Status of U.S. NRC Research Activities for Alloy 690/52/152 Crack Growth Rate Testing

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U.S. Nuclear Regulatory Commission

2015 Meeting – International Cooperative Group for Environmentally Assisted Cracking

Ann Arbor, MI – May 17-22, 2015

The views in this presentation of those of the authors, not necessarily those of the U.S. Nuclear Regulatory Commission.

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Motivation for NRC-Testing Program

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- Establish independent and confirmatory technical basis for inspection requirements of nickel-based alloy components and welds
- Support an efficient and effective process for making regulatory decisions on issues such as relief requests and ASME Code actions
- Leverage resources to benefit complementary research programs, such as initiation testing and peening

Recent Regulatory Issues

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- Relief requests and proposed revisions to ASME Code Case (CC) N729 for inspections of upper heads
- Relief requests and proposed revisions to CC N770 for inspection of welds with overlay, inlay, or onlay
- Relief requests for control rod drive and bottom-mounted instrument half nozzle repairs
- Topical Report and CC N847 for excavation and weld repair (EWR)

NRC Research Prioritization Approach

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- Reviewed and updated testing priorities for 2015-2018 timeframe considering operating and new reactors
- Identified data gaps which are affecting licensing actions, for instance leading to the issuance of requests for additional information
- Communicated with industry counterparts to identify issues of common interest and where coordination is appropriate
- Following progress of Alloy 690 Expert Panel

NRC Research Prioritization Approach (cont.)

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- Low priority issues – NRC believes there are adequate data (pending further deliberation by Expert Panel) or data are not needed for near-term licensing determinations
  - Effects of cold work on base Alloy 690
  - Alloy 690 heat affected zone susceptibility
  - New weld metal variants (e.g., 52MSS, 52i)
  - Low temperature crack propagation

- High priority issues – NRC believes there are data gaps affecting near-term licensing determinations
  - Weld dilution
  - Weld repairs
  - Weld defects
  - Overlays, inlays, onlays
  - Weld strains and heat-to-heat variations

