Alloy 152v2-LAS Dilution Zone PWSCC Testing

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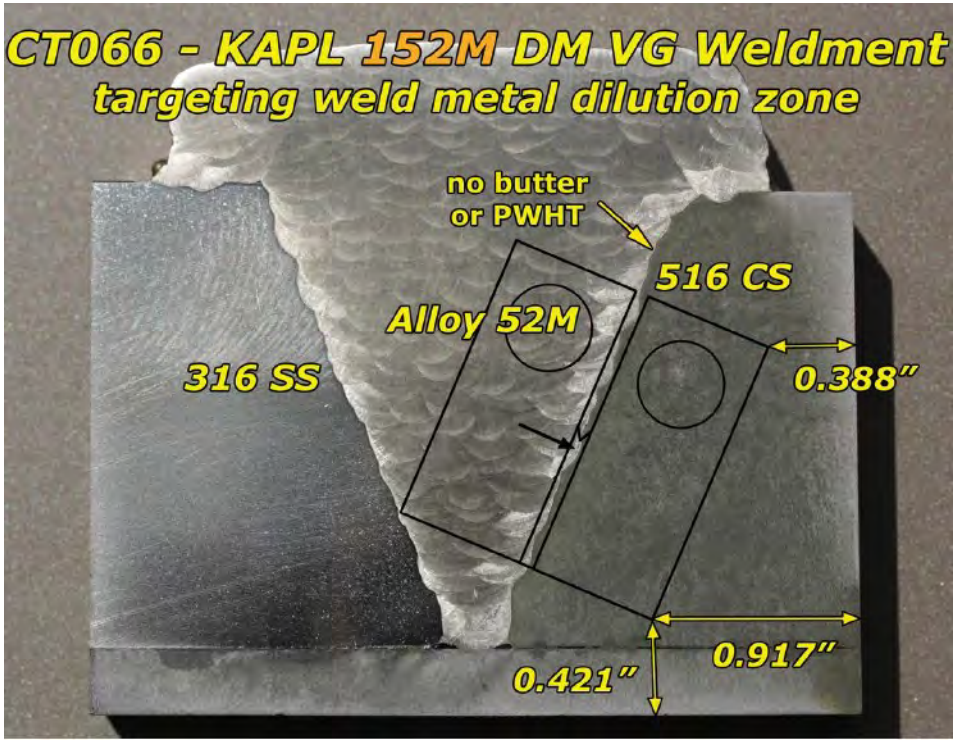
Presentation Outline

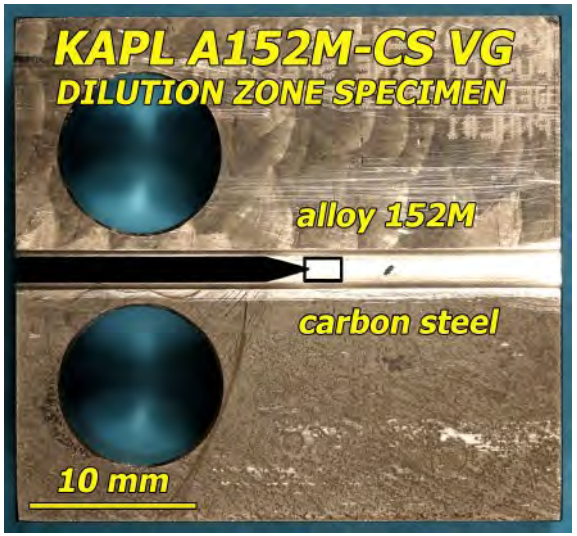
- *Prior Testing at PNNL*
  - *Constant K CGR of ≤3x10^{-9} mm/s observed in a 20Cr dilution zone*
  - *Unfavorable crack path that is nearly perpendicular to elongated weld grain boundaries*
- *Prior Testing at ANL - N152-LAS-11 Specimen*
  - *≥1x10^{-8} mm/s constant load CGR observed, substantial cracking*
  - *Crack path appears to cut across long axis of weld grains*
  - *Examination at PNNL suggests a unique IG crack path*
- *Two new ongoing SCC tests at PNNL*
  - *Testing same weldment as used for N152-LAS-11*
  - *One specimen aligned to assess same region as N152-LAS-11*
  - *Second specimen assessing a different region*

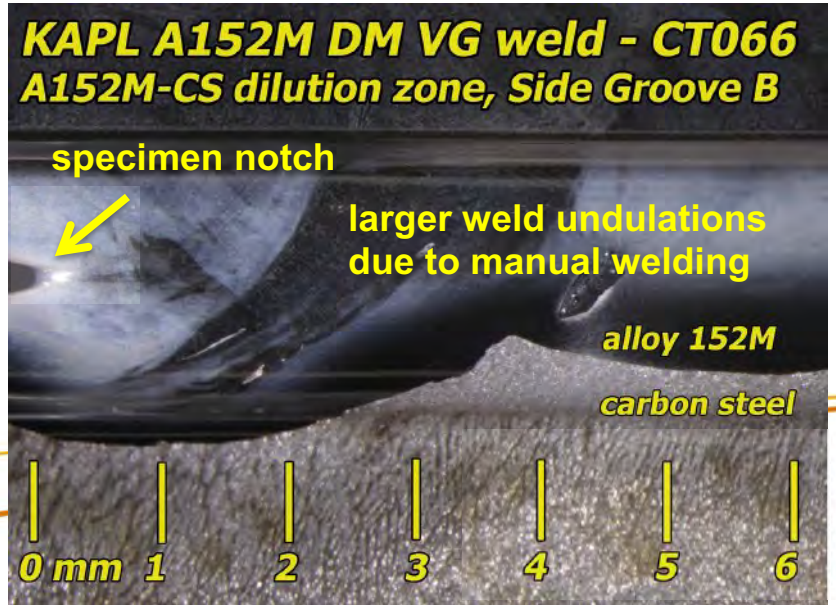
KAPL Alloy 152M-CS (CT066) Dilution Zone Specimen

Goal was to measure weld dilution zone response ~0.5-1 mm from fusion line.

