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NSUF Review Board Irradiation Testing of LWR Additively Manufactured Material

Fran Bolger

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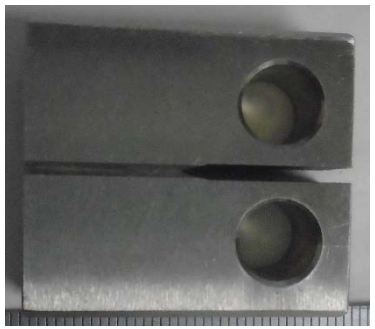
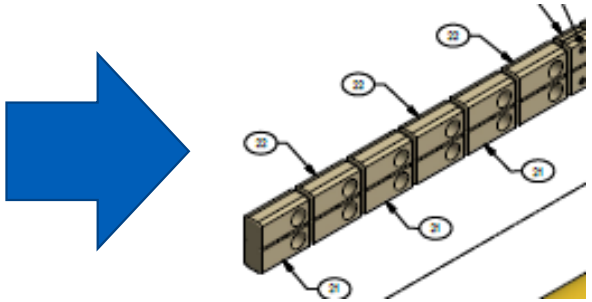
DOE Program - CFA-16-10393

Irradiation Testing of LWR Additively Manufactured Materials

- Objective: Perform full irradiation / PIE on structural materials produced by DMLM
- Participants: GEH (Connor - PI), INL (NSUF facility)
- Activities: Obtain microstructural characterization, mechanical properties, stress corrosion crack growth data for un-irradiated **Type 316L and IN 718** (GEH) and corresponding irradiated data to ~0.7 dpa (INL at the ATR)





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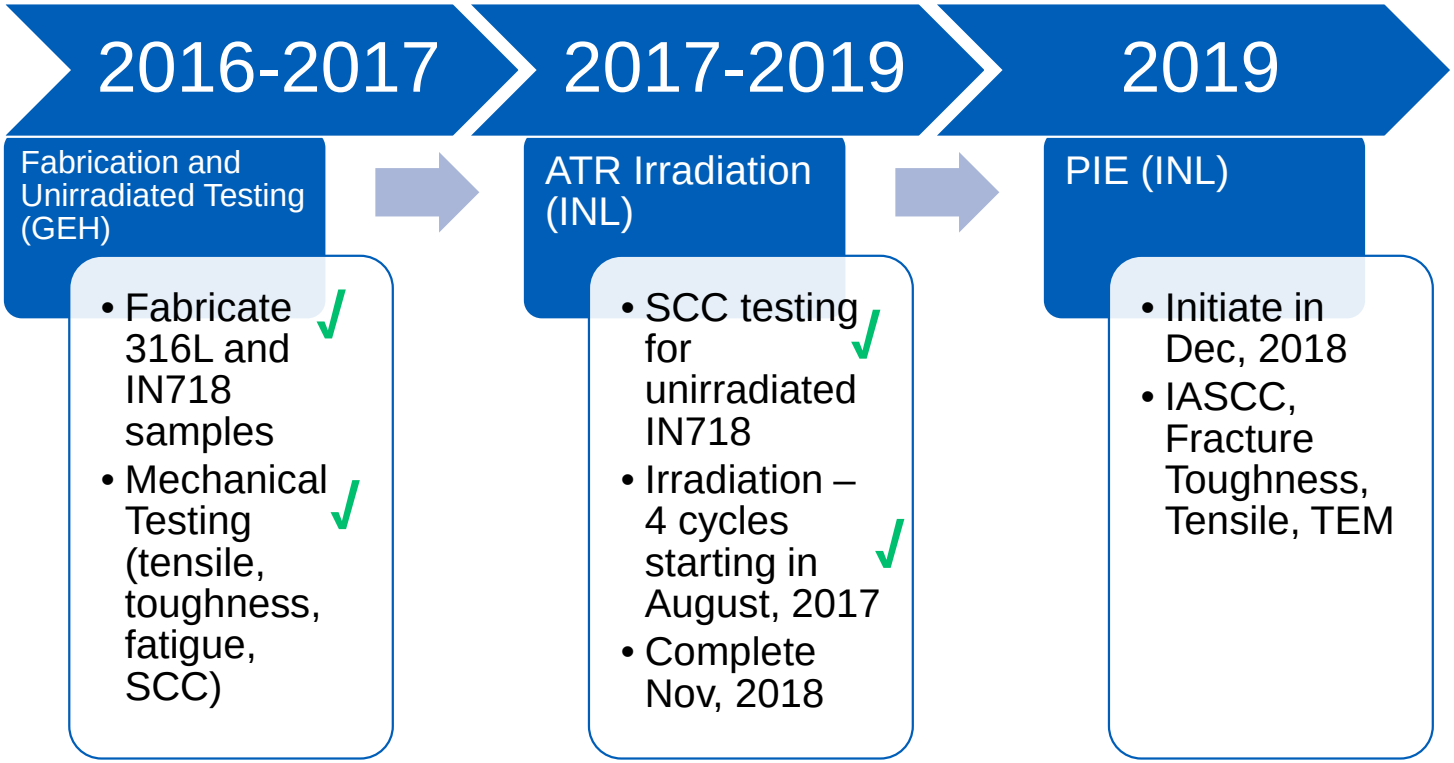
CFA-16-10393 Project

