U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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

G. Oberson, M. Audrain, J. Collins, E. Reichelt

2017 Annual Meeting – International Cooperative Group for Environmentally Assisted Cracking

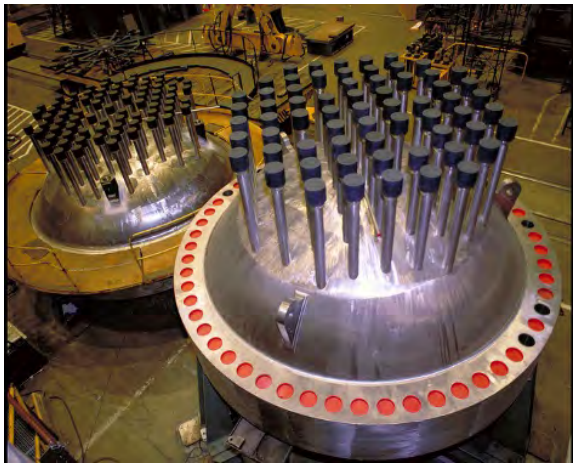
May 7 – 12, 2017

Chester, United Kingdom

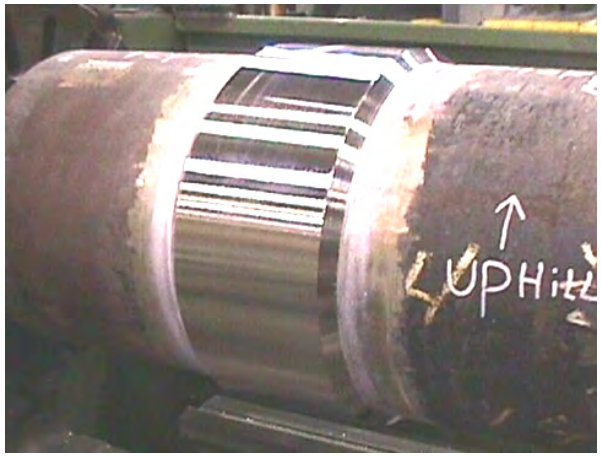
Motivations for NRC Research

- 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

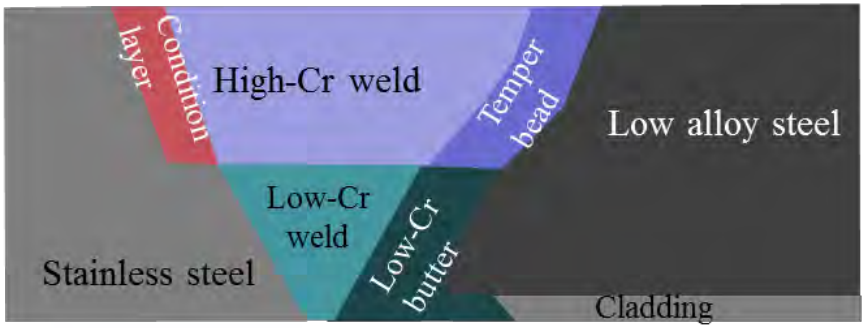
Regulatory Interface



Code Case (CC) N729-1 – upper head inspections



CC N770-1 – piping weld inspections



CC N847 – excavation and weld repair

Half-nozzle repairs

Overall Testing Status

- Alloy 690
  - NUREG/CR on cold worked Alloy 690 by Pacific Northwest National Laboratory published in July 2016 (NRC ADAMS Number ML16190A072)
  - NRC will perform additional testing of very limited amount of cold worked material with reported high crack growth rate
  - Future testing needs may be identified based on emergent knowledge gaps or plant operating experience

