LBB Meeting with the NRC
October 28, 2010

LEAK-BEFORE-BREAK EVALUATION OF OVERLAID ALLOY 82/182 WELDS

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Overview

- Background
- Application of structural weld overlay on nozzle to safe end weld regions
- LBB reevaluation with structural weld overlay on Alloy 82/812 welds
- Conclusions

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Background

- General Design Criteria 4 (GDC-4) of 10CFR50 requires postulation of pipe breaks and provisions of appropriate protection
- Double-Ended Guillotine Break (DEGB) is highly unlikely
- Nuclear industry worked with the NRC to eliminate the Double-Ended Guillotine Break (DEGB) from the structural design basis

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Background

- Concept of Leak-Before-Break (LBB) was developed
- LBB approach is accepted by the NRC as a technically justifiable approach for eliminating, from the structural design basis, postulation of DEGB

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Background

- Leak-Before-Break approach has been adopted in various high-energy lines including primary loop piping and pressurizer surge lines
- A cracking incident occurred in the V. C. Summer primary loop piping at the Alloy 82/182 weld metal in early October 2000
- The cracking occurred due to the primary water stress corrosion cracking (PWSCC)

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Background

- One of the mitigation approaches for PWSCC is to apply the Structural Weld Overlay (SWOL) over the Alloy 82/182 dissimilar metal weld in the nozzle safe-end regions
- In the U.S several plants with LBB have already applied structural weld overlay to the pressurizer nozzles dissimilar metal weld locations

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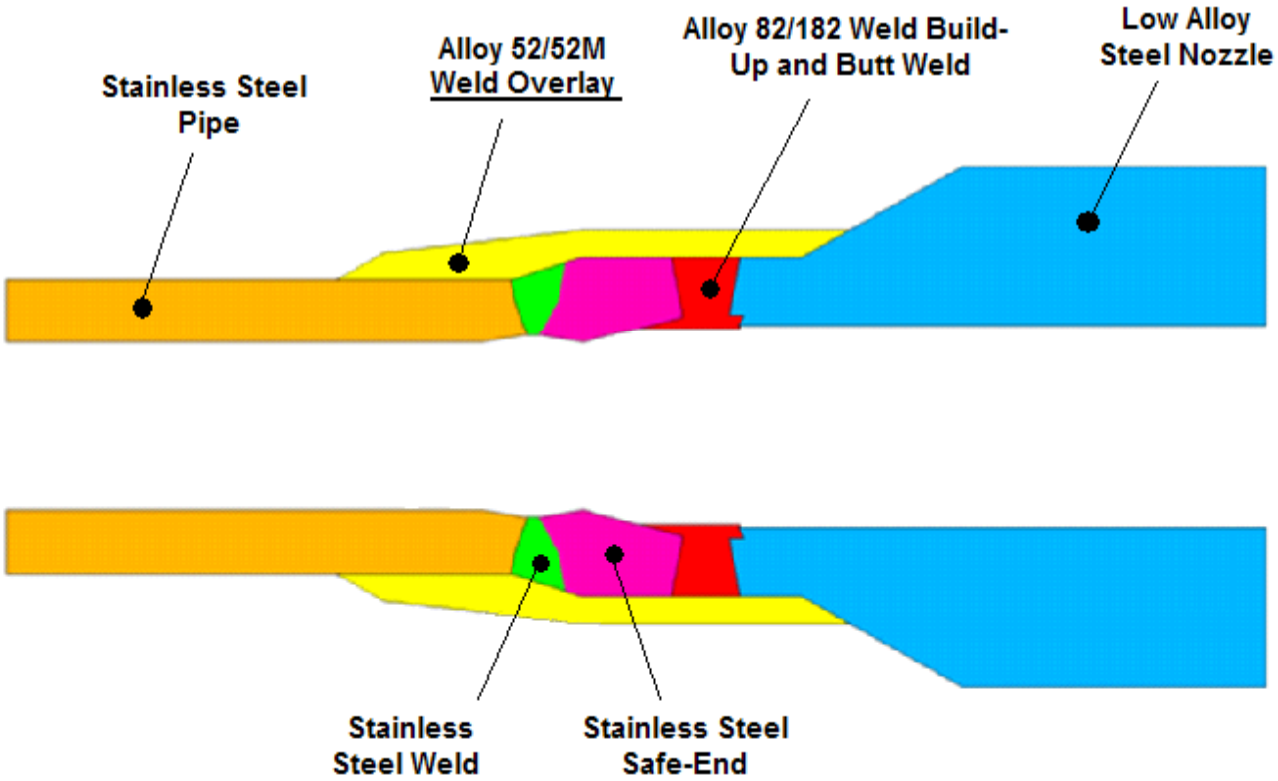
Application of Structural Weld Overlay