Timeline

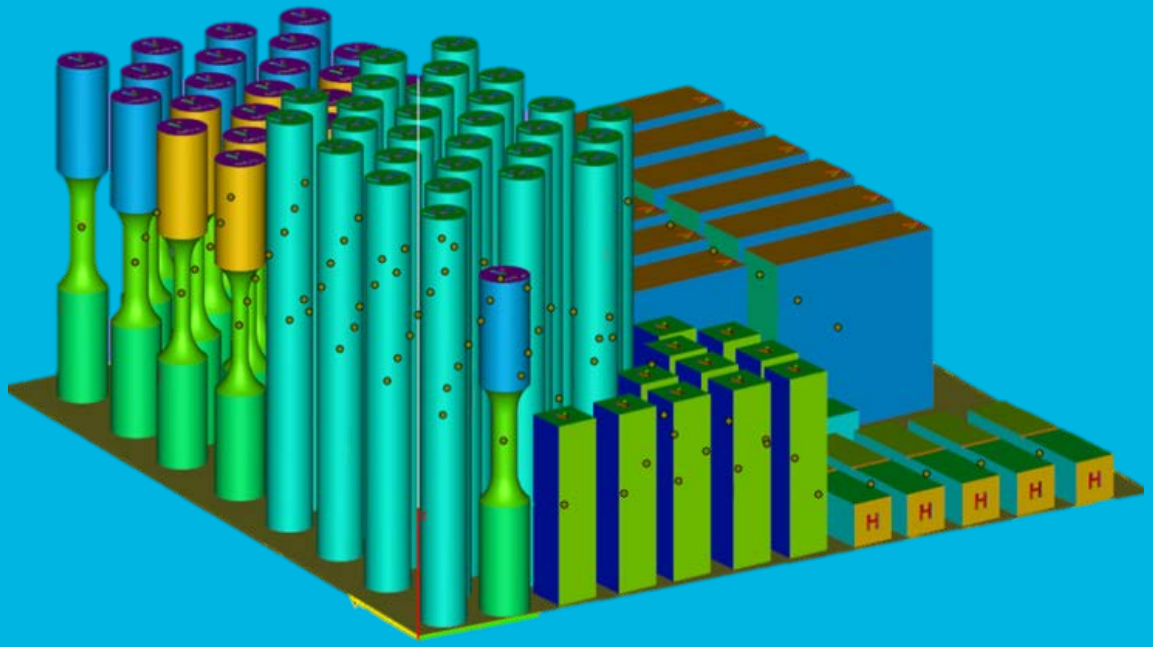


Value and Challenges of Additive

Powder Bed Laser Fusion Process

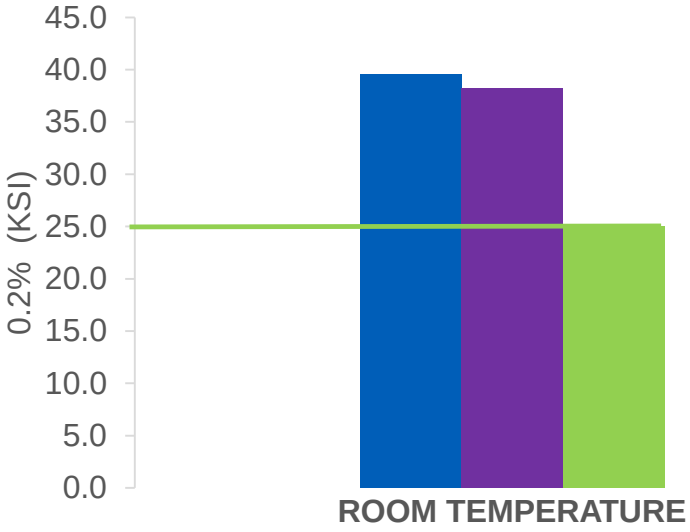
- Additive Manufacturing provides many advantages:
  - Speeds up Innovation
  - Design-driven manufacturing as opposed to manufacturing-constrained design
  - Specialized materials
- Nuclear industry has more difficulty in incorporating new materials, designs
  - Costly validation, limited facilities
- Collaboration between NSUF and GEH will facilitate more rapid use of Additive Manufacturing