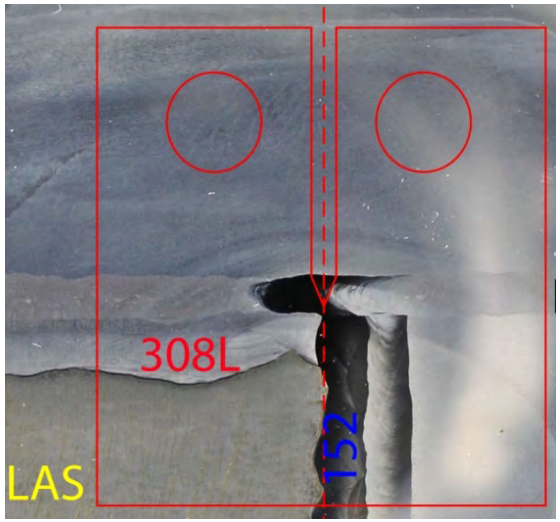
- Alloy 52/152 weld metals
  - Key area for current testing
  - NUREG/CR on weld interface testing by Argonne National Laboratory planned for publication in Summer 2017
  - Presently anticipate sustained level of effort through end of 2018

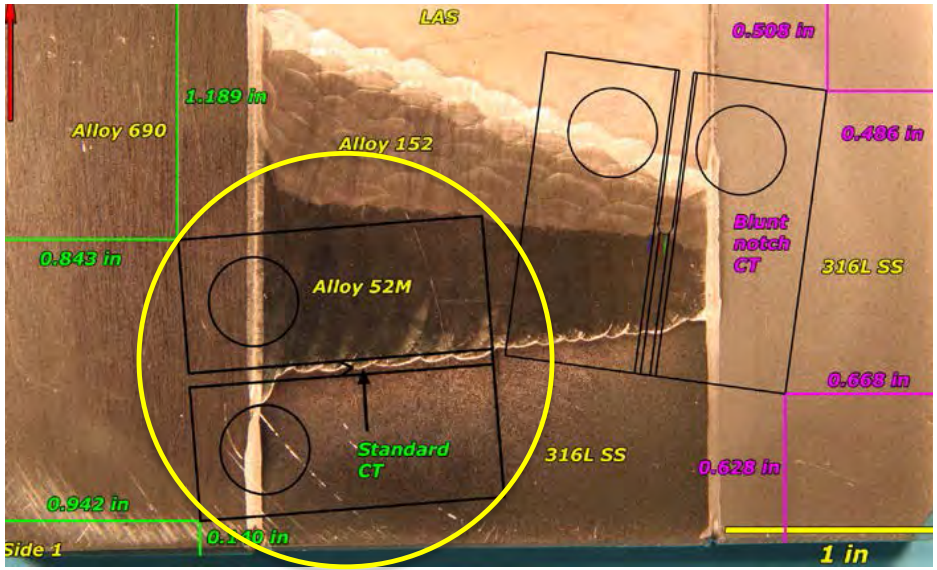
Knowledge Gaps

Issue	Current Data Availability (High/Medium/Low)	Priority for Additional Testing (High/Medium/Low)
Weld dilution	Medium	High
Weld overlays/ inlays/onlays)	Medium	High
Weld repairs	Low	High
Weld flaws	Low	High
Welding parameter variations	Medium	Medium
Weld heat-to-heat variations	High	Medium
Alloy 690 cold work	High	Low
New weld metal variants	Low	Low

Weld Dilution

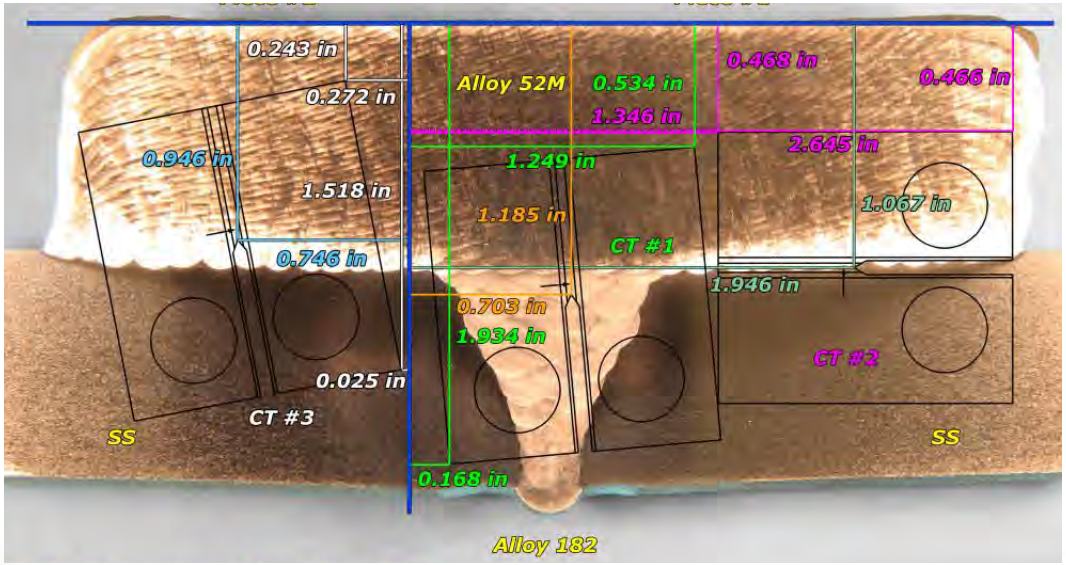
- Previous testing has focused on Alloy 52/152 welds to stainless, low-alloy, and carbon steel
- High crack growth rates (~10^{-7}mm/s) measured for Alloy 152 at low-alloy steel interface but low crack growth in other cases
- Anticipate tests of additional four to six specimens of Alloy 52/152 welds to stainless and low-alloy steel