Recent Work on Alloy 690

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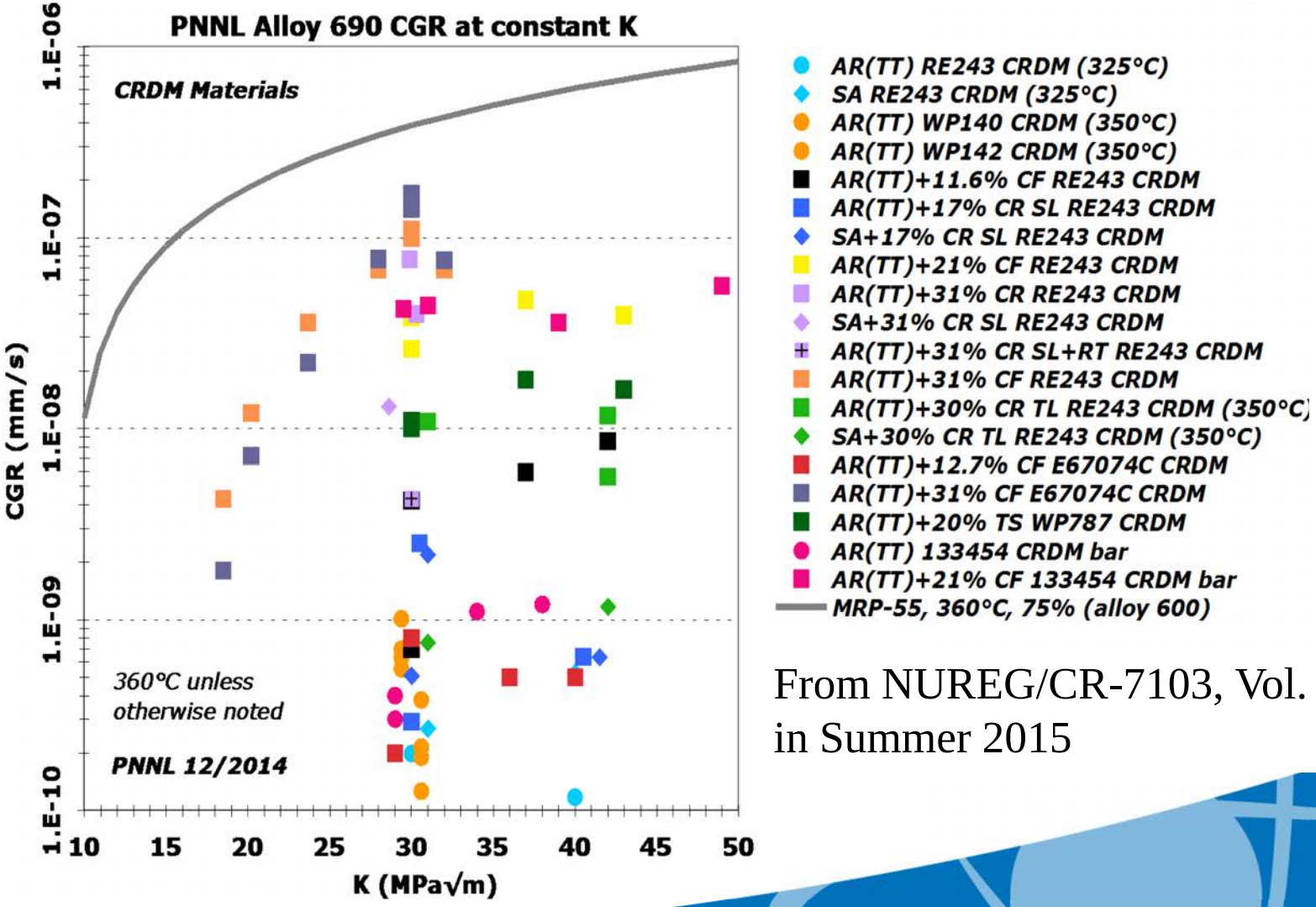
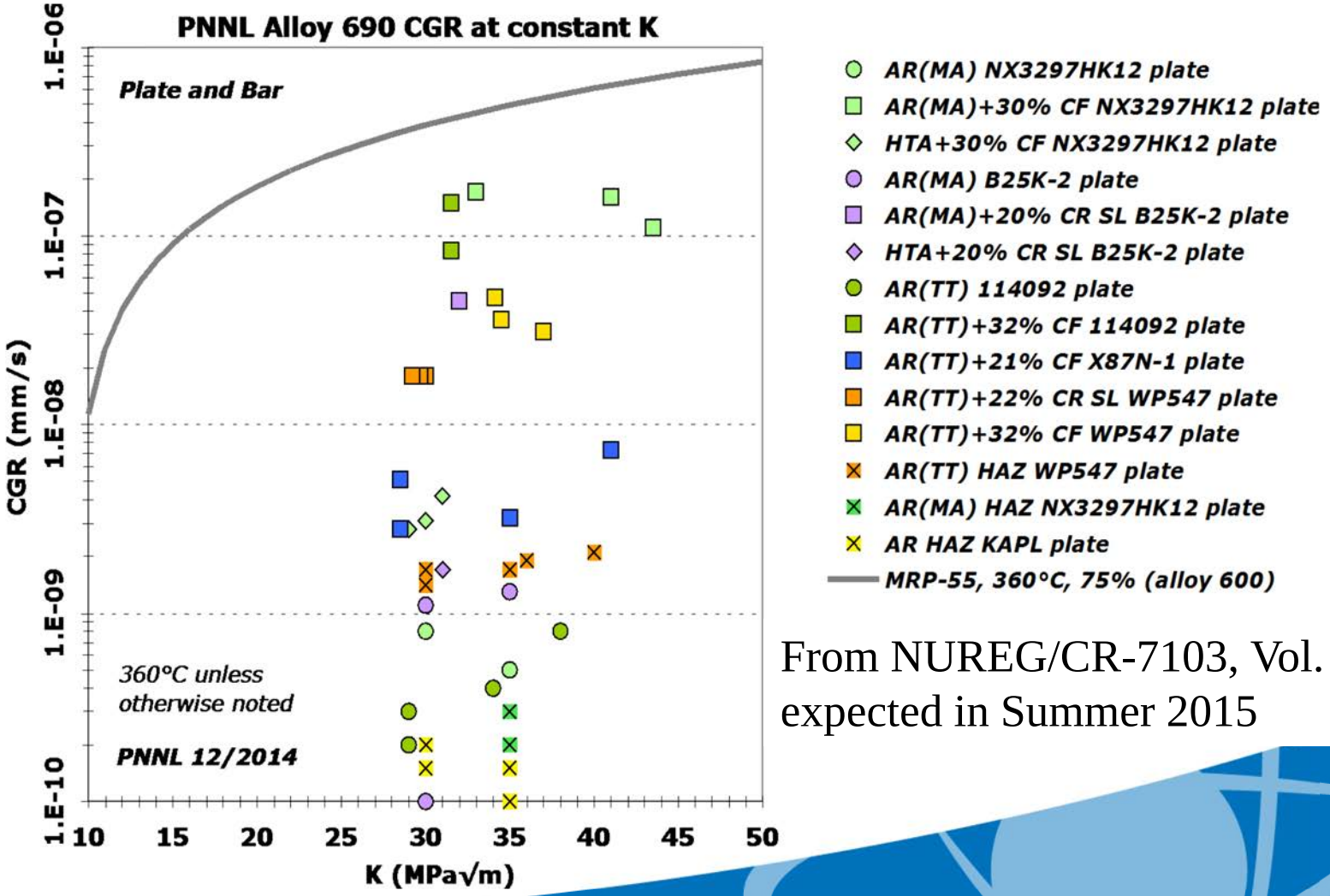
- Testing approach:
  - PNNL systematic study on effects of cold work on Alloy 690 involving 35+ specimens from 10+ heats
  - ANL also tested multiple heats of as-received Alloy 690
- Key findings:
  - As-received material is highly resistant to cracking
  - Prior thermo-mechanical treatment influences material response to cold work
  - Crack growth rates that would be of structural significance for current licensing period are only evident at cold work above ~15%
  - Little evidence of enhanced susceptibility in HAZ

