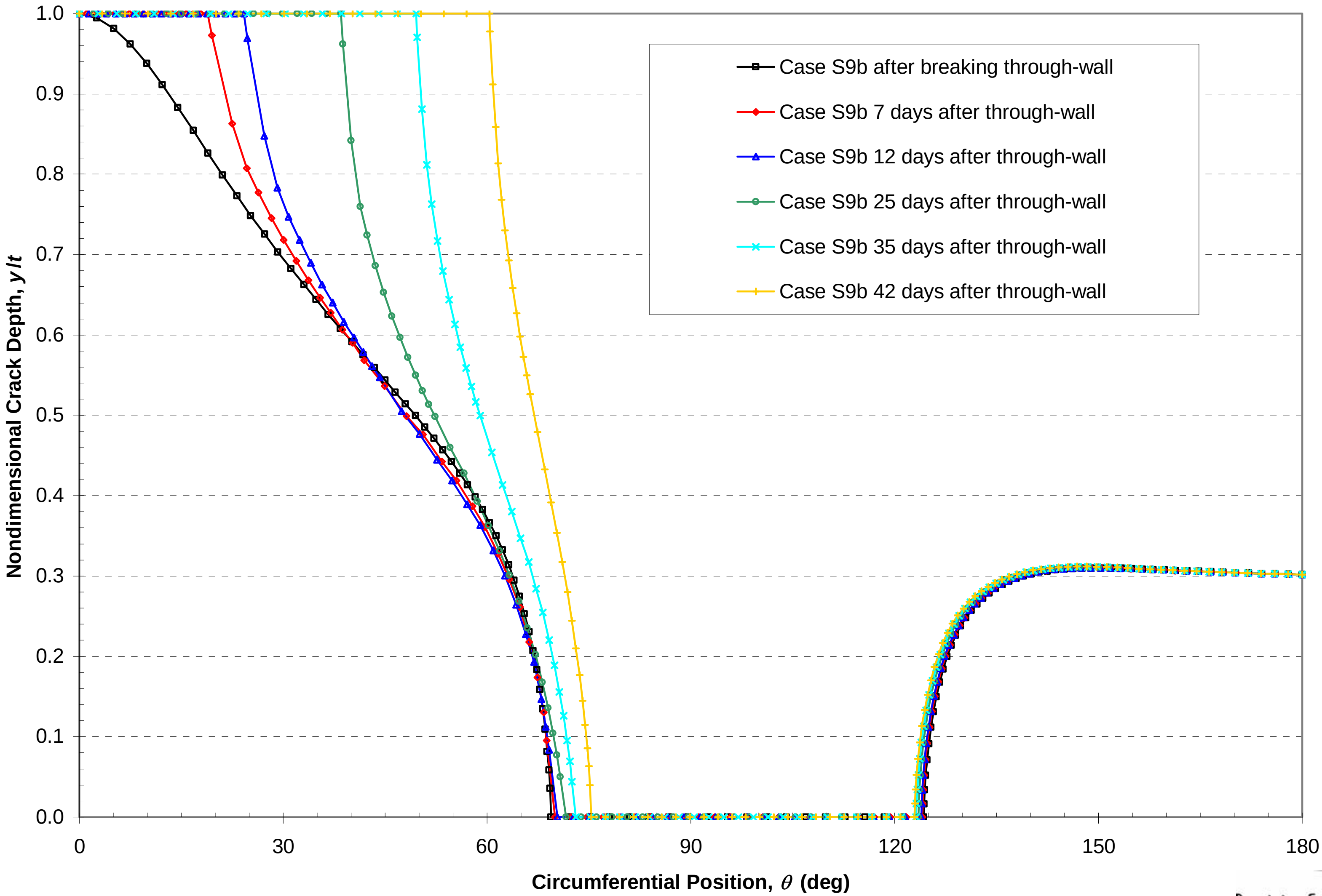
- Case S9b added to further address this concern for limiting surge nozzles
  - Case 9b is based on Case 17b, but with 21:1 26%tw initial flaw placed at top and bottom of weld cross section
  - Crack interaction effects are insignificant for this case based on distance between flaws and Quest Reliability, LLC experience with interaction effects
  - Thus, leak rate and stability margin trends can be based on separate growth of flaws and then combination of flaws in crack stability calculation
  - Two 21:1 26%tw initial flaws represent 46% (167°) of the ID circumference
- Results vs. Case 17b
  - 1.22 years to go through-wall is unaffected
  - Leak rate trend with time of Case 17b is unaffected
  - Stability margin factor trend is lowered by between 0.10 and 0.12
  - Time from 1 gpm to load margin factor of 1.2 is reduced from 35 to 29 days