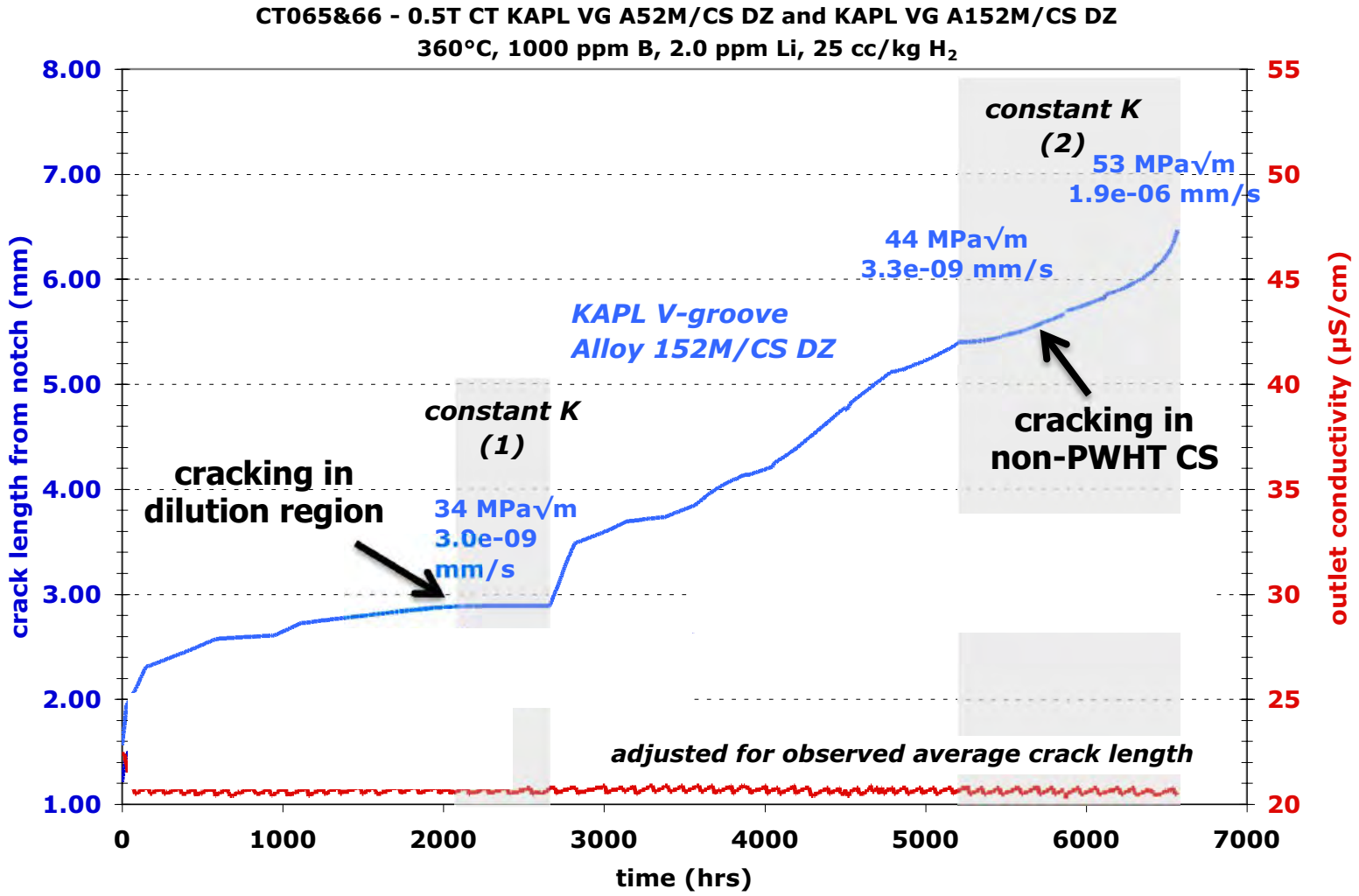
KAPL Alloy 152M weldment







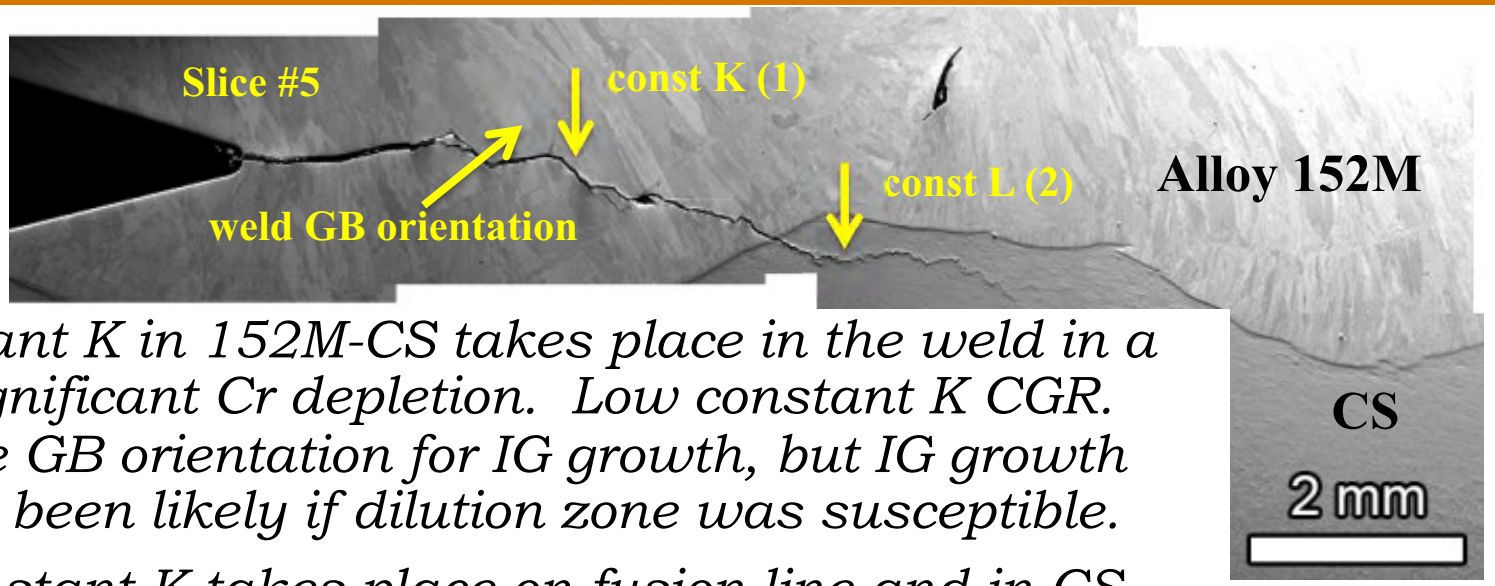
Crack Growth Test on KAPL Alloy 152M-CS Dilution Zone Specimen



Constant K response measured twice for the these specimen with high SCC rates seen at high K level in the non-PWHT CS.

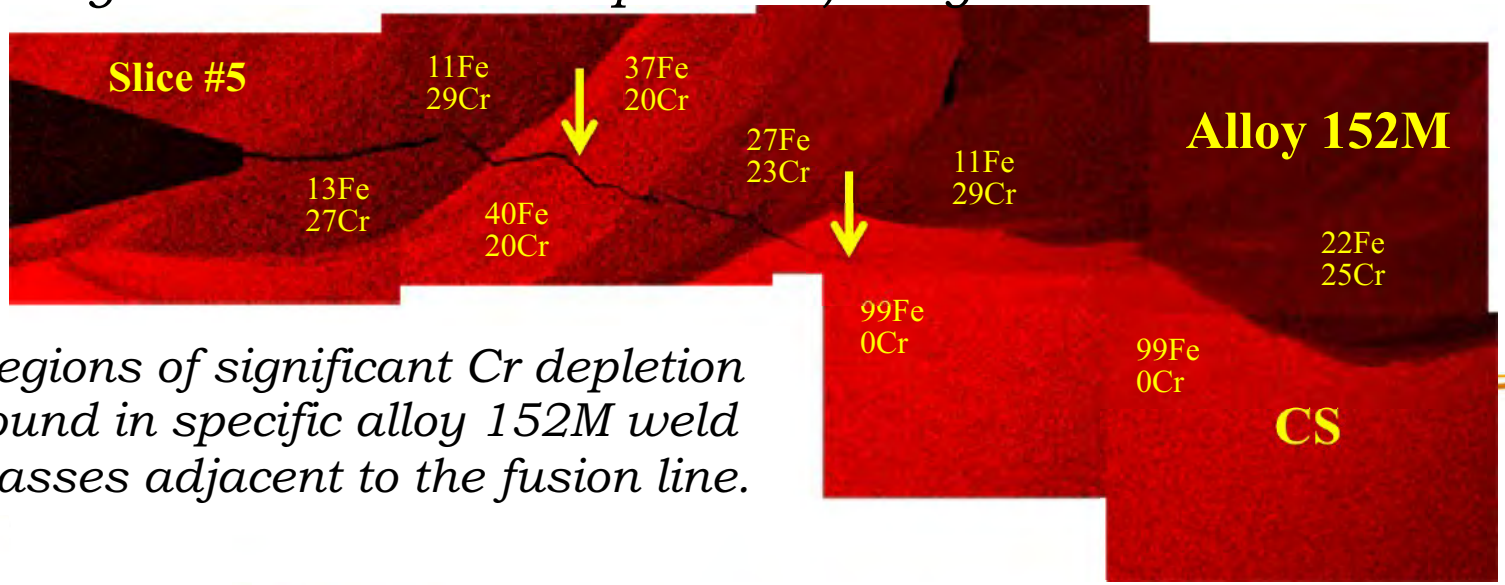
KAPL Alloy 152M-CS Dilution Zone Specimen CT066: Cross-Section

SEM BSE Image



- ***First*** *constant K in 152M-CS takes place in the weld in a region of significant Cr depletion. Low constant K CGR. Unfavorable GB orientation for IG growth, but IG growth would have been likely if dilution zone was susceptible.*
- ***Second*** *constant K takes place on fusion line and in CS HAZ (depending on location in the specimen). High CGR.*

SEM Fe-K EDS Map



Regions of significant Cr depletion found in specific alloy 152M weld passes adjacent to the fusion line.