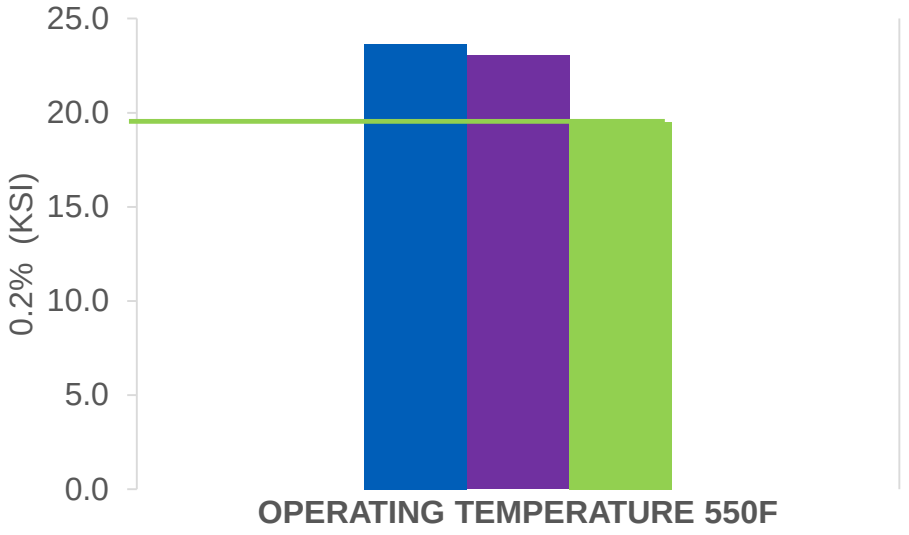
316L DMLM Material Properties



Mechanical Properties

Tensile Testing: Yield Stress

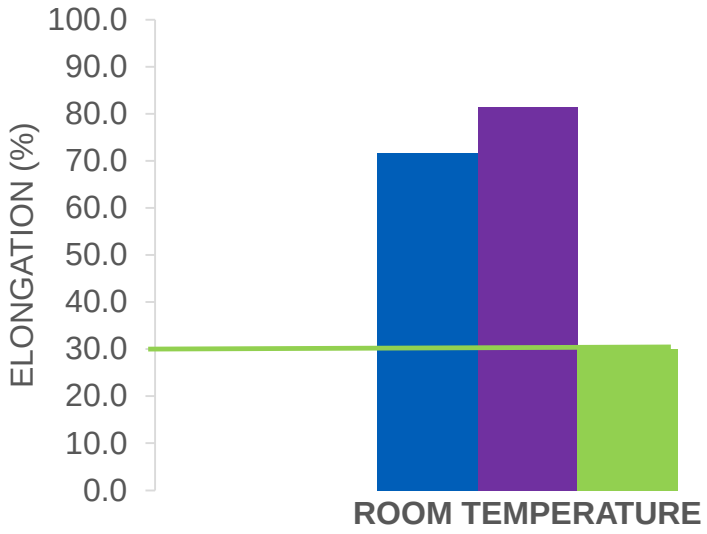


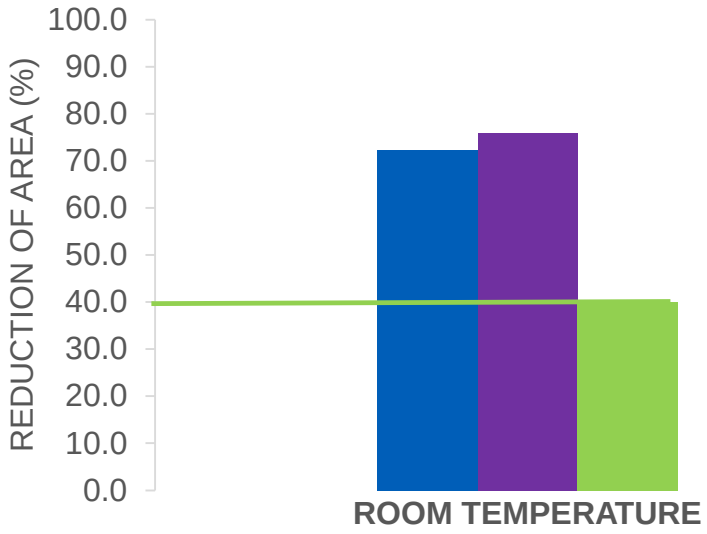


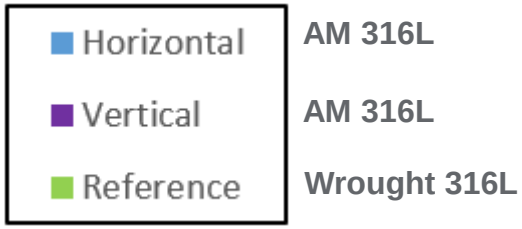
Horizontal	AM 316L
Vertical	AM 316L
Reference	Wrought 316L

Mechanical Properties