New Case S9b
Crack Profiles vs. Time: Cartesian Coordinates



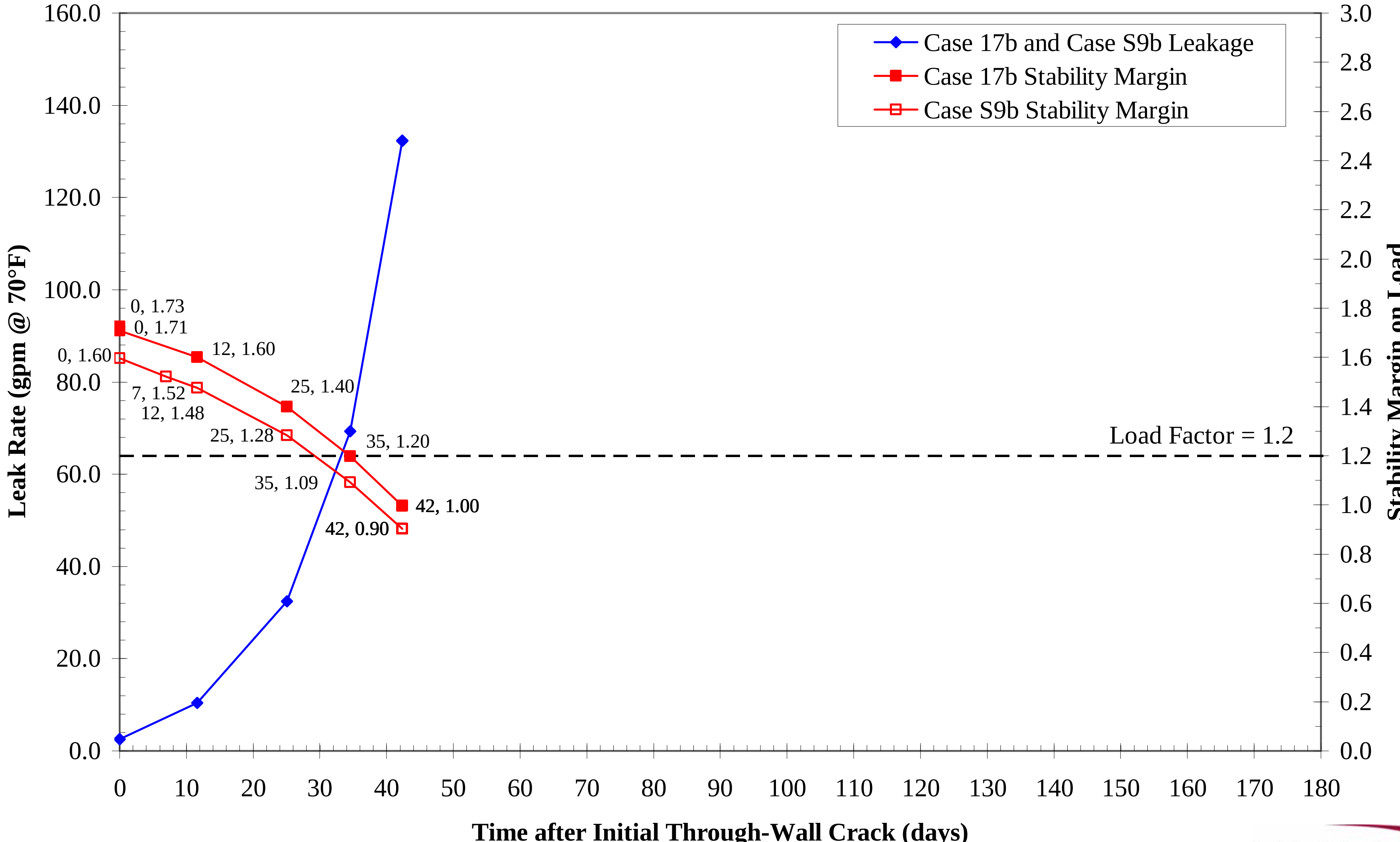
New Case S9b

Crack Profiles vs. Time: Polar Coordinates



New Case S9b

Leak Rate and Load Margin Factor vs. Time



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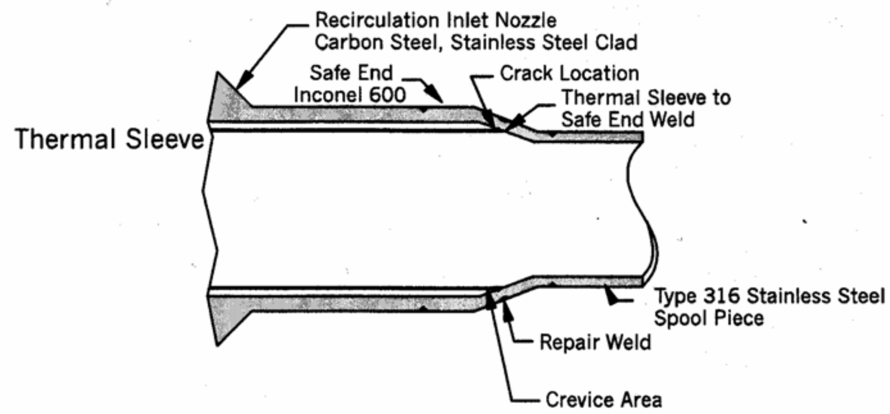
Validation
Topics

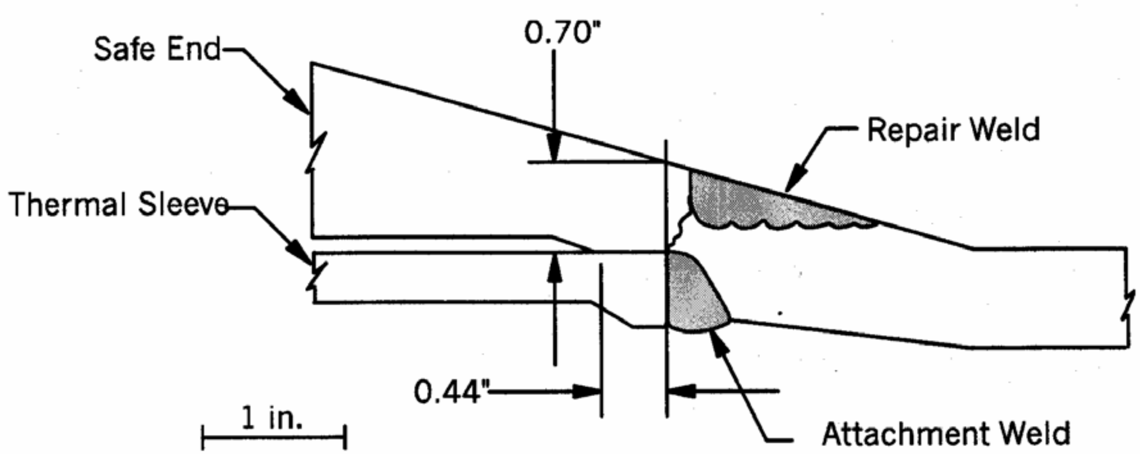
- Duane Arnold
- EU Mockup
- MRP-107

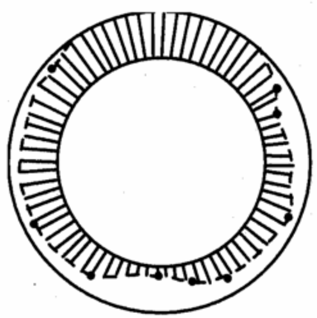
Validation

Duane Arnold Circumferential Crack

- The Duane Arnold crack was applied as a validation case
  - *From MRP-113:* Crack initiation and growth were attributed to the presence of a fully circumferential crevice that led to development of an acidic environment because of the oxygen in the normal BWR water chemistry, combined with high residual and applied stresses as a result of the geometry and nearby welds. The water chemistry conditions that contributed to cracking at Duane Arnold do not exist for the case of Alloy 82/182 butt welds in PWR plants.







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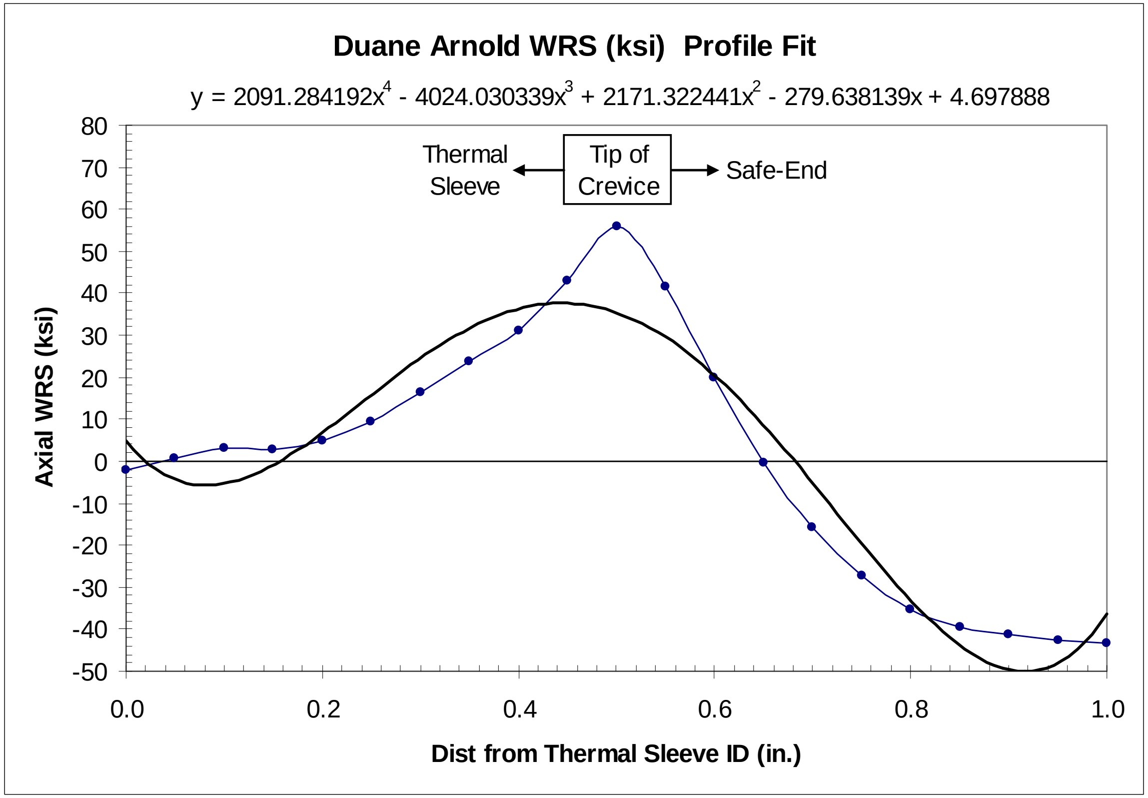
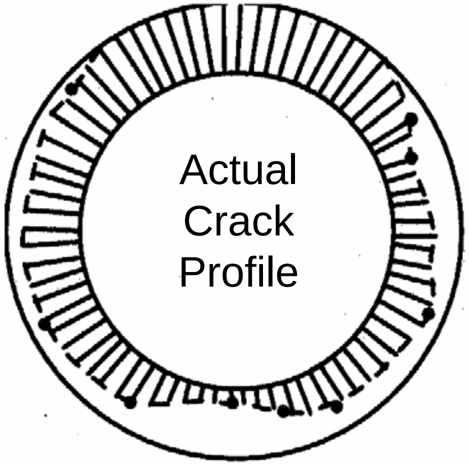
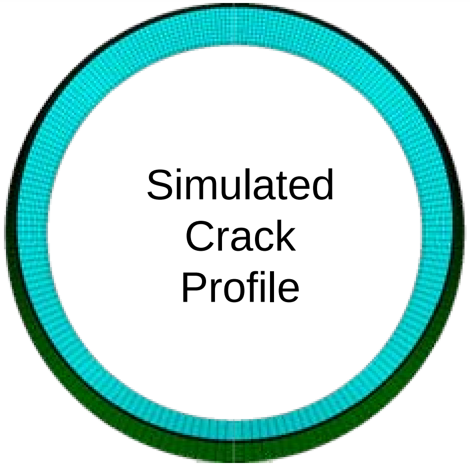
Validation