ANL Test of N152-LAS-11 Specimen

- *Prior Testing at PNNL*
  - *Constant K CGR of ≤3x10^{-9} mm/s observed in a 20Cr dilution zone*
  - *Unfavorable crack path that is nearly perpendicular to elongated weld grain boundaries*
- *Prior Testing at ANL - N152-LAS-11 Specimen*
  - *≥1x10^{-8} mm/s constant load CGR observed, substantial cracking*
  - *Crack path appears to cut across long axis of weld grains*
  - *Examination at PNNL suggests a unique IG crack path*
- *Two new ongoing SCC tests at PNNL*
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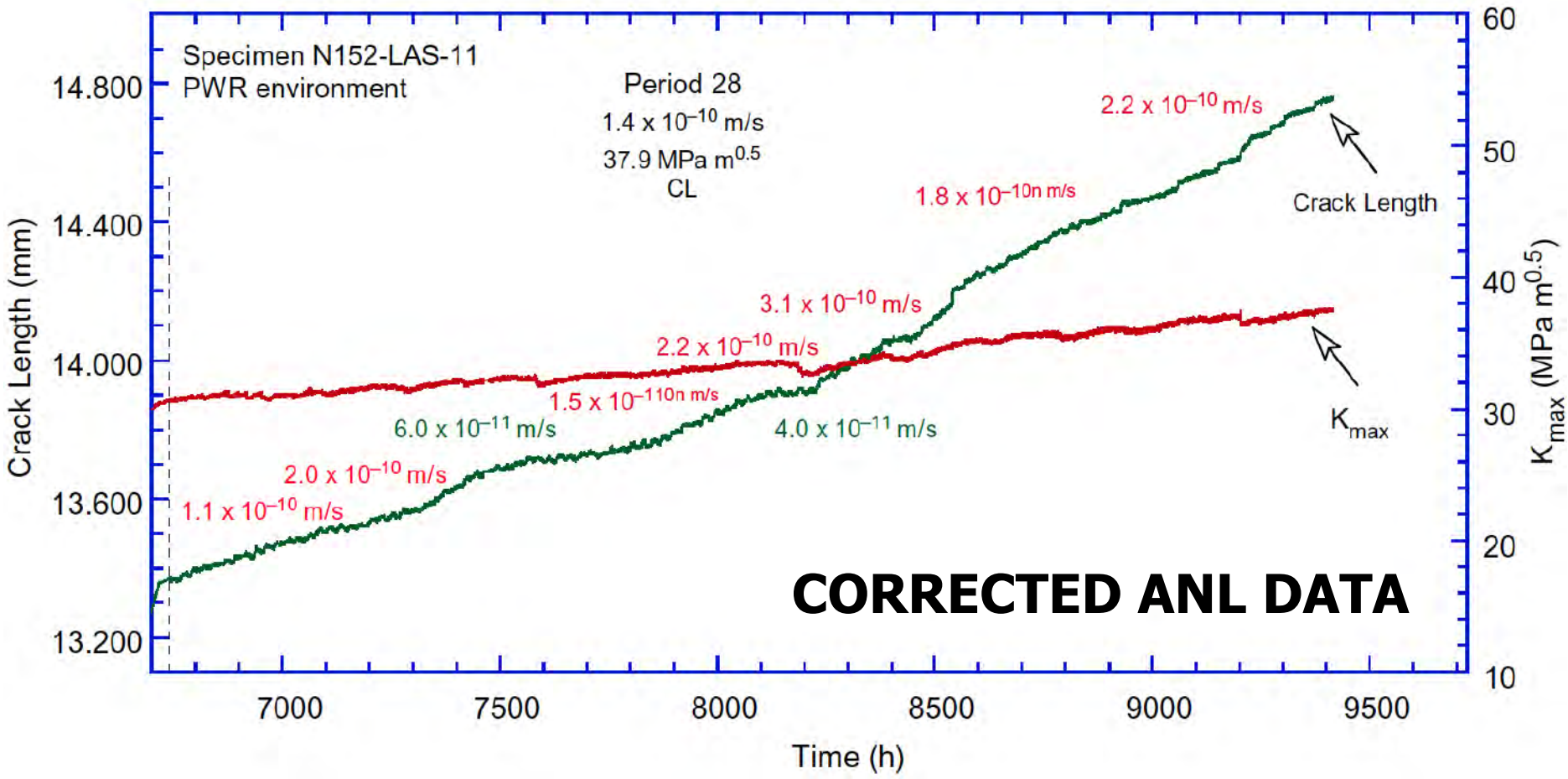
  - *One specimen aligned to assess same region as N152-LAS-11*
  - *Second specimen assessing a different region*

ANL N152-LAS-11 Specimen

- *Roughly similar alignment as for the KAPL alloy 152M-CS dilution zone specimen tested at PNNL.*

Both sides of the specimen

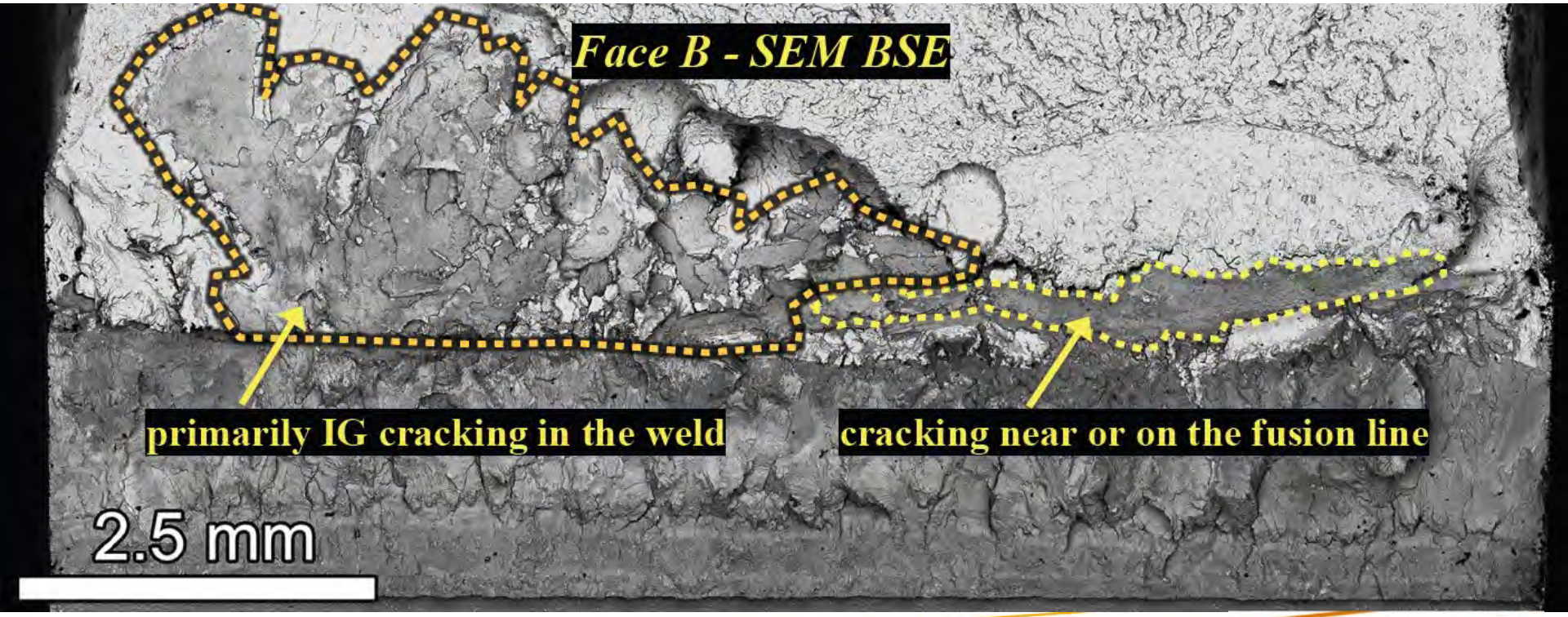
ANL Constant Load Response for N152-LAS-11 Specimen



Post-test corrected average constant load CGRs is >1x10^{-7} mm/s.