PNNL Alloy 690 CRDM Data



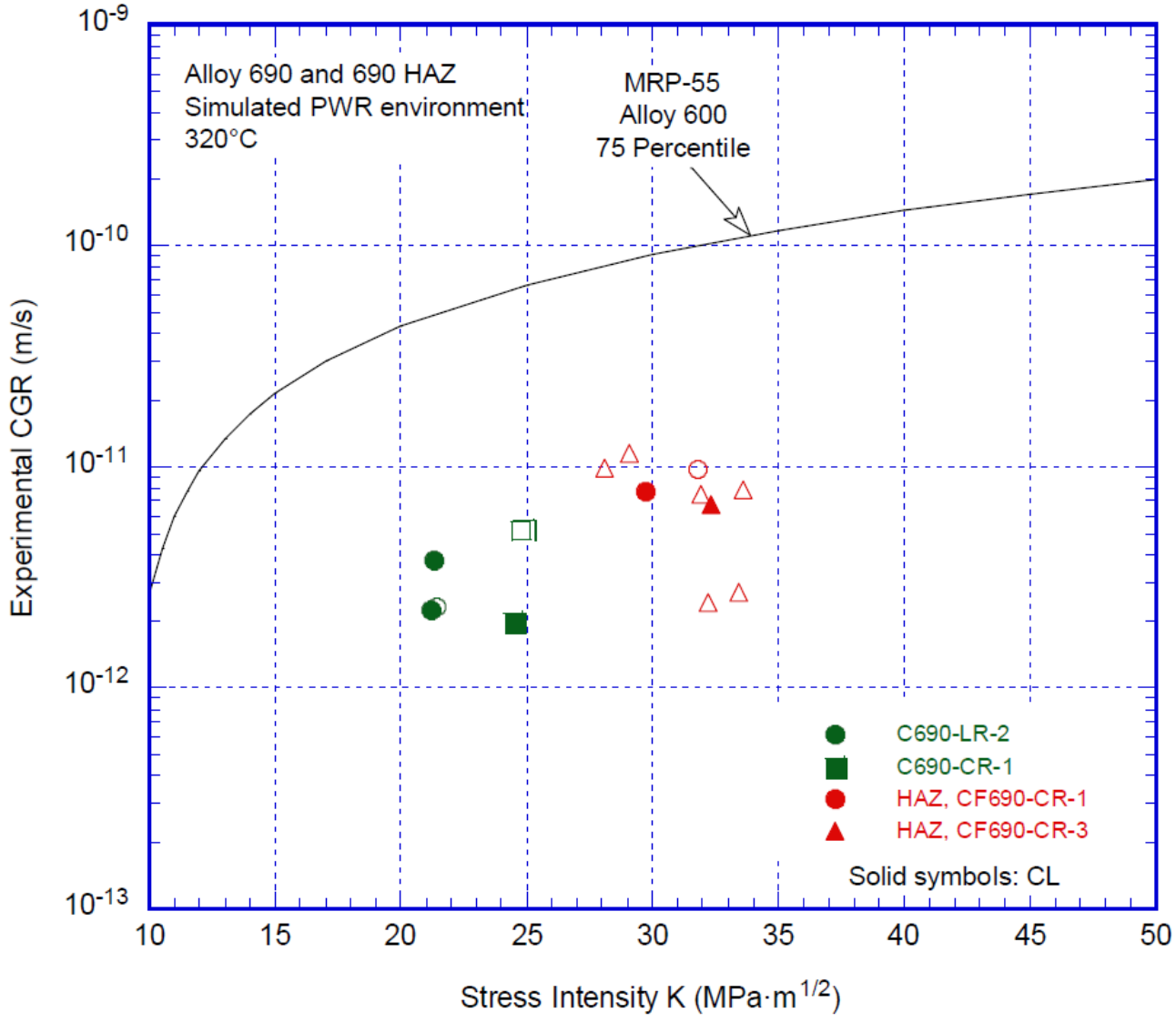
From NUREG/CR-7103, Vol. 3, expected in Summer 2015

PNNL Alloy 690 Bar/Plate + HAZ Data



From NUREG/CR-7103, Vol. 3, expected in Summer 2015

ANL Alloy 690 Data



Weld Dilution

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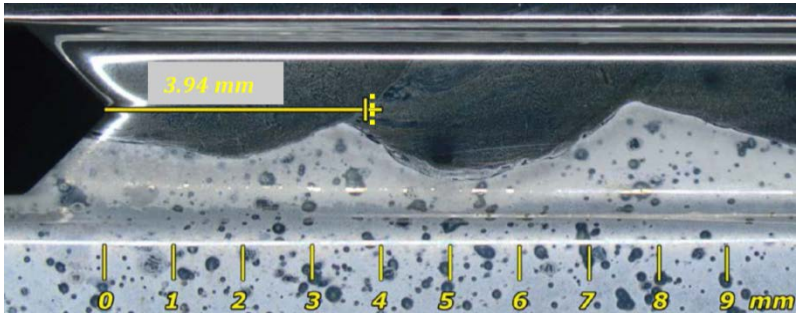
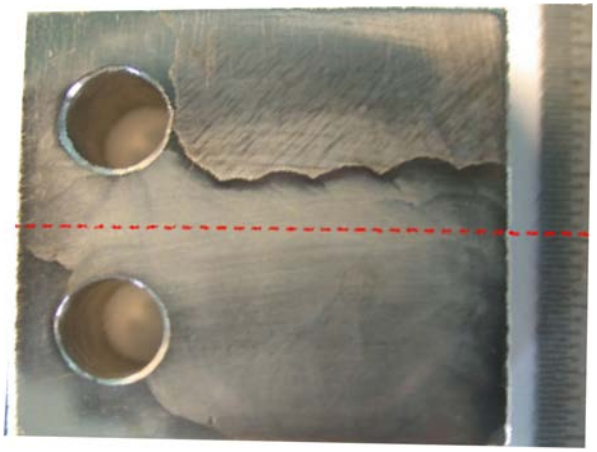
- Uncertain how chemical composition and microstructural features in dilution region affect susceptibility
- Crack growth rate > 10^{-7} mm/s reported by ANL for 152/low alloy steel (LAS) dilution
- Further testing of ANL 152/LAS welds at ongoing PNNL and the second weld layer ongoing at ANL
- Further testing needed for Alloy 52/152 to LAS/SS welds