Duane Arnold Circumferential Crack (cont'd)



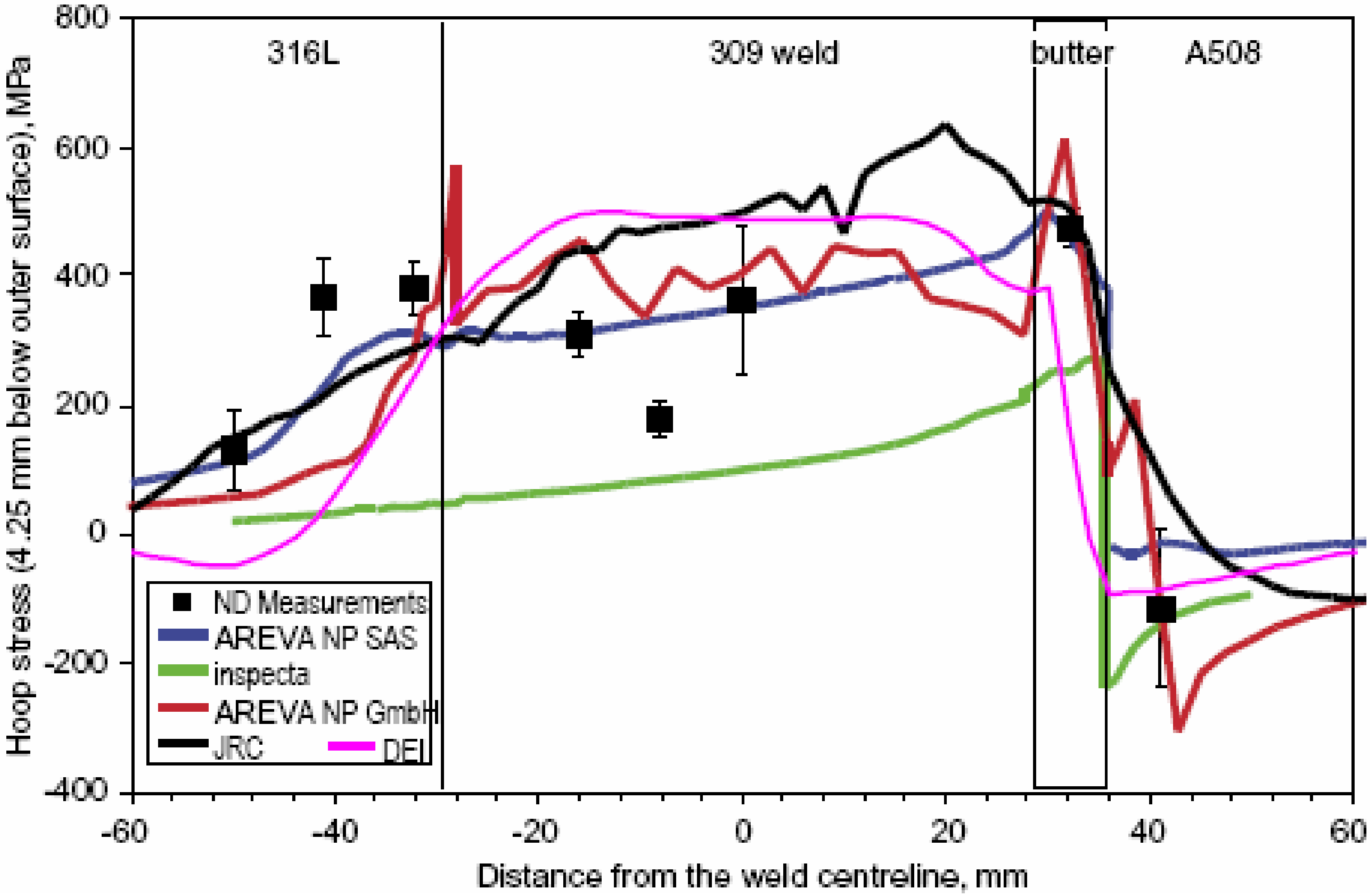




From 30% TW 360° Surface Flaw

Validation

EU Mockup—DEI Hoop Stress



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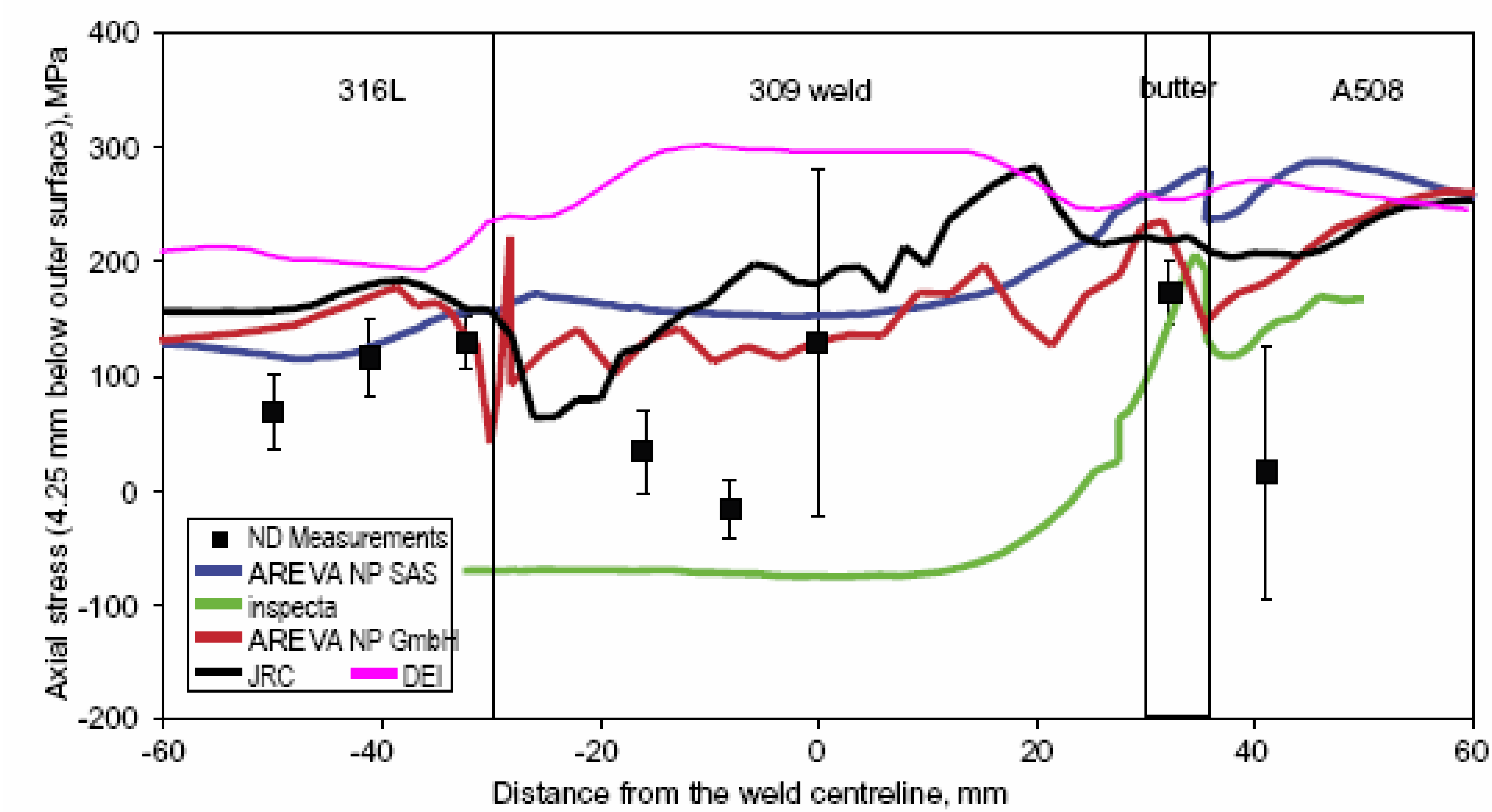
Validation