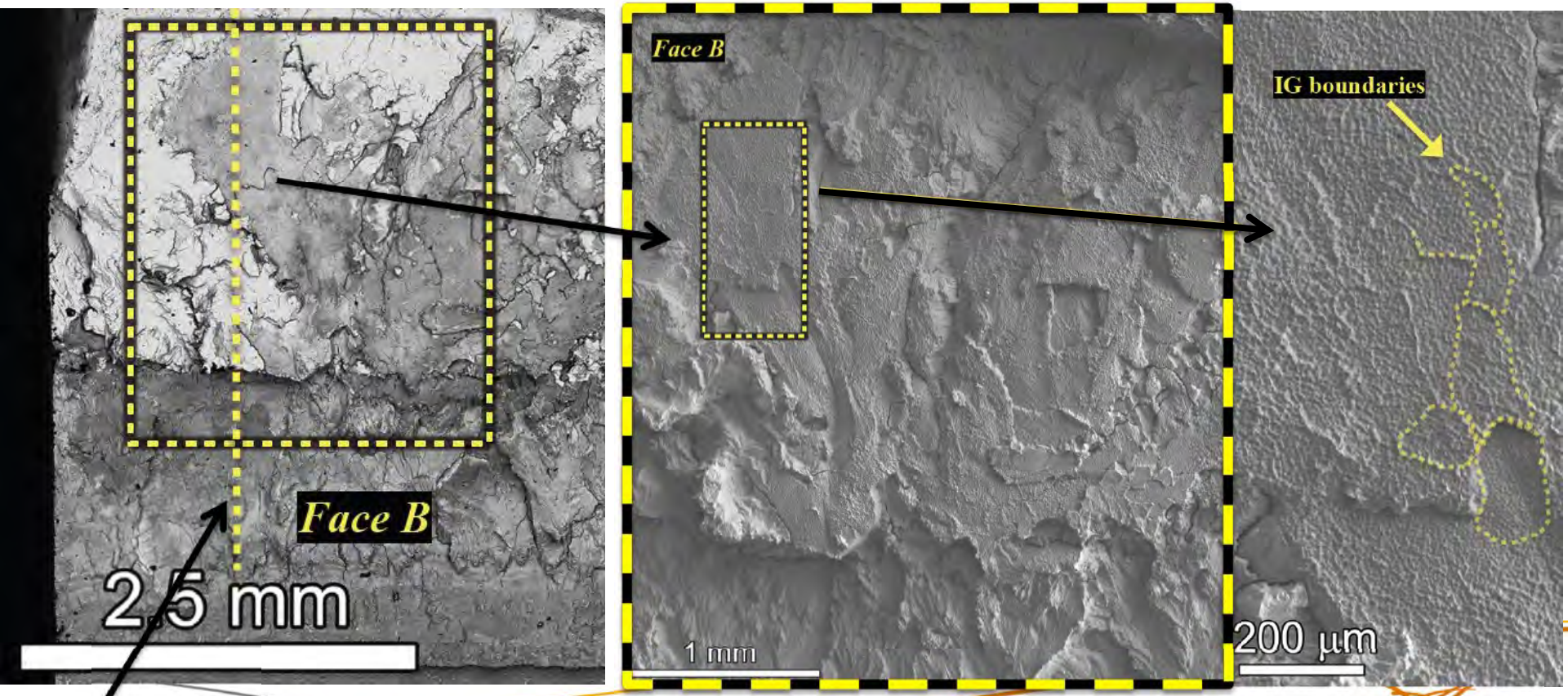
ANL N152-LAS-11 Specimen Crack Surface Observations

- *Region on left is main area of interest. Cracking in the weld and appears to be responsible for high SCC CGRs.*
- *Region on the right is cracking on or near the fusion line.*



ANL N152-LAS-11 Specimen Crack Surface Observations

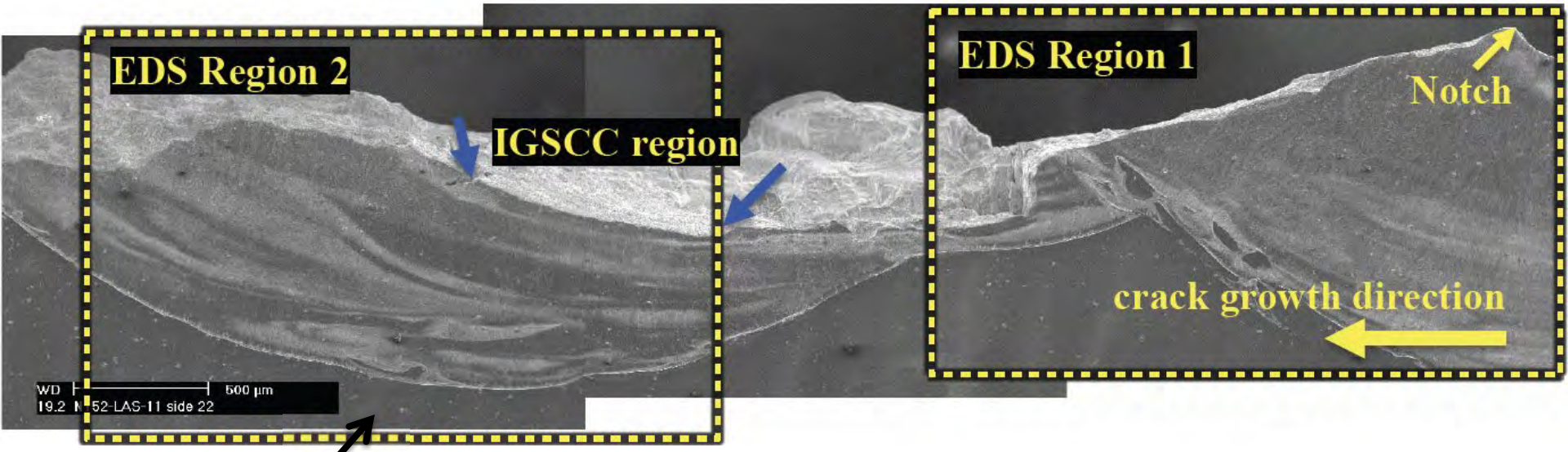
- *Crack surface in the weld does not appear to be transgranular. Has an atypical intergranular appearance.*