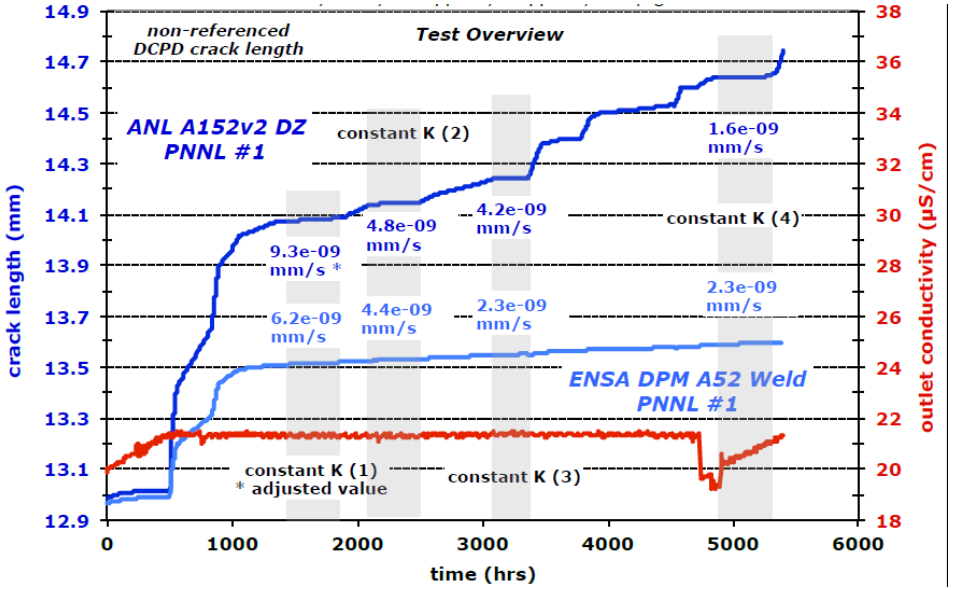
Weld Dilution – Ongoing Tests



Side image of Alloy 152 (top)/LAS (bottom) weld in test at PNNL



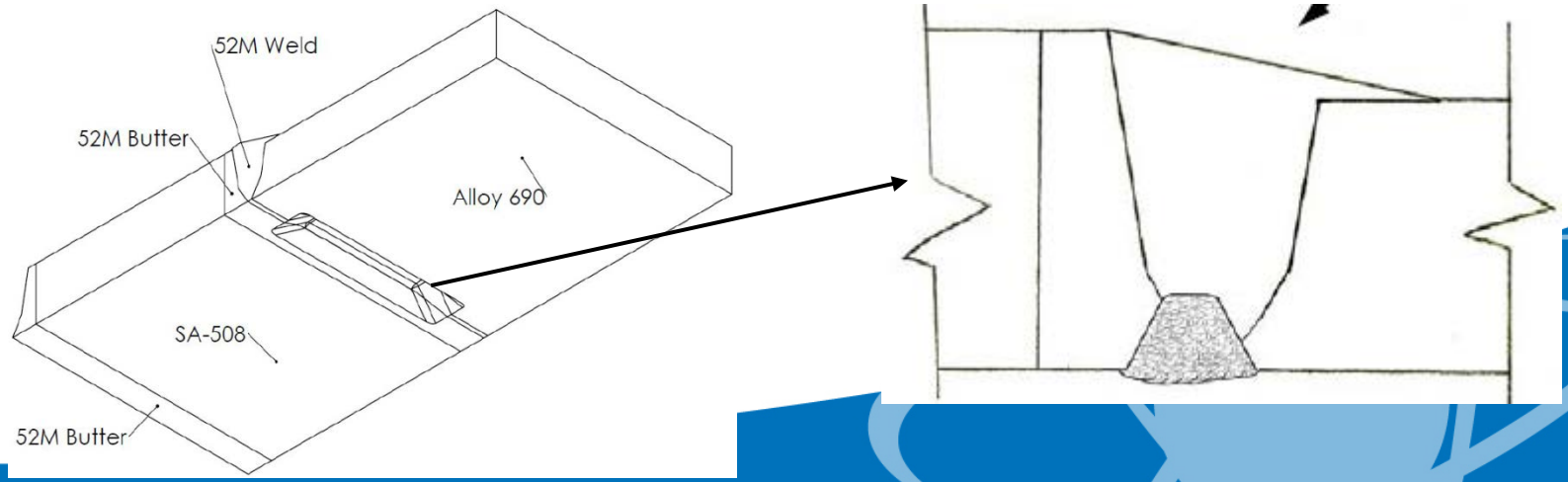
Position of Alloy 152 (bottom)/LAS (top) weld in test at ANL



In-progress CGR data for Alloy 152/LAS weld in test at PNNL