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Background

- Alloy 52/52M is considered highly resistant to PWSCC, IGSCC and TGSCC
- Application of structural weld overlay provides a structural barrier against PWSCC
- Structural weld overlay also produces compressive residual stress at the inner surface of the nozzle/safe end region (Alloy 82/182 welds) that mitigates future crack initiation and/or propagation

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Structural Weld Overlay Analysis

- As a part of the structural weld overlay application analyses are performed to:
  - Demonstrate that SWOL results in a favorable through-wall residual stress profile to mitigate PWSCC
  - Demonstrate acceptable Fatigue crack growth results
  - Demonstrate that SWOL meets the ASME Code criteria

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Application of Structural Weld Overlay

- Westinghouse NSSS and CE designed plants with approved LBB have Alloy 82/182 welds at:
  - RV inlet and outlet nozzle locations for some plants
  - Pressurizer surge nozzle locations for some plants (CE plant has at surge nozzle and hot leg nozzle locations)
  - SG inlet and outlet nozzle locations for one plant

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LBB Criteria Documents

- Standard Review Plan: Public Comments Solicited; 3.6.3 Leak-Before-Break Evaluation Procedures; Federal Register/Vol.52, No. 167/ Friday, August 28, 1987/Notices, pp. 32626- 32633
- NUREG-0800 Revision 1, March 2007, Standard Review Plan: 3.6.3 Leak-Before-Break Evaluation Procedures
- NUREG-0800 Revision 1 allows PWSCC to be considered as an active degradation mechanism in Alloy 600/82/182 welds in PWR plants for LBB

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LBB Analysis Margins

- Margin of 10 on leak rate
- Margin of 2 on flaw
- Margin on load of 1 (by absolute summation method of faulted load combination)