Cut for cross section observation

ANL N152-LAS-11 Specimen Cross Section Observations

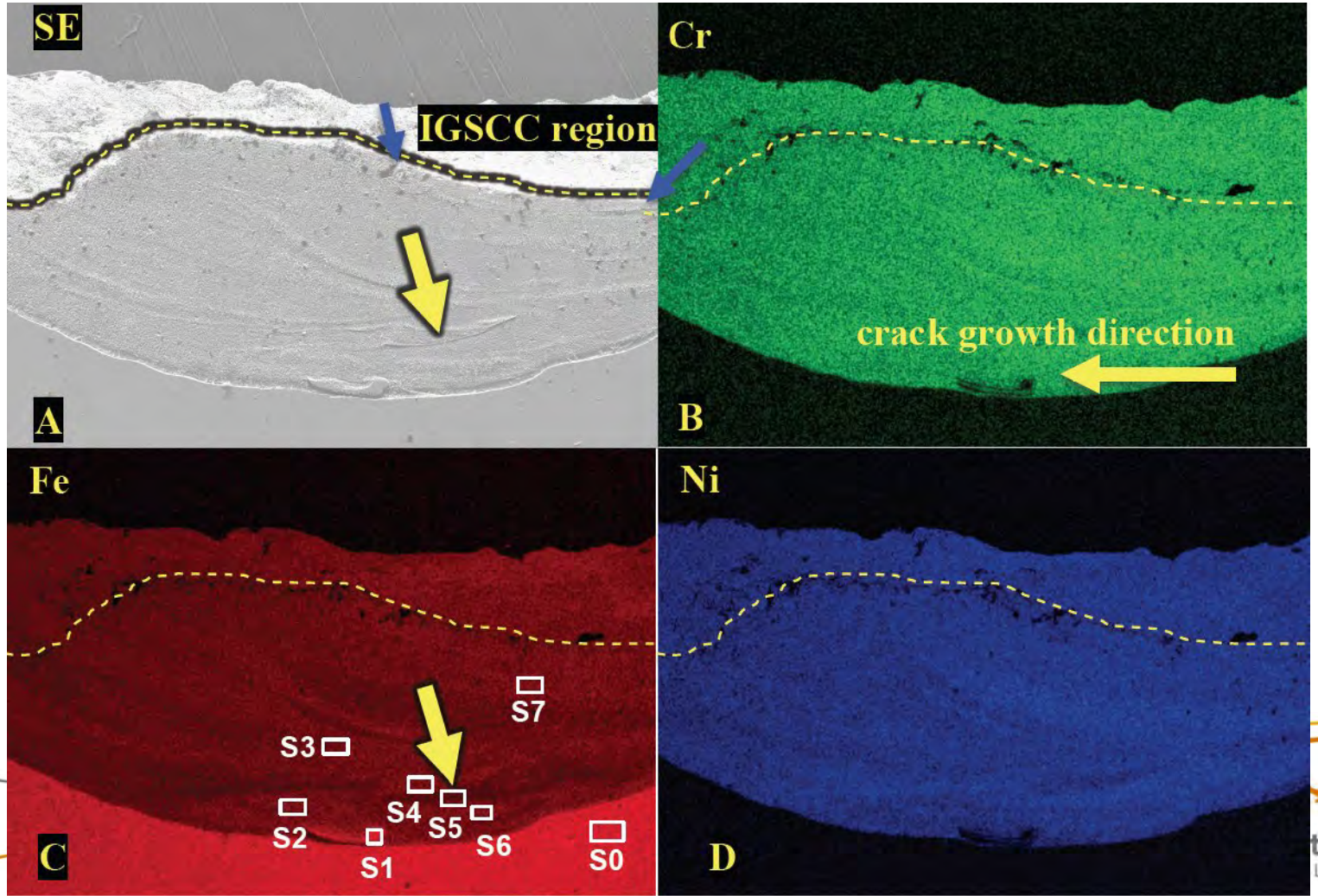
- *Specimen has been fractured, so only one side of the specimen shown here in cross section.*



Region of interest near that contains constant load crack extension

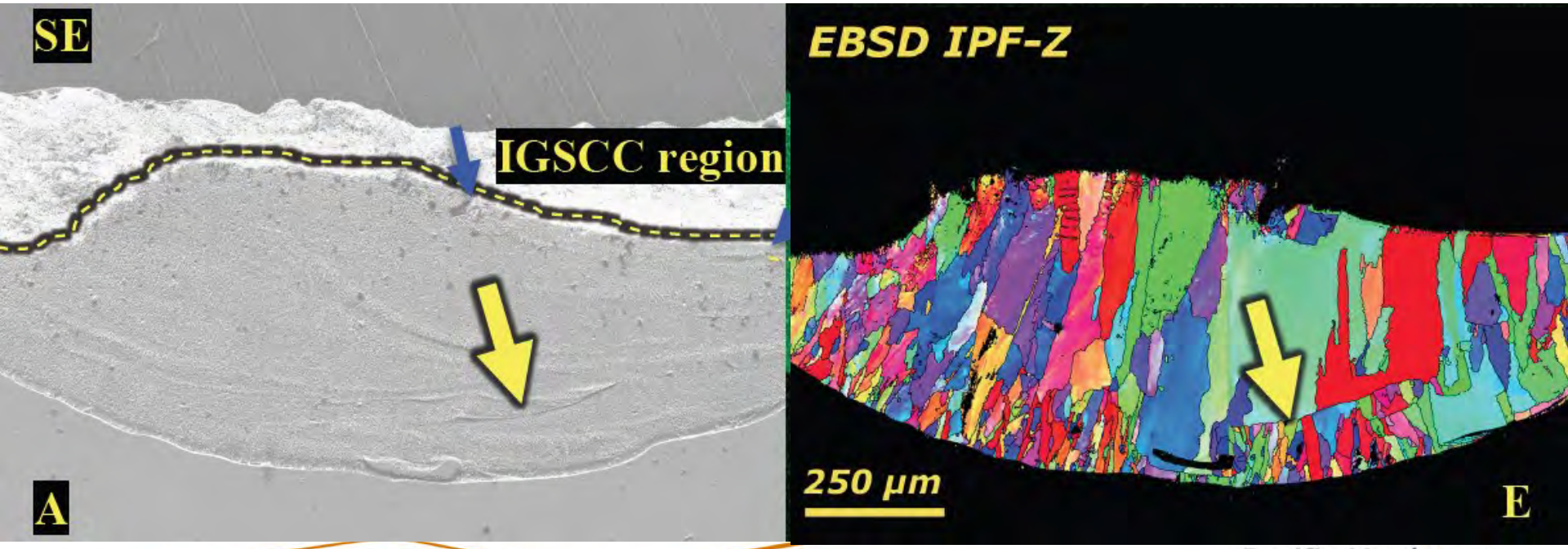
ANL N152-LAS-11 Specimen Cross Section Observations

- *SEM-EDS exams indicate that Cr levels near SCC region are ≥25% on this side of the crack.*



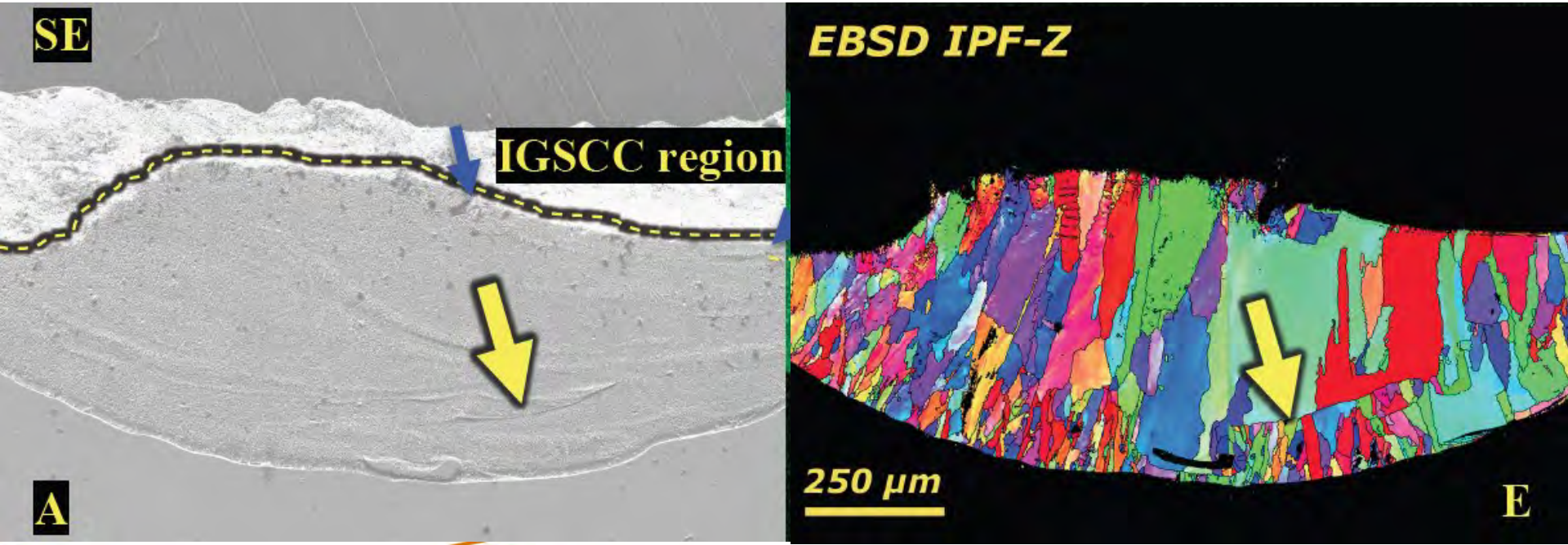
ANL N152-LAS-11 Specimen Cross Section Observations