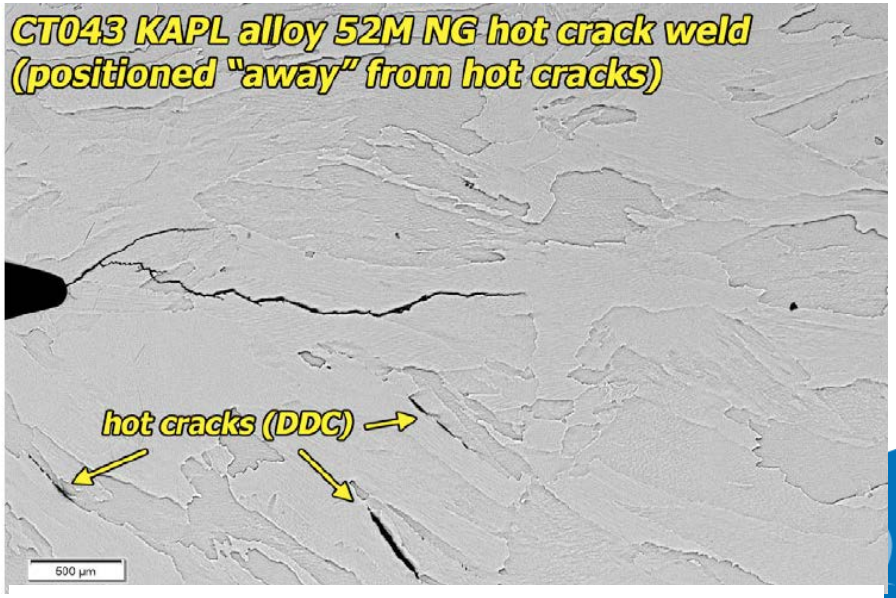
Weld Repairs

- NRC is currently reviewing EPRI topical report on EWR
- Testing of repair weld mockups is intended to complement weld residual stress modeling
- Specimens from EPRI temper bead and 20% ID repair weld are at ANL and PNNL for testing. Additional mockups are needed.