EU Mockup—DEI Axial Stress



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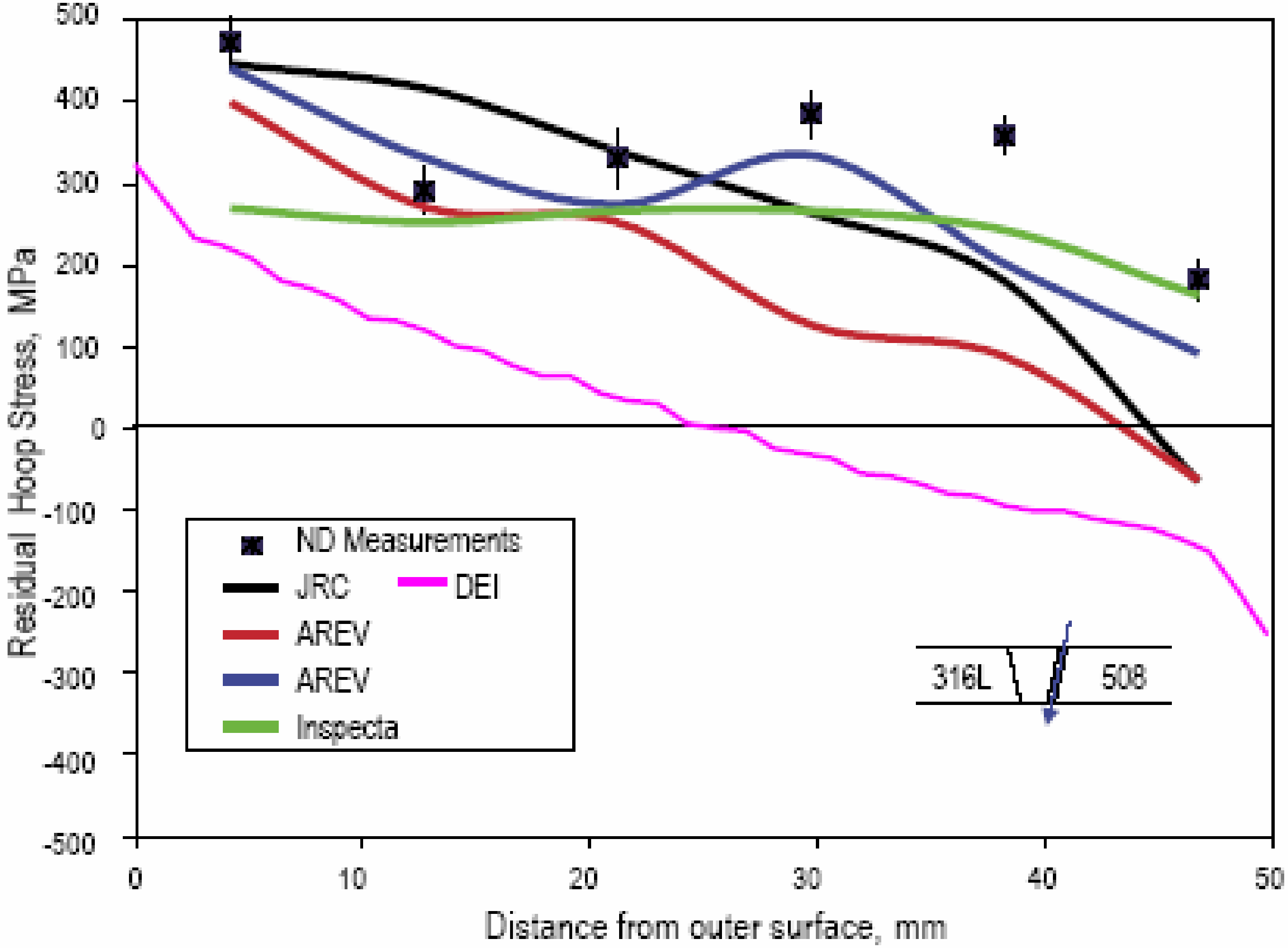
Validation
EU Mockup—DEI Butter Hoop Stress



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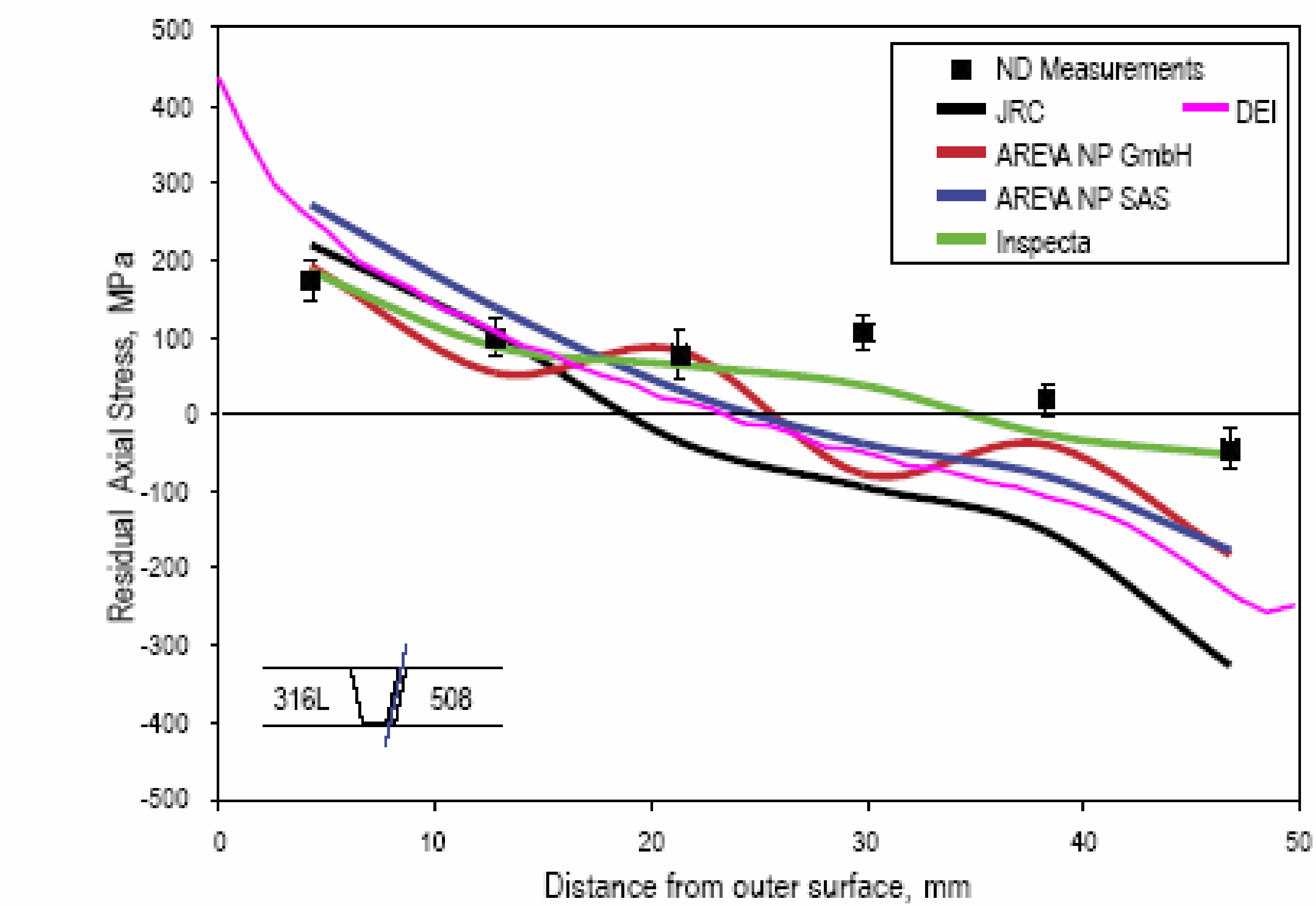
Validation

EU Mockup—DEI Butter Axial Stress



Validation
MRP-107 Lab Study of PWSCC in Alloy 182

- The report summary for MRP-107 (EPRI 1009399, 2004) includes the following:
  - "Abstract: Detailed examinations of Alloy 182 capsule samples containing PWSCC established the relationship between crack initiation sites and the microstructure of the weld metal. These examinations also identified microstructural features that facilitate or arrest PWSCC propagation. Crack initiation only occurred at high angle, high energy, dendrite packet grain boundaries, and growth apparently arrested at low energy boundaries due to low angular misorientation or coincidence of lattice sites. <u>The work also revealed important findings with regard to crack geometries, in particular what aspect ratios may develop during PWSCC of nickel-base (Ni-base) weld metals.</u>"
  - "The cracks exhibited an unusual aspect ratio in that they never showed a large lateral surface extent, even when they extended through the wall thickness. This is a very different feature compared to PWSCC in Ni-base alloys such as Alloy 600. The aspect ratio is thought to relate to indications of crack arrest observed at low energy grain boundaries in Alloy 182."