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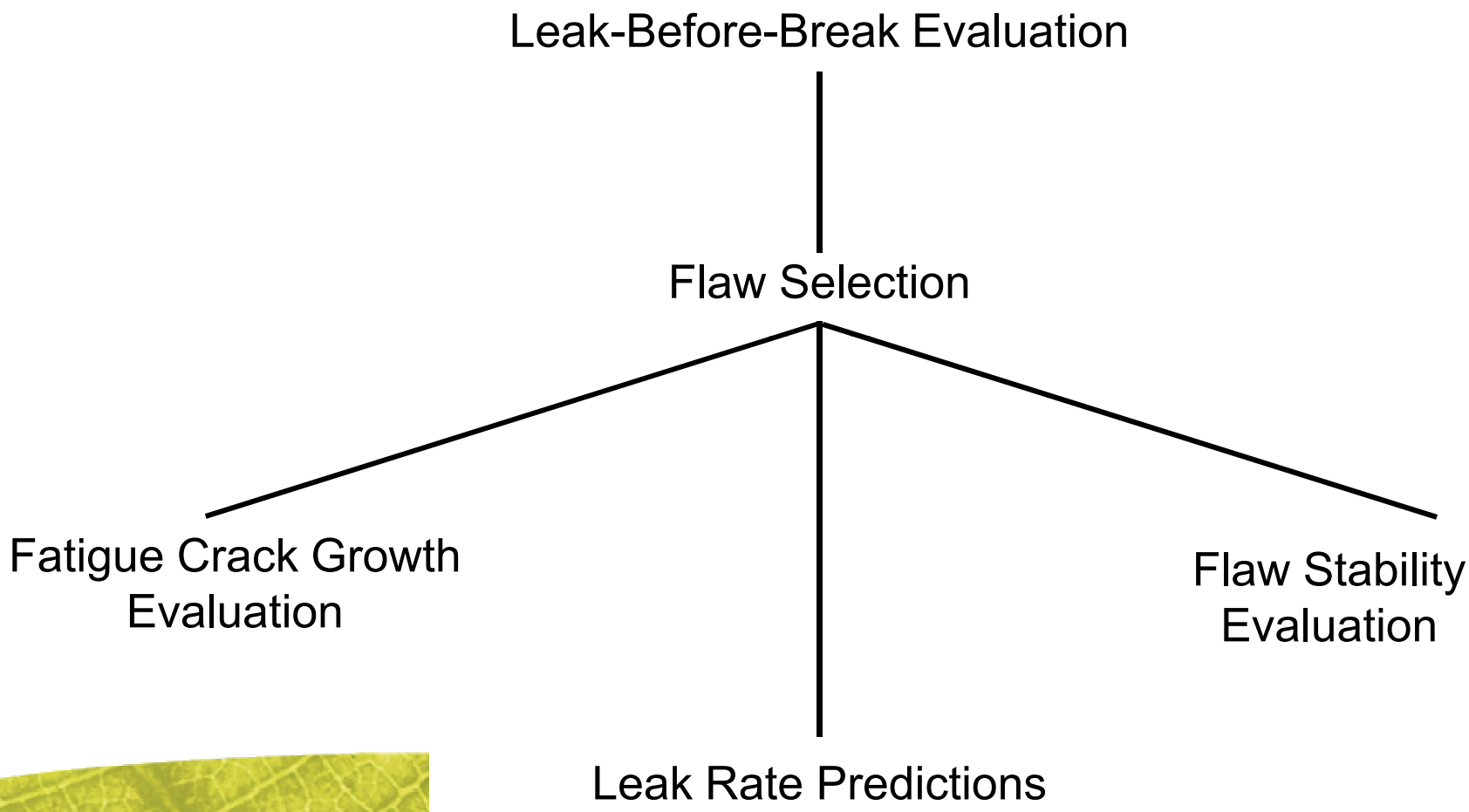
Initial LBB Methodology



LBB Analysis Basic Steps

- Through-wall circumferential flaws are postulated
- Normal operating loads are used to calculate the leakage flaw size
- Algebraic summation method is used to obtain lower bound normal loads (conservative)
- Faulted loads are used to calculate the critical flaw size
- Absolute summation method is used to combine faulted loads (conservative)

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LBB Analysis Basic Steps

- Leak rate calculations are performed with normal loads to determine a leakage flaw size for a leakage of 10 times the leak detection capability of the plant
- Critical flaw size is calculated for the faulted loads and margin on flaw size (critical flaw size/leakage flaw size) is determined

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LBB Analysis Basic Steps

- Postulate surface flaw and perform FCG assessment to show that the through-wall growth will not occur
- Demonstrate the LBB margins
- LBB analysis steps are the same with weld overlay and without weld overlay

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LBB with SWOL- Critical Flaw Size

- Material properties for Alloy 82/182 welds and Alloy 52 weld were developed by Westinghouse for weld overlay application
- Based on the SRP 3.6.3 for high toughness material (Alloy 82/182 or Alloy 52 welds) thermal expansion loads or Z-factors should not be considered for critical flaw size determination
- Critical flaw size was determined by limit load method

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Available PWSCC Crack Morphology Information

- D. Rudland, R. Wolterman, G. Wilkowski, R. Tregoning, "Impact of PWSCC and Current Leak Detection on Leak-Before-Break," proceedings of Conference on Vessel Head Penetration, Inspection, Cracking, and Repairs, Sponsored by USNRC, Marriot Washingtonian Center, Gaithersburg, MD, September 29 to October 2, 2003 (same information was also in PVP2005-71200 paper)
- Based on the study a penalty factor of 1.69 was developed between the PWSCC vs Fatigue crack morphology effects on the leakage flaw size determination
- PWSCC crack morphology parameters used in this study were conservative