Weld Defects

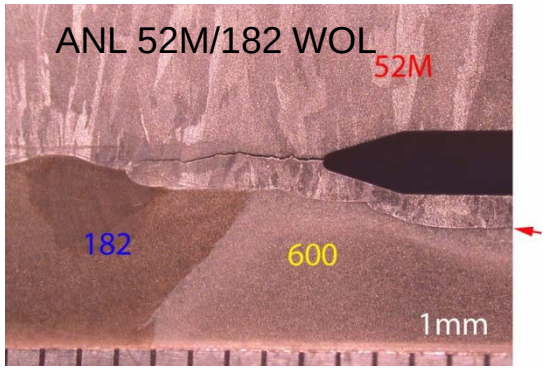
- Effects of pre-existing solidification and ductility dip cracks have not been well-established by prior NRC testing
- Issue is of mutual interest for crack growth rate and initiation test programs
- Mockups with controlled cracking characteristics are needed for systematic testing

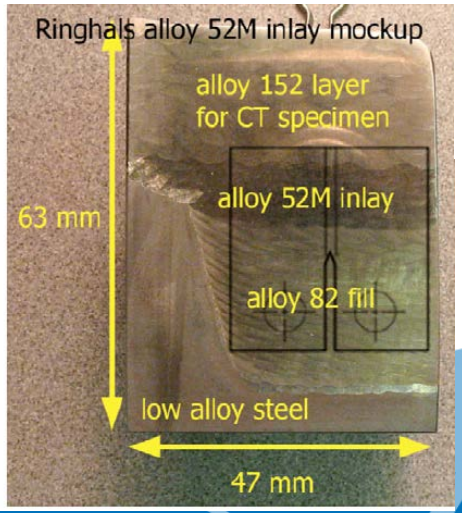


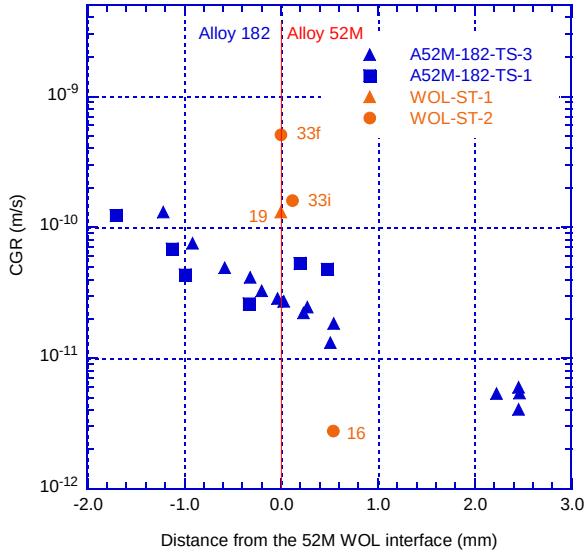
Prior PNNL testing on weld with DDC

Overlays, Inlays, Onlays

- Cracking behavior near interfaces between base material and overlays, inlays, or onlays has not been well-established by prior NRC testing
- Crack growth rates >10^{-7} mm/s reported by ANL for 52M/182 overlay.
- Testing normal to and along interface with additional mockups is needed