Evaluation Criteria
Figure 7-1

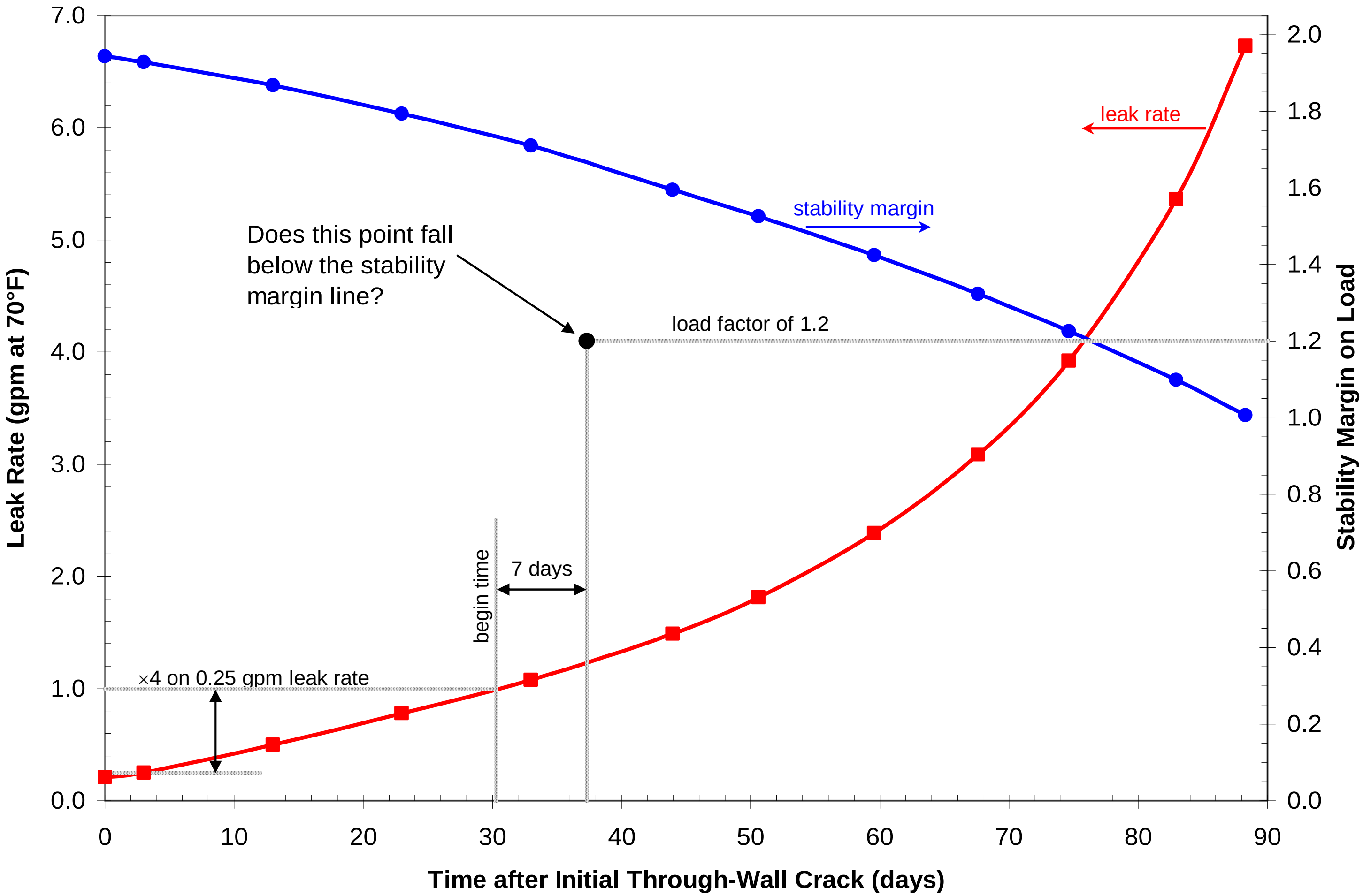


Illustration of Approach for Hypothetical Leak Rate and Crack Stability Results

Final Industry Report
Topics

- Preliminary Results
- Preliminary Conclusions
- Schedule
  - Draft B
  - Industry and NRC Review
    - Main report
    - Appendix A on probabilistic assessments
  - Schedule for Release of Rev. 0
- Missing items
  - EPRI report summary, abstract, and full list of acronyms
  - EU Mockup WRS simulation
  - Discussion of Implications of MRP-107
  - Duane Arnold crack growth case
  - Missing matrix results and discussion, including new Case S9b
  - Move references to Section 9

Final Industry Report
Preliminary Results

- All 105 completed cases in the main sensitivity matrix showed either
  - stable crack arrest (59 cases), or
  - crack leakage and crack stability results satisfying the evaluation criteria (46 cases)
  - generally considerable margins beyond evaluation criteria
- 10 supplemental cases further investigated effect of multiple flaws on limiting surge nozzle cases
  - Conservative application of the three indications found in the Wolf Creek surge nozzle weld to limiting surge nozzles (fill-in weld and relatively high moment load) gives results meeting the evaluation criteria with additional margin
  - Multiple flaw case based on Case 17b with two 21:1 26%tw initial flaws at opposite sides of model shows modest effect on crack stability, with reduction of only 6 days in time interval from 1 gpm leak rate to 1.2 load margin factor (35 to 29 days)
  - On this basis, it is concluded that the concern for multiple flaws in the limiting surge nozzles is adequately addressed by cases that satisfy the evaluation criteria with additional margin