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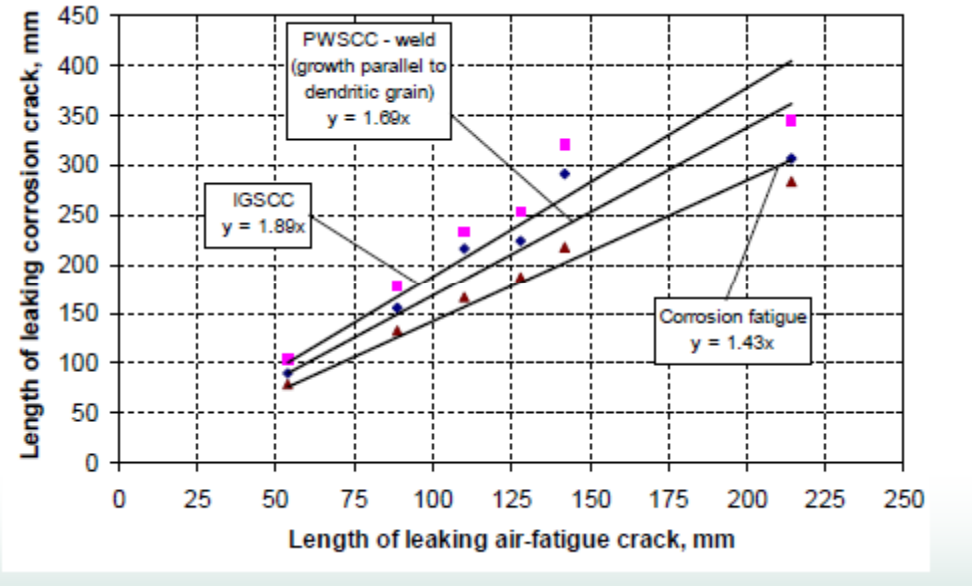
Available PWSCC Crack Morphology Information



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Available PWSCC Crack Morphology Information

- A.D Nana, K.K Yoon, PVP2006-ICPVT11-93767, “Comparison of Leak Rates from Alloy 82/182 Butt Weld Cracks for Leak-Before-Break Applications”

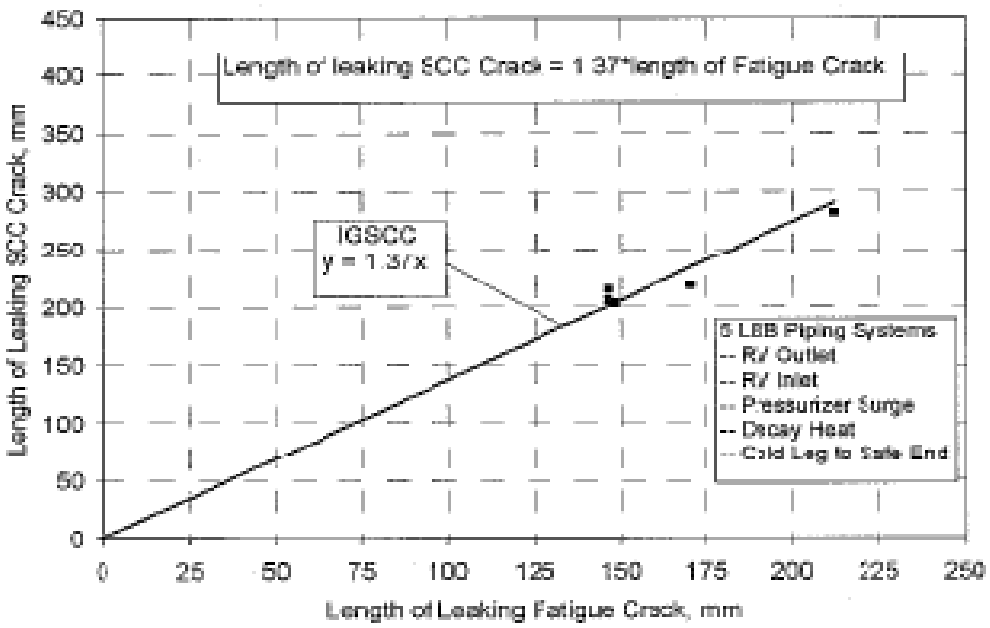

Figure 5 Predicted Length of SCC Crack over Length of Fatigue Crack

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LBB with SWOL- Leakage Flaw Size