Figures from previous ANL and PNNL testing

Weld Strain and Heat-to-Heat Variation

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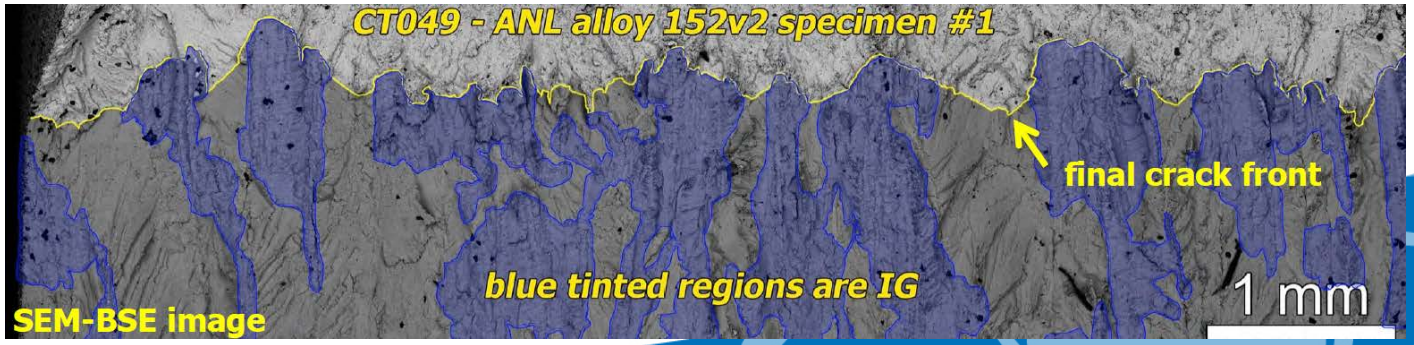
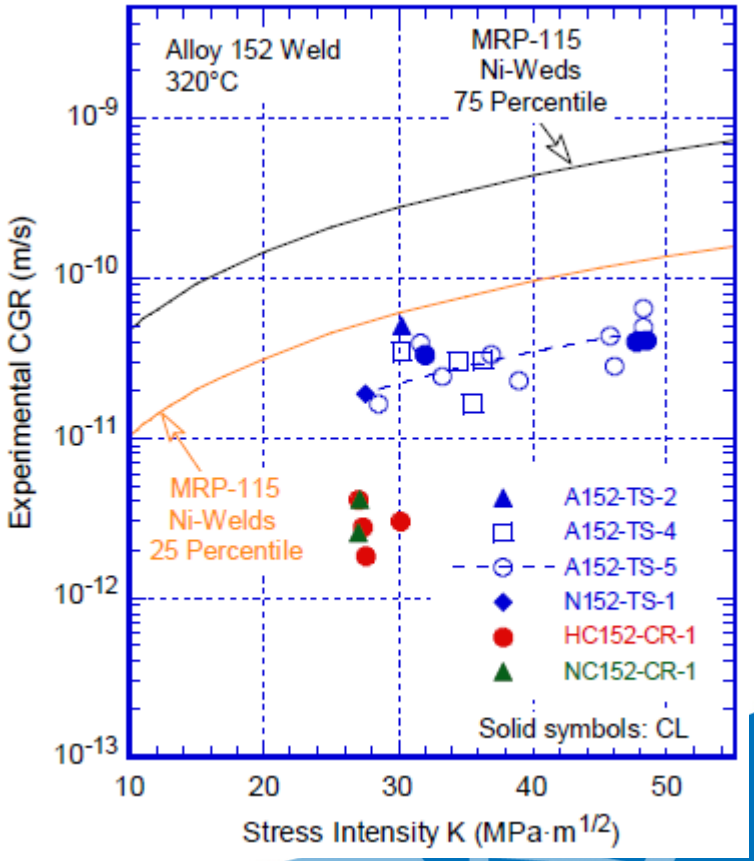
- Uncertainties remain with respect to behavior of Alloy 52/152 weld metals
- High engagement is reported for specimens even with low measured crack growth rate
- Effects of warm or hot work compared to cold work are not well-established.



ANL Recent/Ongoing Tests for Alloy 52/152

- MHI Alloy 52 on Sumitomo Alloy 690 tube – complete
- MHI Alloy 152 for Keuwanee mockup – complete
- ANL Alloy 152, normal and high current – complete
- MHI Alloy 52 on Sumitomo Alloy 690 tube , 20% CF – ongoing



Alloy 690 Expert Panel

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- NRC supports Alloy 690 Expert Panel via Memorandum of Understanding with EPRI
- Primary participation is through NRC contractors at ANL and PNNL who are members of Expert Panel
- Engagement limited to issues of testing methodologies and data quality, not data application
- NRC will review findings of Expert Panel for applicability to licensing actions and for determination of further research needs

Summary

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- NRC continues to support active research program for Alloys 690/52/152
- High-priority research issues for 2015-2018 timeframe include weld dilution, weld defects, weld repairs, overlay/inlays/onlays, weld strains, and weld heat-to-heat variations
- NRC is participating in the Alloy 690 Expert Panel and anticipates that the findings will influence licensing determinations and research prioritization