- *SEM-EBSD exam shows the crack plane to be perpendicular to the long axis of the grain boundaries, but no other direct information about the SCC crack.*
- *However, an unusal interface was seen in the weld pass that is aligned similar to that of the SCC crack path.*
- *Interface is likely due to a welding artifact.*



ANL N152-LAS-11 Specimen Summary

- *SCC tested at ANL. Additional exams performed at PNNL.*
- *High constant load crack growth rates were observed.*
- *Crack path not well aligned to weld grain boundaries.*
- *Crack surface had an IG appearance.*
- *No strong weld dilutions in cross section of one side of crack.*
- *Unusual boundary that could explain SCC crack path.*

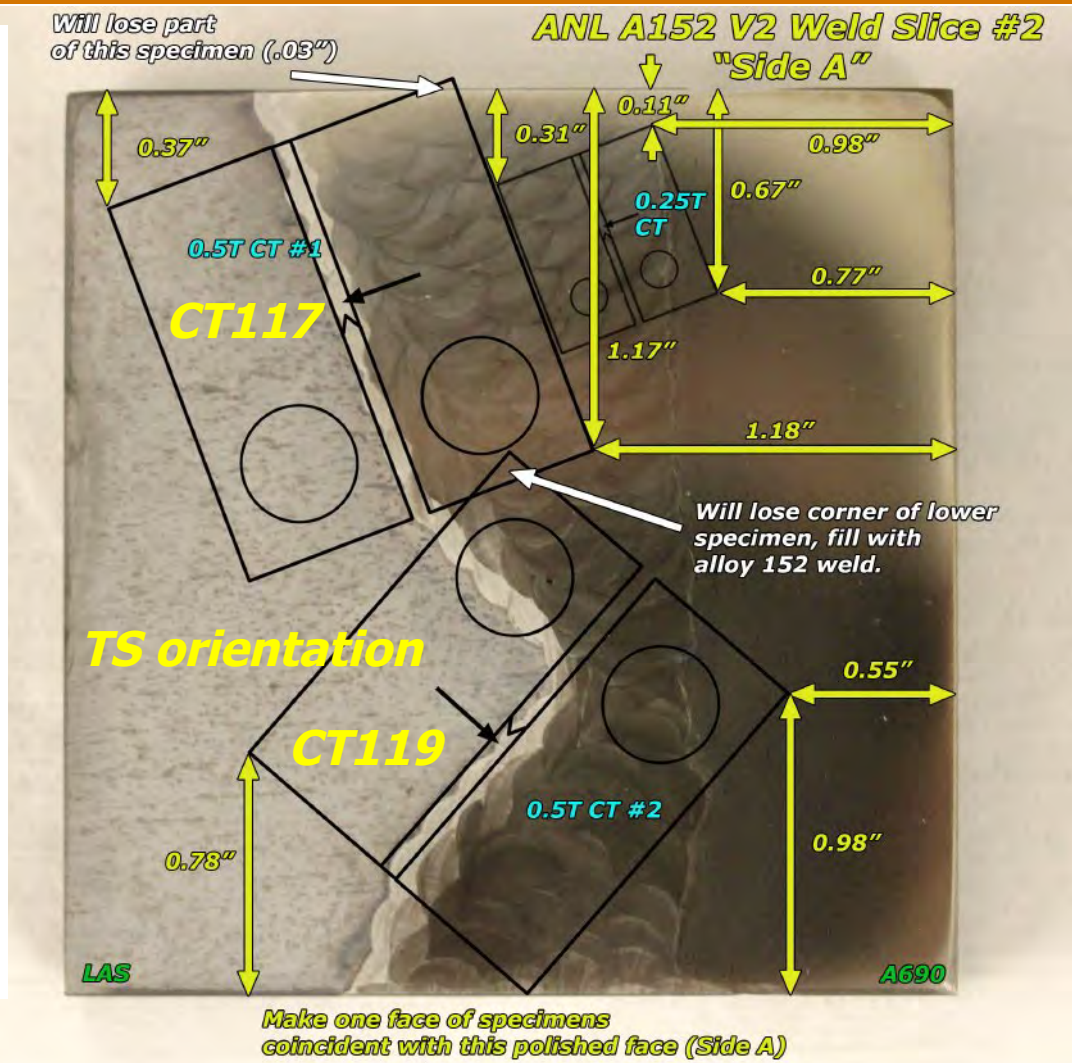


ANL Test of N152-LAS-11 Specimen

- *Prior Testing at PNNL*
  - *Constant K CGR of ≤3x10^{-9} mm/s observed in a 20Cr dilution zone*
  - *Unfavorable crack path that is nearly perpendicular to elongated weld grain boundaries*
- *Prior Testing at ANL - N152-LAS-11 Specimen*
  - *≥1x10^{-8} mm/s constant load CGR observed, substantial cracking*
  - *Crack path appears to cut across long axis of weld grains*
  - *Examination at PNNL suggests a unique IG crack path*
- *Two new ongoing SCC tests at PNNL*
  - *Testing same weldment as used for N152-LAS-11*
  - *One specimen aligned to assess same region as N152-LAS-11*
  - *Second specimen assessing a different region*

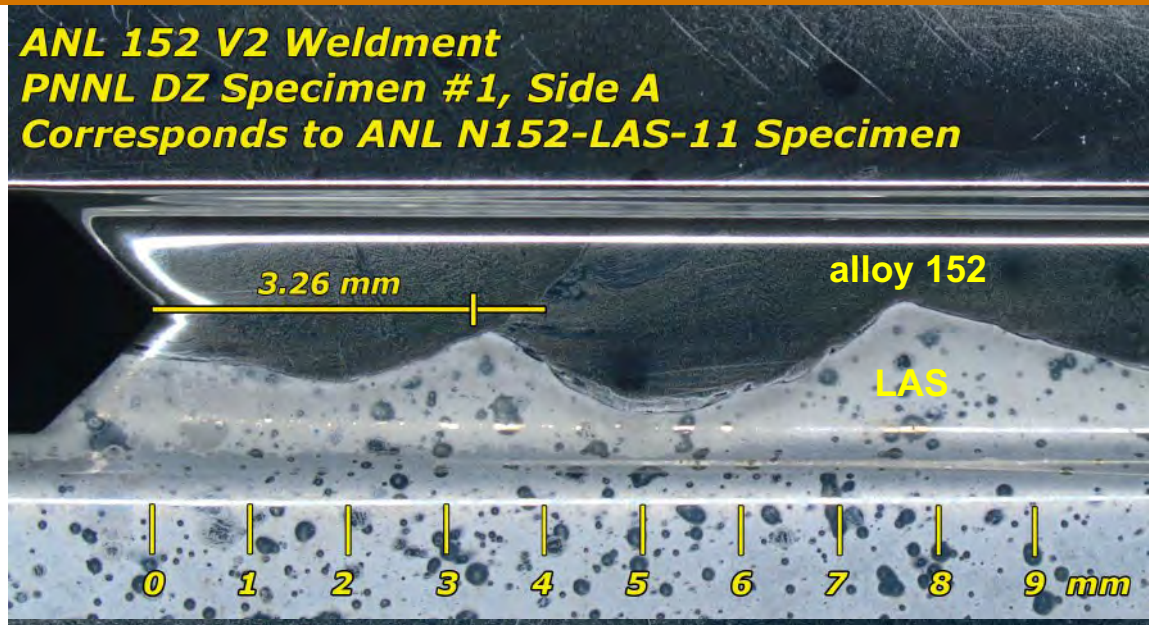
A152v2-LAS PNNL #1 (CT117) and #2 (CT119)