- PWSCC crack morphology conservatively applied to Alloy 82/182 welds
- Fatigue crack morphology is applied to the Alloy 52/52M weld
- PWSCC crack morphology penalty factor of 1.69 applied to Alloy 82/182 welds conservatively
- Alloy 52/52M welds have no penalty factor (a penalty factor of 1.0) since fatigue crack morphology applies

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LBB with SWOL-Leakage Flaw Size

- An estimated effective penalty factor was developed to perform the leak rate calculations for two layers of material
- Effective penalty factor = $[(P_1 \times t_1) + (P_2 \times t_2)]/ t_{total}$ where:

  P_1 =penalty factor of 1.69 for Alloy 82/182 welds

  P_2 = penalty factor of 1 for Alloy 52/52M welds

  t_1 = base material thickness for Alloy 82/182 welds, t_2 = SWOL thickness for Alloy 52/52M welds, t_{total} = total thickness (Alloy 82/182 plus Alloy 52/52M)

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LBB Evaluation with SWOL

- The through-wall leakage flaw using fatigue crack morphology parameters was determined first with total thickness
- The calculated leakage flaw size was then increased by the estimated effective penalty factor to obtain leakage flaw size for the PWSCC effects
- Margin on flaw size was determined

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LBB Evaluation with SWOL

- The margin between the critical flaw size and the leakage flaw size was satisfied
- A margin of 10 on leak rate was also satisfied
- Margin on loads of 1 was also satisfied since the faulted loads are combined by the absolute summation method

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Conclusions

- Westinghouse performed the LBB reevaluation of the SWOL at pressurizer surge line nozzle dissimilar metal weld locations
- Based on the LBB reevaluation, it has been confirmed that the LBB conclusions remain valid after SWOL application at the dissimilar metal weld location for the pressurizer surge lines

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Licensing Aspects

- NUREG-800, Rev.1 SRP 3.6.3 allows PWSCC to be considered as an active degradation mechanism.
  - Acknowledges the consideration of PWSCC effects.

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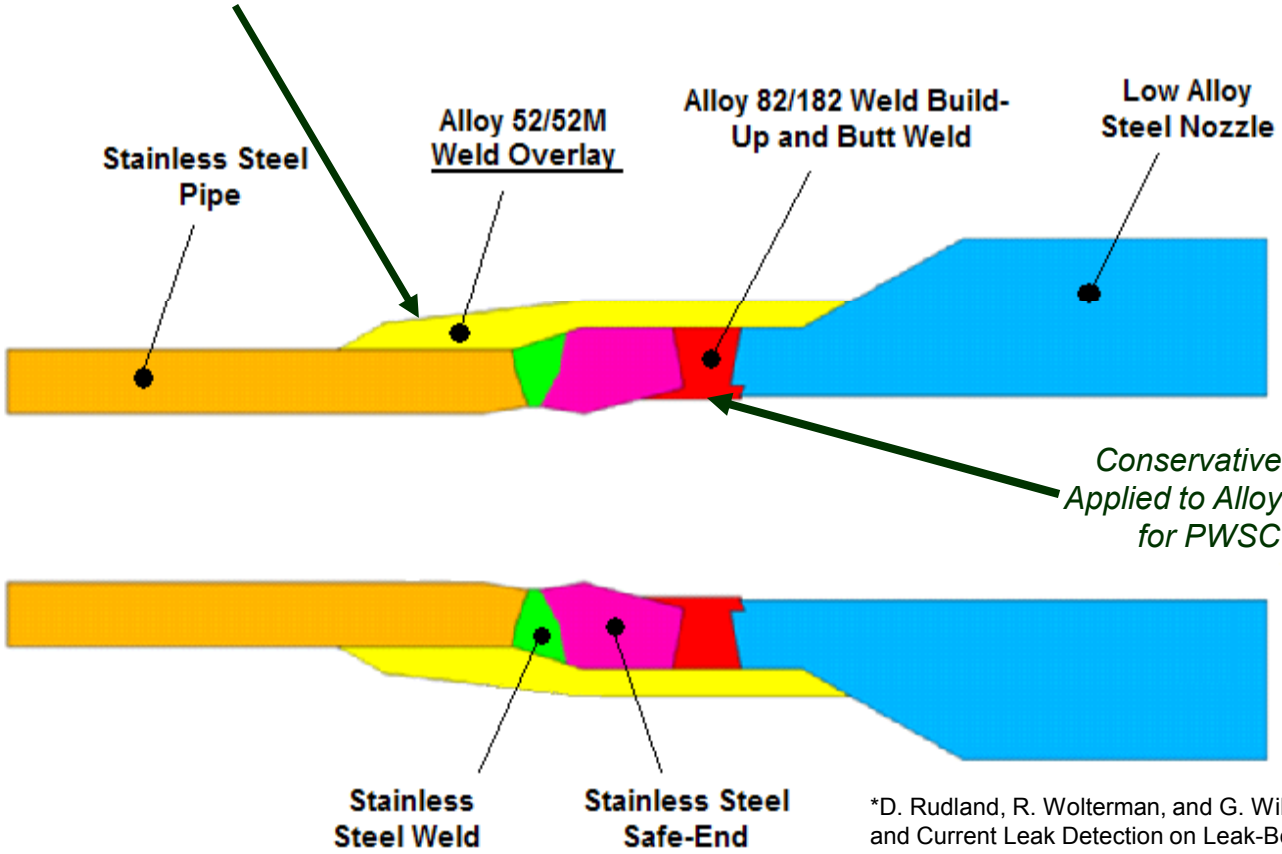
Crack Morphology of Structural Weld Overlay