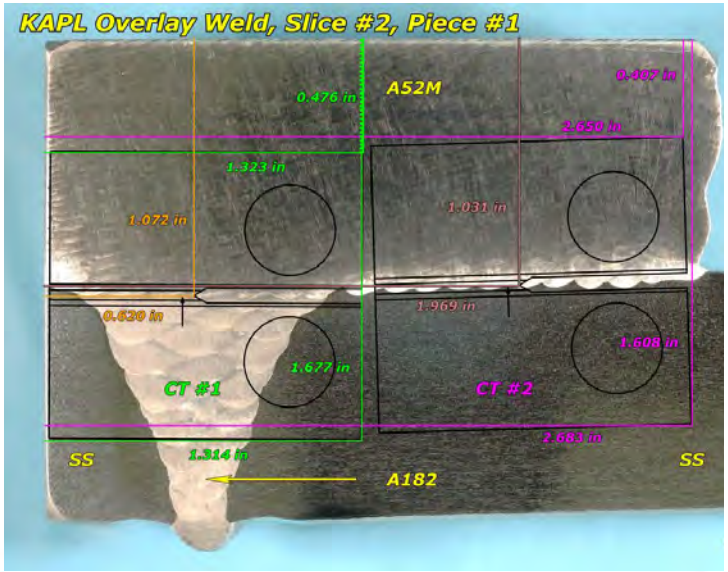




Weld Overlays/Inlays/Onlays

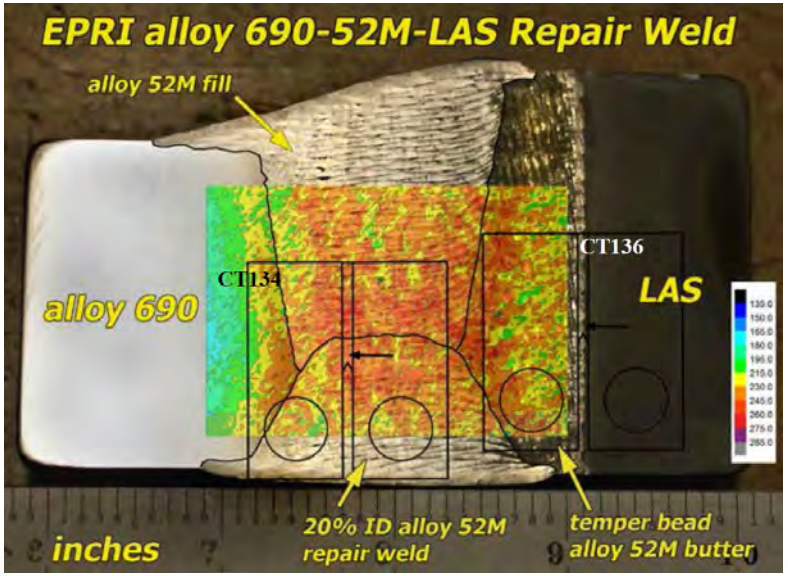
- Previous testing has focused on Alloy 52/152 overlays/inlays for Alloy 82/182 filler metal
- High crack growth rates (~10^{-7}mm/s) measured for Alloy 52M at Alloy 182 along interface, but low growth rates measured across interface
- Anticipate tests of additional six to eight specimens of Alloy 52/152 weld overlays/inlays/onlays to Alloy 82/182