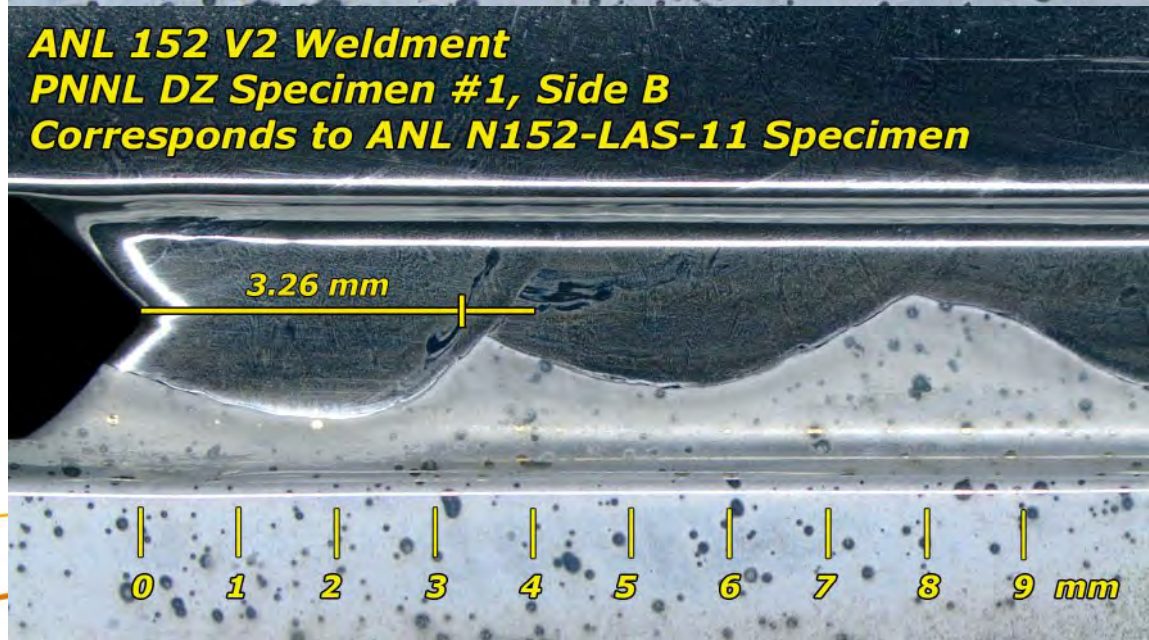
- *CT117 aligned to same region of weld as ANL N152-LAS-11 specimen tested at ANL.*
- *Tested separately.*
- *Tested at 360°C PWR primary water with 25 cc/kg dissolve H_2.*
- *No resistivity drift correction used.*



A152v2-LAS PNNL #1 (CT117)
Side Groove Images

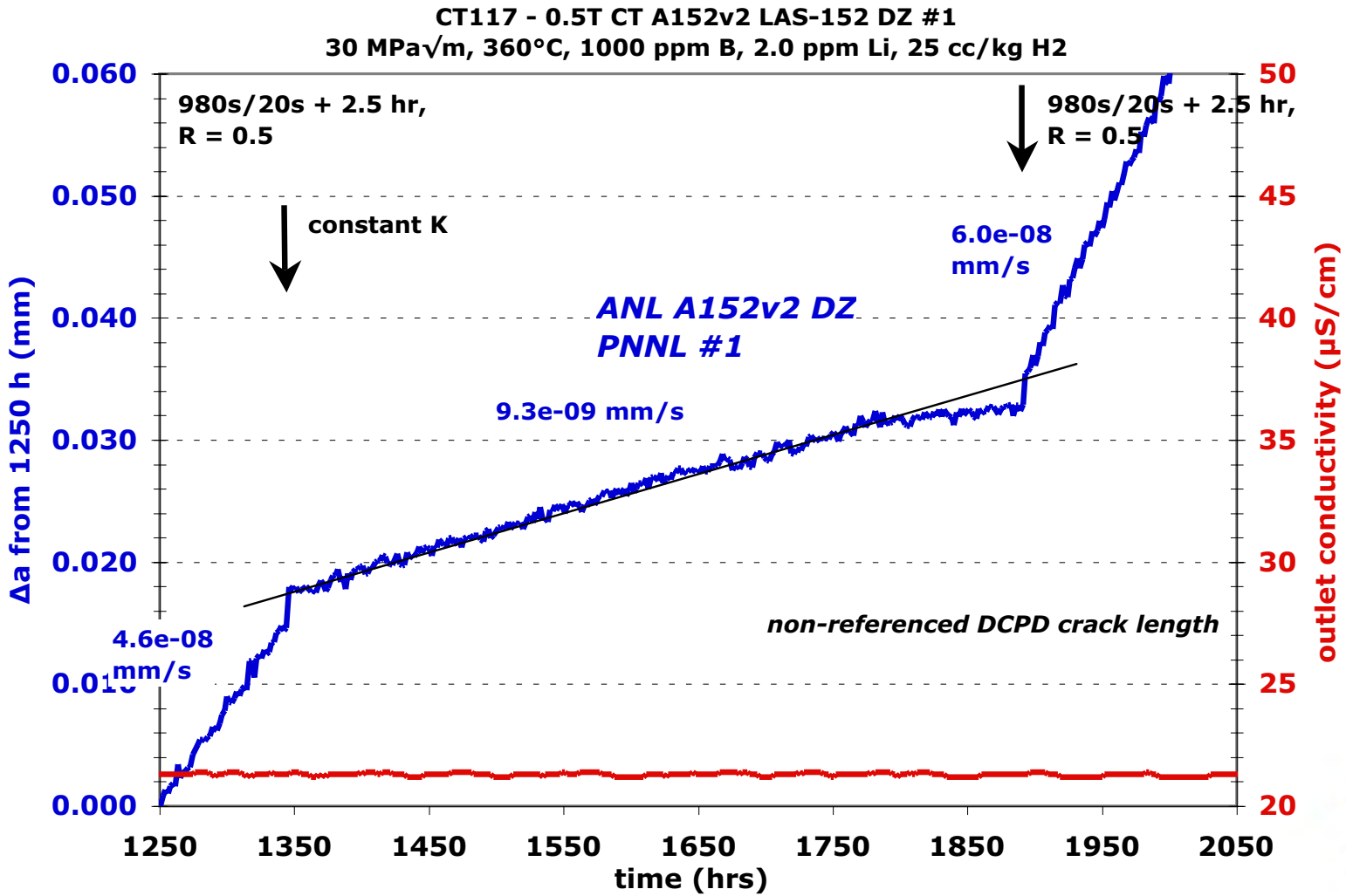
- *First weld pass has dilution near interpass boundary as indicated by etching contrast.*
- *Second pass has dilution near the same interpass boundary.*
- *Current crack front location indicated by hash marks. In a region of dilution in first weld pass.*





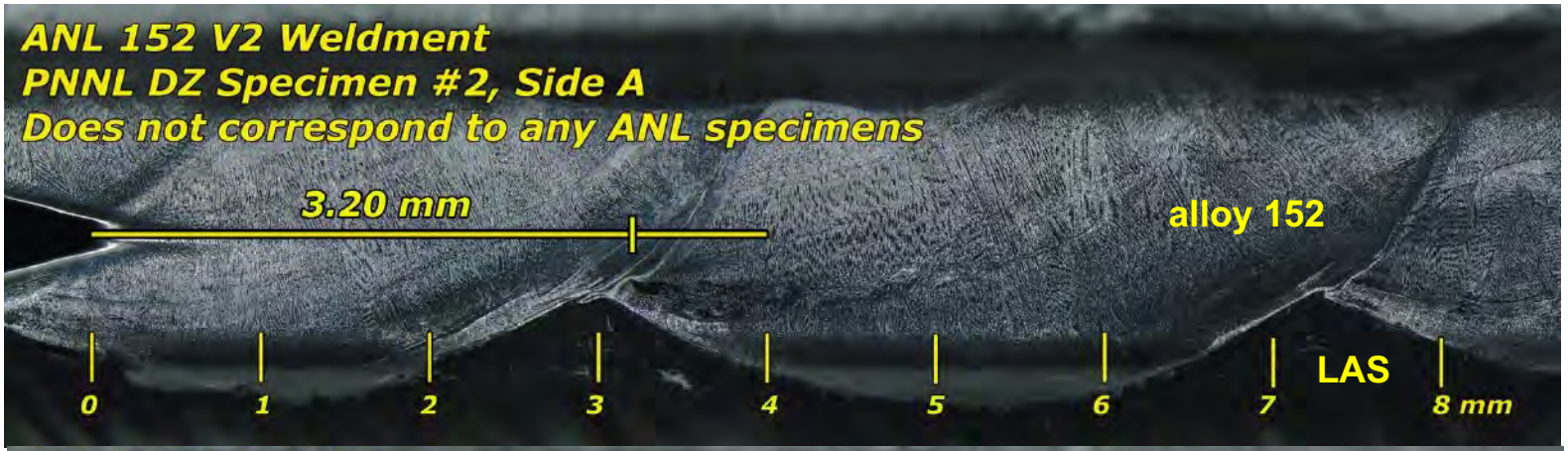
A152v2-LAS PNNL #1 (CT117) Constant K CGR