Fatigue Crack Morphology Parameters Applied to Calculate Leakage Flaw Size of Alloy 52/52M Weld Overlay



Conservative Penalty Factor of 1.69 Applied to Alloy 82/182 Weld To Account for PWSCC Crack Morphology*

*D. Rudland, R. Wolterman, and G. Wilkowski , "Impact of PWSCC and Current Leak Detection on Leak-Before-Break Acceptance", 2005 ASME Pressure Vessels and Piping Division Conference

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PWSCC Penalty Factor

- *Penalty Factor of 1.69* Applied to 82/182 Weld to Account for PWSCC Crack Morphology*

(*D. Rudland, R. Wolterman, and G. Wilkowski, *"Impact of PWSCC and Current Leak Detection on Leak-Before-Break Acceptance*", 2005 ASME Pressure Vessels and Piping Division Conference. This paper was written as part of a Battelle Program that was conducted for the NRC-RES Materials Engineering Branch, Division of Engineering Technology.)

- Crack morphology parameters describe the properties of a crack such as the crack roughness, number of turns and are used to calculate leakage crack length. It was determined in the program stated above that leakage flaw length in PWSCC increases 69 percent over fatigue crack length.

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Original LBB Analysis and LBB/SWOL Analysis

Original LBB Analysis

- Fatigue Crack Morphology Parameters Applies to Calculate Leakage Flaw Size in Alloy 82/182 Welds.

LBB/SWOL Analysis

- Same methodology as original LBB analysis applied.
- Penalty factor applied to Alloy 82/182 Welds fatigue crack morphology parameters to account for PWSCC.

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50.59 Evaluation Approaches of LBB/SWOL Analysis

- Input Change (Approach 1)
  - The LBB/SWOL analysis applied the same methodology used in previously NRC approved LBB analysis.
  - Fatigue Crack Morphology Parameters were used in LBB/SWOL analysis just as they were used in the original LBB analysis.
  - Conservative factor was applied to Alloy 82/182 parameters to account for PWSCC.
  - Per NEI Guide 96-07, Revision 1, the following is not considered a departure from a method of evaluation:

    "Use of a methodology revision that is documented as providing results that are essentially the same as, or more conservative than, either the previous revision of the same methodology or another methodology previously accepted by NRC through issuance of an SER."

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50.59 Evaluation Approaches of LBB/SWOL Analysis

- Screen in Approach as a Methodology Change (Approach 2)
  - Per NEI Guide 96-07, Revision 1, "...licensees can make changes to elements of a methodology without first obtaining a license amendment if the results are essentially the same as, or ***more conservative*** than, previous results."

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Thank You

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