Final Industry Report
Preliminary Conclusions

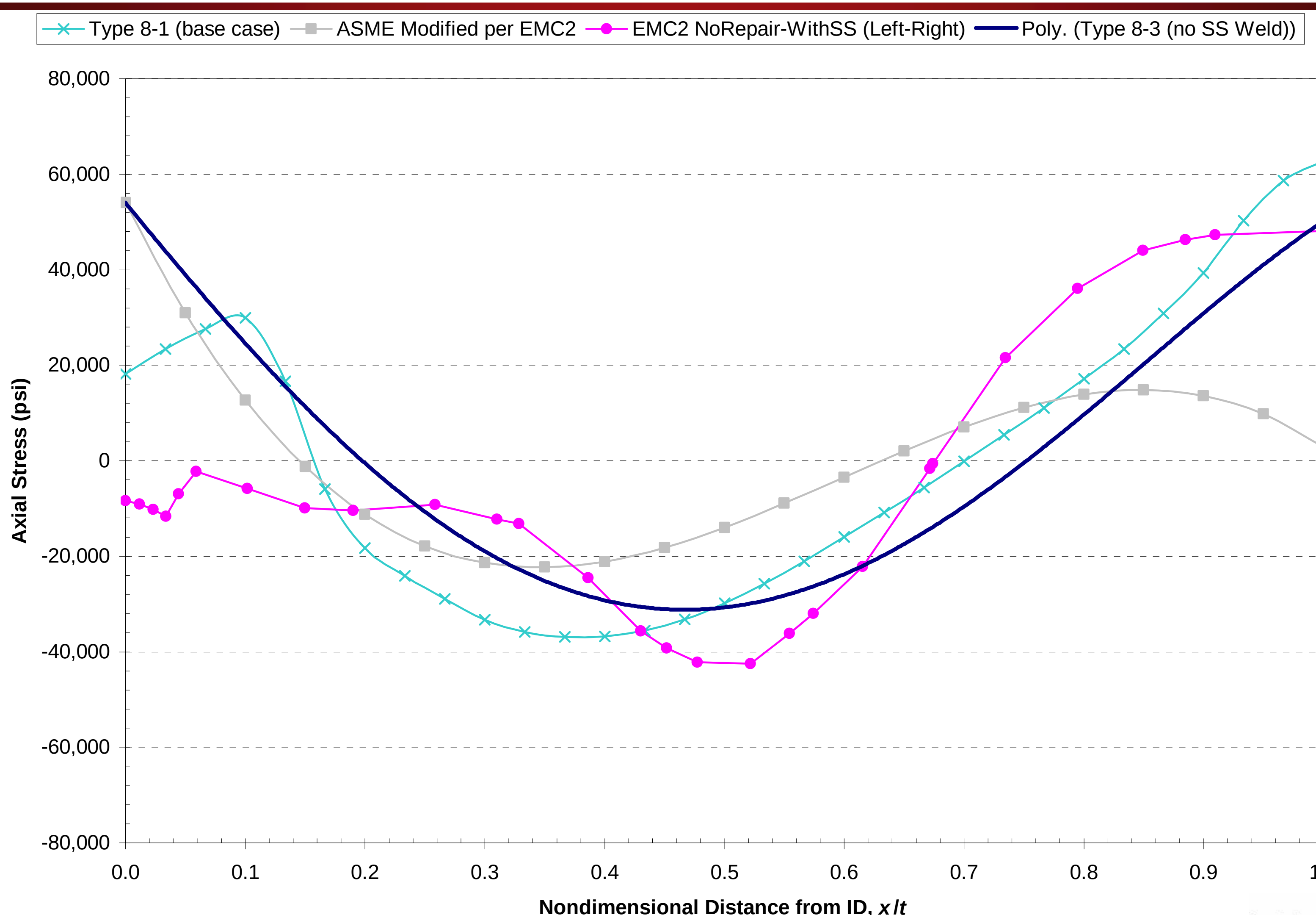
- Assumption of semi-elliptical flaw shape shown to result in large unnecessary overconservatism
- All 51 subject welds are adequately covered by crack growth sensitivity cases that satisfy the evaluation criteria
- Results show tendency of circumferential surface cracks to show stable arrest
  - Axisymmetric welding residual stress profile must self-balance
  - Consistent with Wolf Creek experience given unlikeliness that four indications found in narrow depth band were growing rapidly at that time
- Sensitivity cases indicate a large beneficial effect of relaxation of secondary loads upon through-wall penetration
  - Detailed evaluations tend to support such a relaxation effect
  - Not credited in main cases

July 12 NRC Comments

Welding Residual Stress Uncertainty

- The WRS profile applied in Case 17b is conservative with respect to:
  - DEI WRS FEA result for Type 8 surge nozzle, including SS weld simulation
  - EMC2 WRS FEA result for Type 8 surge nozzle, including SS weld simulation
  - ASME profile as modified by EMC2
- Because the WRS profile applied in Case 17b is shifted significantly in the conservative direction versus all three of these profiles, it appropriately addresses the effect of WRS uncertainty
- Consistent with the most likely Wolf Creek behavior, the EMC2 WRS FEA result for Type 8 surge nozzle (including SS weld simulation) leads to crack arrest in the growth model

July 12 NRC Comments
Surge Nozzle Axial WRS at NOT



July 12 NRC Comments
Effect of Multiple Through-Wall Crack Segments

- Bill Shack of ACRS inquired on July 11 regarding the effect of multiple through-wall flaw segments on the leak rate
- The effect of multiple through-wall flaw segments to reduce the leak rate (in comparison to a single through-wall flaw) is mitigated by the increased resistance to rupture provided by the ligaments between the flaw segments
  - Significant axial offsets between crack segments are perhaps likely because of the relatively long axial region of susceptible material
- The effect of the tight intergranular SCC type morphology is generally addressed by the leak rate prediction methodology

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July 12 NRC Comments
Effect of Multiple Through-Wall Crack Segments (cont'd)

- Substantial margin beyond the evaluation criteria exists for nearly all cases in main matrix
  - Applying a leak rate margin factor of 10 rather than 4 on the 0.25 gpm detectability limit results in all 14 of the most limiting cases* in the main matrix satisfying the evaluation criteria with one exception (Case 44c)
  - A leak rate margin factor of about 9 does satisfy the evaluation criteria for Case 44c
  - All other cases in the main matrix very likely satisfy the evaluation criteria with a leak rate margin factor of 10 based on the compiled leak rate and stability data
  - A leak rate margin factor of 10 has historically been applied in long-term regulatory LBB assessments
  - The most limiting surge nozzle case (Case 17b) is predicted to have an initial through-wall leak rate of 2.6 gpm, with the leak rate increasing to 69 gpm when the load margin factor decreases to 1.2, indicating robustness with respect to the value of the leak rate margin factor

*The 14 most limiting cases are defined here as those cases for which the load margin factor is 1.75 or less at the time the leak rate is calculated to be 1 gpm.

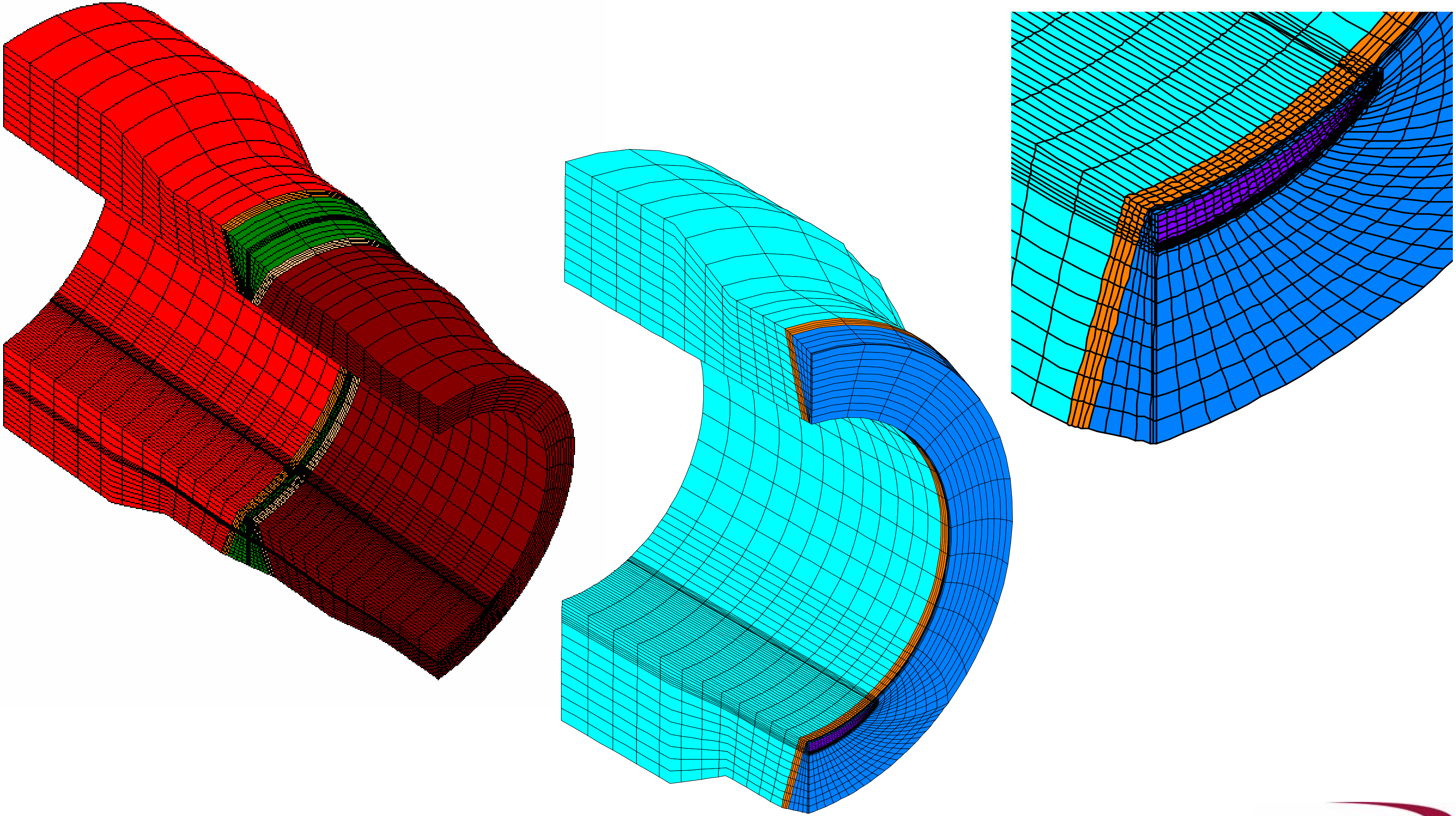
July 12 NRC Comments
Effect of Multiple Through-Wall Crack Segments (cont'd)