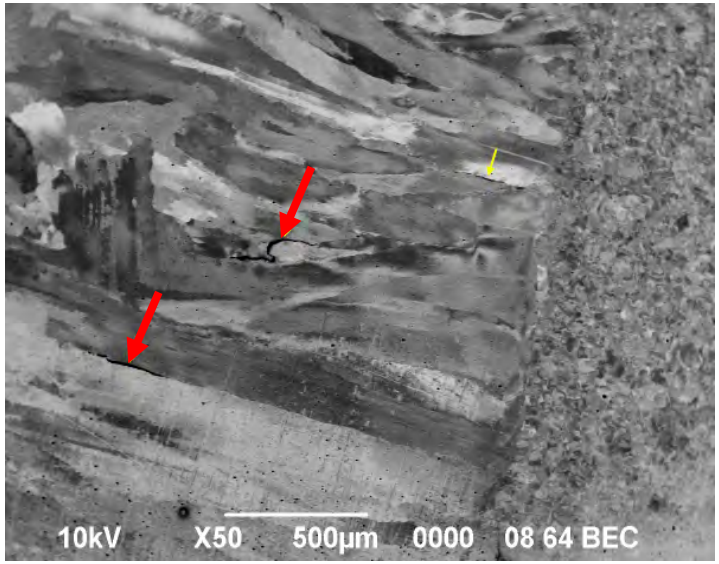
Weld Repairs

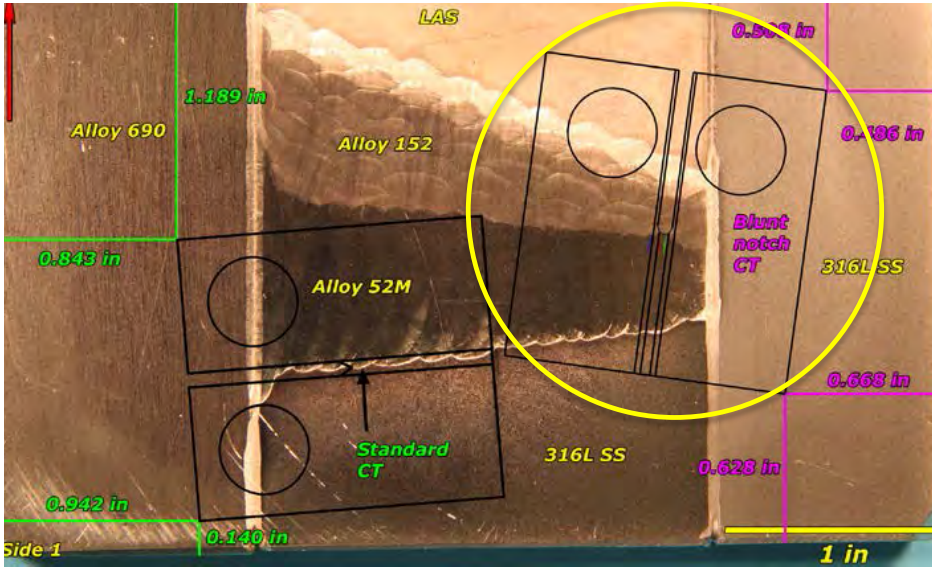
- Tests on two specimens from a 20% inner diameter repair weld made by EPRI have been completed to date and showed low crack growth rates
- Effects of repairs on Alloy 52/152 welds are not fully understood, but they appear to increase the hardness in the weld
- Tests on at least one more repair weld mockup are anticipated – currently in procurement process