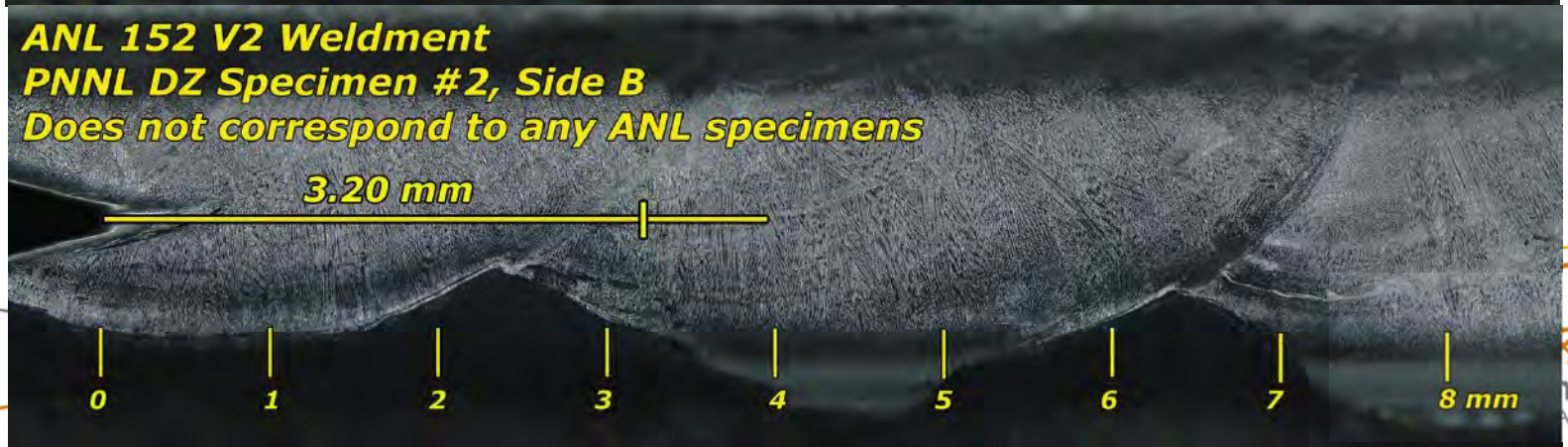
- *~1x10^{-8} mm/s observed SCC CGR for ~400 hrs.*
- *Possible ligament formation in last 100 hours at constant K.*



A152v2-LAS PNNL #2 (CT119)
Side Groove Images

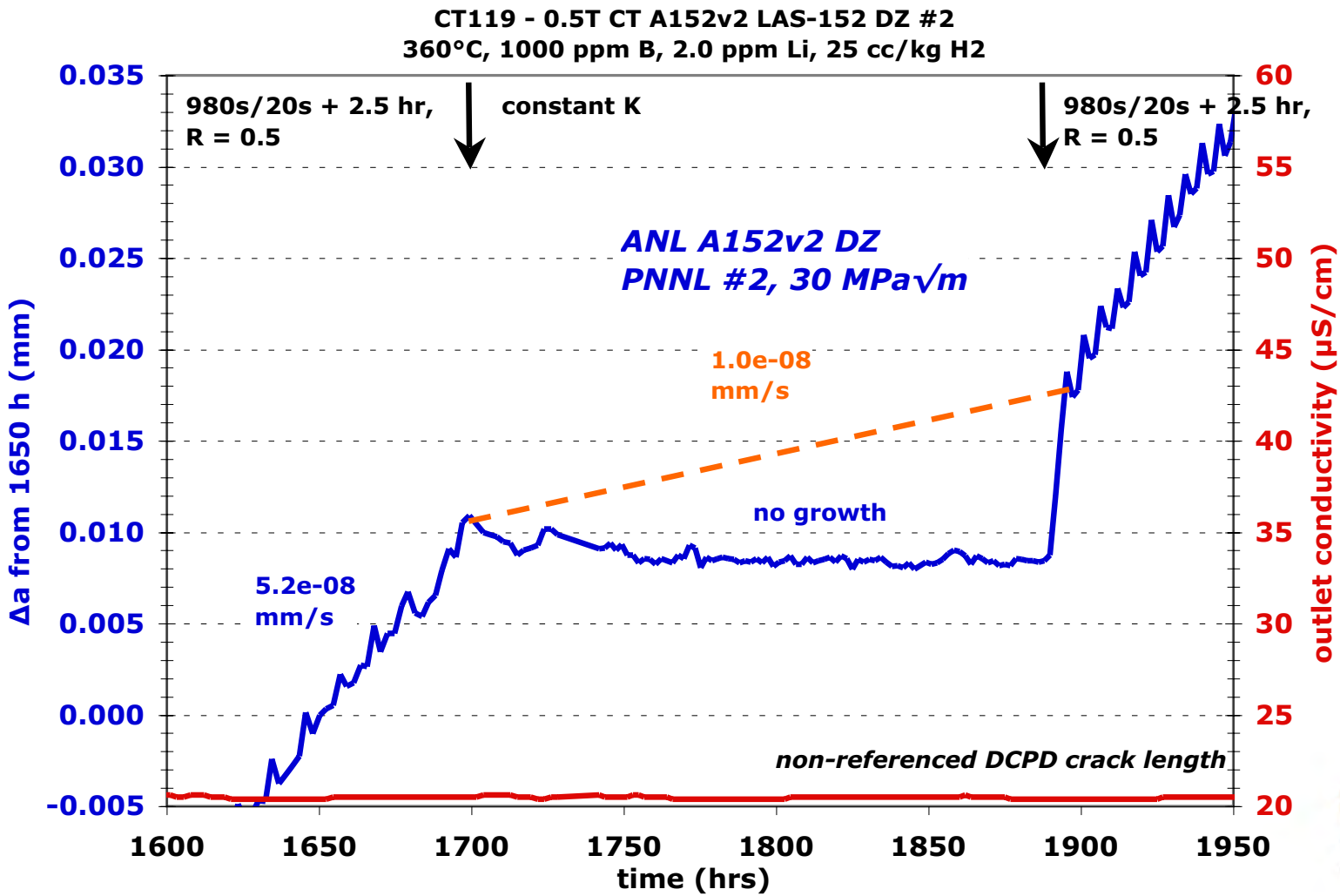
- *Crack in this specimen also currently positioned to assess dilution zone near interpass boundary.*
- *Side A is in the first pass while Side B is in the second pass.*





A152v2-LAS PNNL #2 (CT119) Constant K CGR

- *No DCPD-indicated growth at constant K*
- *Ligament formation. Estimated CGR is ~1x10^{-8} mm/s.*



Alloy 152/52-LAS Dilution Zone Summary

- *Prior PNNL Test*
  - *One specimen (CT066) with a region of ~20Cr was assessed.*
  - *Geometric crack plane was not well aligned to weld grain boundaries.*
  - *Low SCC CGRs were observed with transgranular cracking.*
- *Analysis of ANL N152-LAS-11 Specimen at PNNL*
  - *Also not well aligned to weld grain boundaries, but high SCC CGR.*
  - *Minor dilution on one side of crack that was examined in cross section.*
  - *Crack surface had an intergranular appearance.*
  - *Cross section observation revealed an unexpected boundary that was aligned in the crack growth direction. Would explain the apparent intergranular crack appearance.*
- *New tests at PNNL are assessing the same weldment as tested at ANL. Some indication of susceptibility. Testing will continue.*