- Given the above points, the matrix results show sufficient margin to address modeling uncertainties such as those associated with the potential for multiple through-wall crack segments
- More detailed evaluation of the effect of multiple through-wall crack segments may be considered in the context of longer-term evaluations
  - More detailed evaluations will require significant additional developmental effort
  - Current study has had benefit of significantly refining crack growth evaluation tools, but explicit evaluation of multiple flaws is an emerging area

Remaining Work

- Remaining DEI Work
  - Nozzle-to-safe end geometry crack growth cases
- Final Industry Report
- August 9 Meeting at North Bethesda Marriott
- NRC Safety Assessment

Nozzle-to-safe-end Geometry Cases
Example Cracked Model



Meeting Summary and Conclusions

- Industry
- NRC

NRC Questions and Comments on the Industry Advanced FEA Draft Report

UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

Ted Sullivan & Al Csontos

July 17, 2007

General Comments

- NRC staff has reviewed the industry draft report and will provide our comments and questions today
- NRC recognizes the significant effort to develop, benchmark, verify, and evaluate the advanced FEA program and the validation of weld residual stresses
- Overall, the industry developed a groundbreaking and technically sound research program
- The products from this research program will be essential in resolving the regulatory issues at hand

General Comments

- NRC comments are for clarification & completeness
- For many, the industry’s advanced FEA report will be sole source of information on this issue
- Report needs some additional information provided in the industry’s presentations at public meetings
- Interested parties outside the project deliberations may need the additional information for clarity
- NRC needs to review the references, supporting sections, and appendices as soon as they become available

General Questions

- When will the supplementary analyses discussed in the draft industry report be available to the NRC?
  - EU validation writeup?
  - Westinghouse fabrication writeups?
  - David Harris leak rate writeup?
  - References?
- What, if any, additional cases will the industry run?
- Will the industry respond to Bill Shack's comments related to leak rate modeling with multiple TWCs?
- What are industry's plans for a peer review?

Comments and Proposed Changes:Due Date: July 20, 2007

Advanced FEA Evaluation of Growth of Postulated Circ PWSCC Flaws in PZR Nozzle DM Welds - Rev. A

Cmt #	Reviewer's Organization	Comment Location		Comment	Proposed Change	Comment Resolution
		Page #	Line #			
	NRC	**1-2**	**27-29**	The group of nine PWRs should be planning to accelerate outages or take mid-cycle outages based on commitments made.	Revise to read...the group of nine PWRs planning to accelerate outages or take mid-cycle outages based on commitments made. Should this study demonstrate flaw stability via sufficient time from initial detectable leakage until pipe rupture, as demonstrated to the NRC, these plants could then resume plans to perform PDI inspection or mitigation during the spring 2008 outage season.	
	NRC	**1-6**	**6-7**	The images of each example pressurizer nozzle should contain identification markers for all major fabrication components	Add identification markers	
	NRC	**1-7**	**1**	The image of the CE pressurizer nozzle should contain identification markers for all major fabrication components	Add identification markers	
	NRC	**2-General**		In general, this section needs to be augmented with the information provided in previous public meetings to include more figures detailing the nozzle geometries, dimensions, and typical fabrication procedures for the three types of plants; CE, W, W with CE-like fabrication procedures	Augment this section to include information previously provided in public meetings by DEI (Glenn White) and Westinghouse (Cameron Martin)	
	NRC	**2-2**	**14**	It would be helpful to explain why the definition of Pm is given as PDo/4t in this section, but the pressure is used differently in the crack growth portion of the work	Add explanation	
	NRC	**2-3**	**9**	With regards to the back welding, this should clearly state that certain amounts of the ID material are removed and weld material is reapplied to the ID.	Revise, make similar to Type 8 Surge Nozzle description on pate 3-5, lines 23-31.	
	NRC	**2-3**	**16**	In addition to no fill-in welds, include no back chipping/backwelding completed	Make revision	
	NRC	**2-5**	**3**	In this table labels such as land thickness and fill-in weld are a bit confusing. It is suggested that figures in the WRS section be placed here to help better explain these geometric details.	Provide figures with the major fabrication details of the nozzles identified.	
	NRC	**2-6**	**-**	Question for Plant H spray line PDI results.	Recheck Plant H results.	
	NRC	**3-1**	**16-30**	Some dimensions are needed for completeness of the report, i.e., SS weld location, fill-in dimensions, etc. (see general comment)	Add dimensions, figures, or references as needed.	
	NRC	**3-2**	**6**	Note that the 5/16 inch repair simulates the back chipping and weld buildup	Make revision	
	NRC	**3-2**	**22**	How long is the repair?	Add length of repair to explanation	
	NRC	**3-2**	**24**	this line notes that minor simplifications are made	List the minor simplifications	
	NRC	**3-2**	**26**	In the WRS analyses long slender weld beads were used. Since these beads differ from actual weld beads, please explain how the approximation resulting from this approach was assessed and reflected in the study.	Add explanation	
	NRC	**3-2**	**35**	How was piping system compliance treated in the WRS analysis? How long was the stainless steel pipe in the analysis?	Add explanation	
	NRC	**3-3**	**16-31**	Why was the elastic limit defined as the yield strength for the base metal but the flow strength for the weld material? The base metal near the weld may also melt and solidify as would the weld.	Add explanation	
	NRC	**3-3**	**34**	The stainless steel yield strength of 28.9 ksi at 600F seems to be a high value; in looking at 550F tensile data from Vol. 8 of Degraded Piping semi-annual reports, the yield strengths for 5 stainless steel pipes ranged from 20.1 ksi to 26.1 ksi with an average value of 22.7 ksi. How would this affect the WRS modeling and critical crack size calculations?	Add explanation	
	NRC	**3-4**	**4**	Different than what, the base material?	Add explanation	
	NRC	**3-5**	**4-10**	The stress improvement observed from a hydrotest will be limited for low R/t pipes such as on the pressurizer	None	
	NRC	**3-5**	**8**	hydrostatic testing referred to as a form of mechanical stress improvement	Delete mechanical and just refer to as a form of stress improvement	
	NRC	**3-5**	**13**	Why was 653F listed as the operating temperature when the surge line will be at a temperature closer to 644F?	Add explanation	
	NRC	**3-5**	**34**	Refers to an amount of the ID that was "ground out"	Was this ground or machined? If machined, revise.	
	NRC	**3-5**	**36**	Statement that the inside surface is 0.25 inch smaller should read, "the inside diameter is 0.25 inches smaller	replace surface with diameter	
	NRC	**3-6**	**1**	"removed back"	Replace with machined, if actually machined	
	NRC	**3-6**	**5**	States the welds were v-weld…. Should be U-groove	Verify this is suppose to be U-groove	
	NRC	**3-6**	**5**	v-weld	Refer to as v-groove weld	
	NRC	**3-6**	**36**	Was it verified that a stress path perpendicular to the axial direction represents the maximum stress path for PWSCC growth?	Add explanation	
	NRC	**3-7**	**3-16**	Was the path changed for the case with the SS weld since the path of maximum stress may shift location??	Add explanation	
	NRC	**3-8**	**10**	Section 3.3 should be referred to as Validation and Benchmarking	Add title	