Weld Flaws

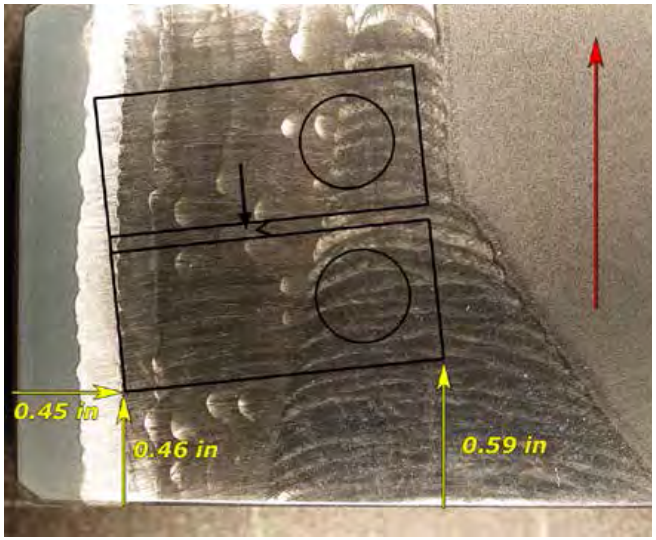
- Previous attempts have been made to test welds with fabrication defects
- No effect on cracking susceptibility was determined but alignment of cracking direction with respect to defects was not ideal
- Anticipate tests of additional two to three specimens of Alloy 52/152 with ductility dip cracks or hot cracks – blunt notch testing





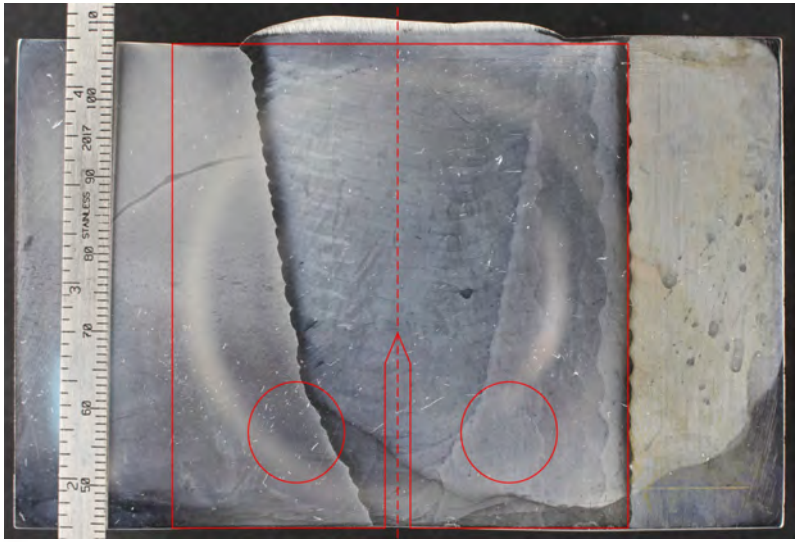
Weld Heat-to-Heat Variations

- Significant amount of testing has been done on typical Alloy 52/152 weld filler metal
- Testing of Alloy 52/152 filler metal shows generally very low crack growth rate but in some cases with high intergranular engagement
- Anticipate testing of additional three to five specimens, primarily as dual-loaded with higher value specimens



Welding Parameter Variations

- No systematic effects of welding parameters on Alloy 52/152 cracking susceptibility have been identified
- Primary NRC interest is on bounds of “typical” parameters (e.g., highest heat input) used in plant welds
- Anticipate testing at least two specimens from high heat input Alloy 52M weld made by Electric Power Research Institute (EPRI)