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		Page #	Line #			
	NRC	**3-8**	**14-17**	Based on the available WRS validation and benchmarking activities to the EU report, this section should assess uncertainties related to WRS and how they will be addressed in the overall advanced FEA Phase II sensitivity matrix.	Add section	
	NRC	**3-15**	**5**	Identify what is meant by 'backweld'	Add clarification in text.	
	NRC	**4-1**	**20**	U-groove weld geometry stated here vs. V-groove geometry sated in section 3, page 6 and in the figures	Revise to make consistent between sections	
	NRC	**4-1**	**27**	What the rationale for using 8-noded brick elements in a computational fracture mechanics analysis? The crack tip singularity ahead of simulated sharp crack is approximated by collapsed 20-noded elements with the midpoint nodes moved to the quarter point location. If 8-noded elements are used, they must be of sufficient small size.	Explain and provide mesh sensitivity results for using the 8-noded elements	
	NRC	**4-2**	**16**	Since ANSYS does not calculate fracture parameters, please explain the process on how it was done in this study	Add explanation	
	NRC	**4-5**	**39**	What is meant by '… remain self- similar…'?	Add correction	
	NRC	**4-6**	**14**	Why was the time between leakage and rupture not reported for the Phase I study?	Add Phase I leakage and margin results	
	NRC	**4-7**	**5**	When you provide Duane Arnold crack validation, please provide what parameters were modified to obtain the final validation results.	Add explanation	
	NRC	**5-1**	**28**	Explain CMTR	Add explanation	
	NRC	**5-2**	**7**	The study conducted by Riccardella and Anderson should be discussed in more detail since the report refers to the results several times. It would be nice if they could be included in detail as part of this report or in an appendix	Add work from Riccardella and Anderson to report	
	NRC	**5-2**	**15**	Along with radial differential thermal expansion, WRS are also not included in the stability calculations	Modify sentence	
	NRC	**5-3**	**18**	The DPZP may not be greater than unity for the cases of a complex crack where the apparent toughness is greatly reduced as compared to the C(T) toughness	remove this sentence or modify	
	NRC	**5-4**	**8**	It should be noted that in this study the DPZP was calculated using the C(T) toughness and not the apparent toughness for complex cracks	This should be noted in this sentence	
	NRC	**6-1**	**14**	Spell out COD	Spell out as crack open displacement (COD)	
	NRC	**6-1**	**25**	Explain what (albeit over a longer length) means	Add explanation	
	NRC	**6-2**	**29**	List what the summary is provided in	List Table 6-2 (?) as containing the summary of inputs	
	NRC	**6-3**	**10-11**	Explain what is meant by the potentially important effect of moment bending	Add explanation	
	NRC	**7-2**	**6-7**	Further explain how the conversion is a conservative assumption given the complex crack envelopes the TW crack	Add explanation	
	NRC	**7-2**	**15-16**	Why were different axial stresses used in the stability and crack growth calculations?	Modify sentence	
	NRC	**7-2**	**35**	Rather than state the acceptability involves licensing and regulatory issues, state the acceptability is dependent upon uncertainty of input parameters and the accuracy of the modeling methodology	Revise as noted	
	NRC	**7-3**	**25**	Recommend listing either six or seven days as being conservative.	Change to state "six days is conservatively required for the plant to shut down….	
	NRC	**7-3**	**5**	What is the basis for the 7 day criteria?	Provide the basis	
	NRC	**7-3**	**26-27**	Would like to see discussion of where 0.25 gpm comes from, i.e. RCS leak rate monitoring committed to by licensees. Some mention of the baseline and that the margin factor of 4.0 also addresses leak rate changes that may occur that could affect the baseline but have not been incorporated in the baseline, i.e. a high baseline may have been measured in 1st seven days of operation that decreases over time or leaks may have been identified and repaired that effectively reduce the baseline. It would also be worthwhile to list the range of values used as baseline at the nine plants assessed in this evaluation.	Indicate where the 0.25 gpm is from. Include discussion of the baseline and how the margin factor of 4 encompasses baseline changes that may not have resulted in a baseline revision. Include range of baseline values being used.	
	NRC	**7-4**	**3**	New readers may not understand the stability margin factor.	Provide a definition of the stability margin factor	
	NRC	**7-4**	**5**	Expand the explanation for why the factor of 1.2 is considered appropriate	expand explanation	
	NRC	**7-4**	**12**	The statement that there is no clear evidence that a purely limit load based approach is insufficient should be worded differently since there is no clear evidence that the purely limit load based approach is sufficient for cracks in A82/182	Modify the statement to say… there is no experimental data on circumferential cracks in A82/182 that verify that limit load or elastic-plastic fracture conditions control.	
	NRC	**7-6**	**19**	Here the operating temperature is given as 650F. Table 6-1 and Page 3-5 give the operating temperature as 653F	Correct temperature	
	NRC	**7-7**	**35**	Were the stresses from Figure 3-19 used in the repair analyses?? Were the values interpolated from what's shown in Figure 3-19 to each circumferential position in the crack growth analyses?	Add explanation	

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	NRC	**7-10**	**28**	This write-up always assumes that the dominate crack initiates on top of the pipe. What if it does not initiate on the top of the pipe?	Add explanation	
	NRC	**7-12**	**33**	Same as previous	Add explanation	
	NRC	**7-14**	**20-21**	Under what conditions would the thermal loads be reduced during surface crack growth in such a way that the reduction would cause arrest?? If the surface crack is near critical, and much rotation occurs, some of the displacement-controlled loads may be reduced, but during subcritical crack growth, I'm not sure when the displacement controlled loads would be relieved	Add explanation	
	NRC	**7-14**	**30-31**	It is stated that using 360 deg flaws in surge nozzle analyses is not appropriate. However, 360 deg cracks were assumed in Case 18,26,29 and 30. Please clarify?	Add explanation	
	NRC	**7-15**	**1-2**	Same comment as 7-10 line 28	Add explanation	
	NRC	**7-15**	**16**	It may be helpful to have a table that shows the how the parameters varied in the sensitivity matrix affected the margin, i.e., 10% decrease in as built wall thickness can decrease margin by 30%	Add table if possible	
	NRC	**7-15**	**16**	In addition, it may be worthwhile to comment on how the changes in margin due to the sensitivity parameters may be combined. For instance, a 10 % decrease in wall thickness and the high growth rate can decrease the margin by more than 50% - Are these cases probable?	Add explanation	
	NRC	**7-15**	**24**	Why was the 21:1 aspect ratio only used for the large bending moment cases?	Add explanation	
	NRC	**7-15**	**35**	Same comment as 7-10 line 28	Add explanation	
	NRC	**7-16**	**7**	Earlier it was stated that only two of the wolf creek surge flaws were enveloped with the 21:1 surge nozzle flaw. How are the three wolf creek flaws applied in the crack growth analyses?	Add explanation	
	NRC	**7-16**	**17**	The wolf creek flaws may not have been growing rapidly in the depth direction, but may have been growing rapidly in the length direction, as indicated by the Phase 1 results.	Please modify sentence	
	NRC	**8**		The same comments given above apply to the conclusion section		
	NRC	**8-2**	**31-33**	Cases CS1b (SMF = 1.03 at TW leakage) and CS2b (3 days to SMF=1.2) do not support the statement that the results met the evaluation criteria with additional margin	Revise to reflect actual results.	
	NRC	**A1-7**	**Table 2-1**	There are some numbers in Table 2-1 of the probabilistic study in Appendix A that we believe are not correct. Calvert 2 had indications in the CL drain and the HL drain. Table 2-1has the CL drain listed as a circ indication, when it was actually an axial indication, as documented in LER 2005-001-00. The HL drain had 2 axial flaws attributed to PWSCC and a circumferential that was attributed to original construction once the original radiographs were digitized (this fact was not listed in the LER, but we have first hand information on this item). Also, the depths and lengths were not measured for these flaws, as the procedure used was not qualified for length or depth measurement for this size nozzle. It is unclear where the numbers for the flaw information come from. We also checked Calvert 1 in Table 2-1 with the information Constellation sent to us in their flaw evaluation. The HL Drain thickness is 0.54, not 0.375; the surge nozzle thickness is 1.6", not 1.3, and the relief indication length was 0.6" not 0.000".	This is a high number of inaccuracies in 5 indications. It calls into question the accuracy of the remaining information in this table. We recommend that all the data in the table be verified for accuracy and a portion of section 2.1 be devoted to data accuracy and verification.	
	NRC	**General**	**-**	Supplementary analyses need to be provided for NRC review.	Provide supplementary analyses as soon as possible to expedite NRC's review.	
	NRC	**References**	**-**	References are needed to expedite NRC's review.	Provide references as soon as possible to expedite NRC's review.	