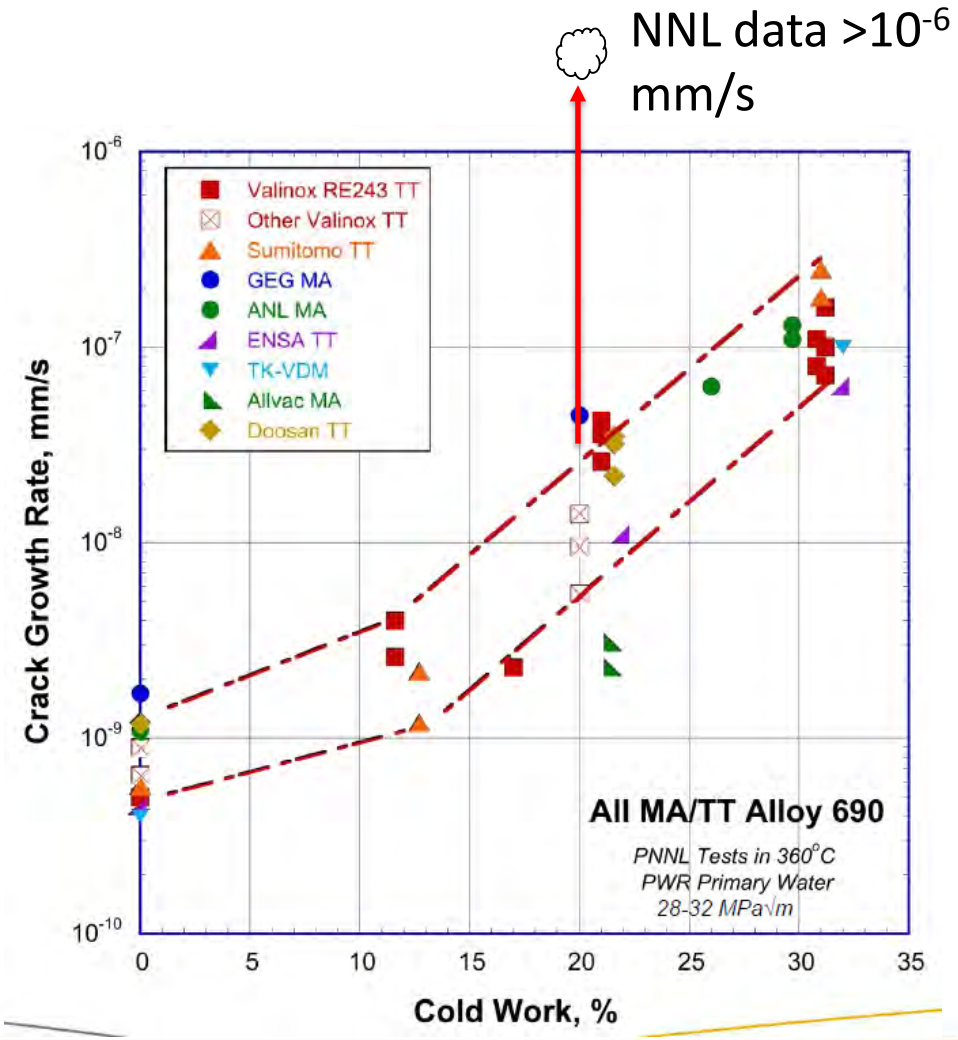


Parameter	Root	Layer 2-13	Layer 14-30
Current (amp)	190/120	235/175	235/175
Voltage (V)	10.8/0	11.4/0	11.4/0
Travel Speed (in/min)	2.4	2.4	2.4
Pulse Freq. (Hz)	1.6	1.6	1.6
Pulse Width (%)	50	50	50

Alloy 690 Cold Work

- Data from Naval Nuclear Laboratory (NNL) for 20% cold worked material shows substantially higher crack growth rate than previously tested cold worked material

- Anticipate tests and microstructural characterization of at least two specimens of NNL material to understand behavior and relevance to field material



EPRI Alloy 690/52/152 Expert Panel

- NRC is involved in the EPRI Alloy 690/52/152 Expert Panel via a legal Memorandum of Understanding
- NRC contractors are members of the panel data evaluation group while NRC staff are only observers
- NRC involvement does not imply endorsement of Expert Panel conclusions, which may be subject to formal Staff review
- NRC anticipates that the first revision of the Expert Panel report will not address all knowledge gaps and that ongoing engagement will be needed

Summary

- NRC envisions ongoing research program for Alloys 690/52/152 at least through 2018.
- Main focus of current testing is Alloy 52/152 weld metals
- Ongoing and upcoming tests include weld interfaces, weld repairs, welds with defects, high heat input weld, and limited cold worked Alloy 690
- NRC continues to support the Crack Growth Rate Expert Panel via a Memorandum of Understanding with EPRI
- NRC anticipates further deliberations on key technical issues currently being considered by the Expert Panel