Tensile Testing: Elongation and Reduction of Area







AM 316L

AM 316L

Wrought 316L

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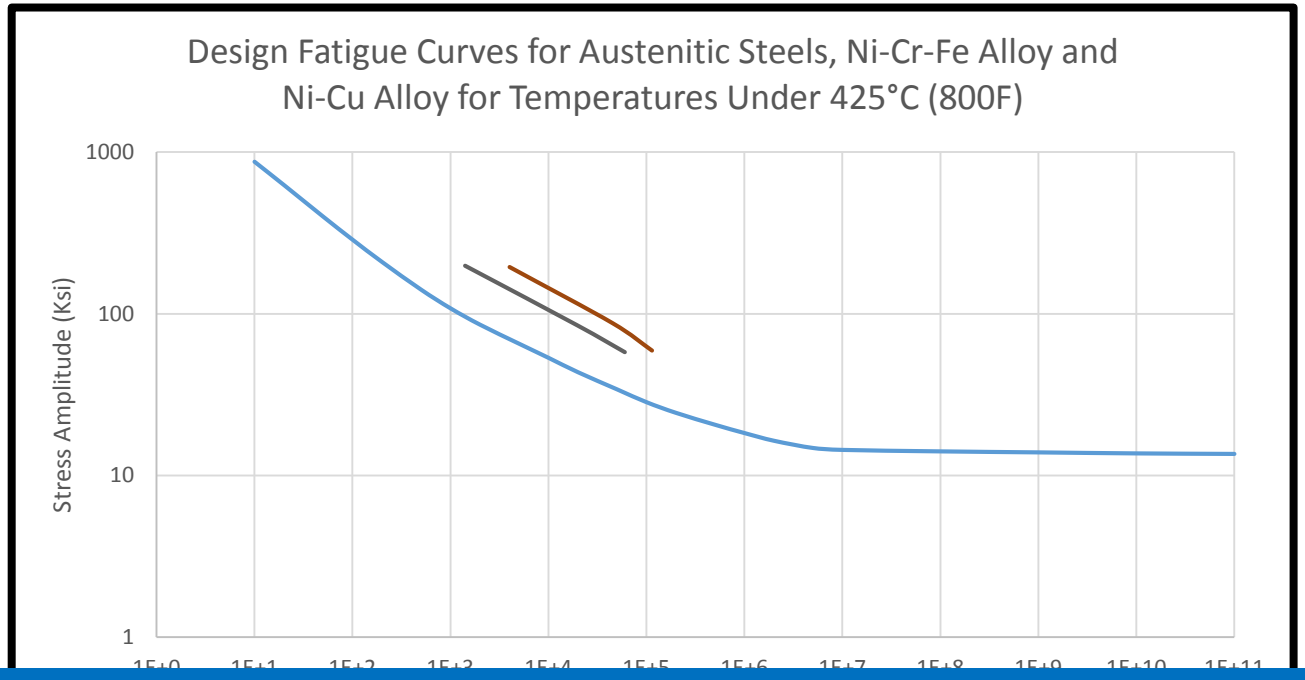
Mechanical Properties

Fatigue Test for AM 316L



Fatigue Performance meets design limits. Machining and Surface Treatment Improve Life.

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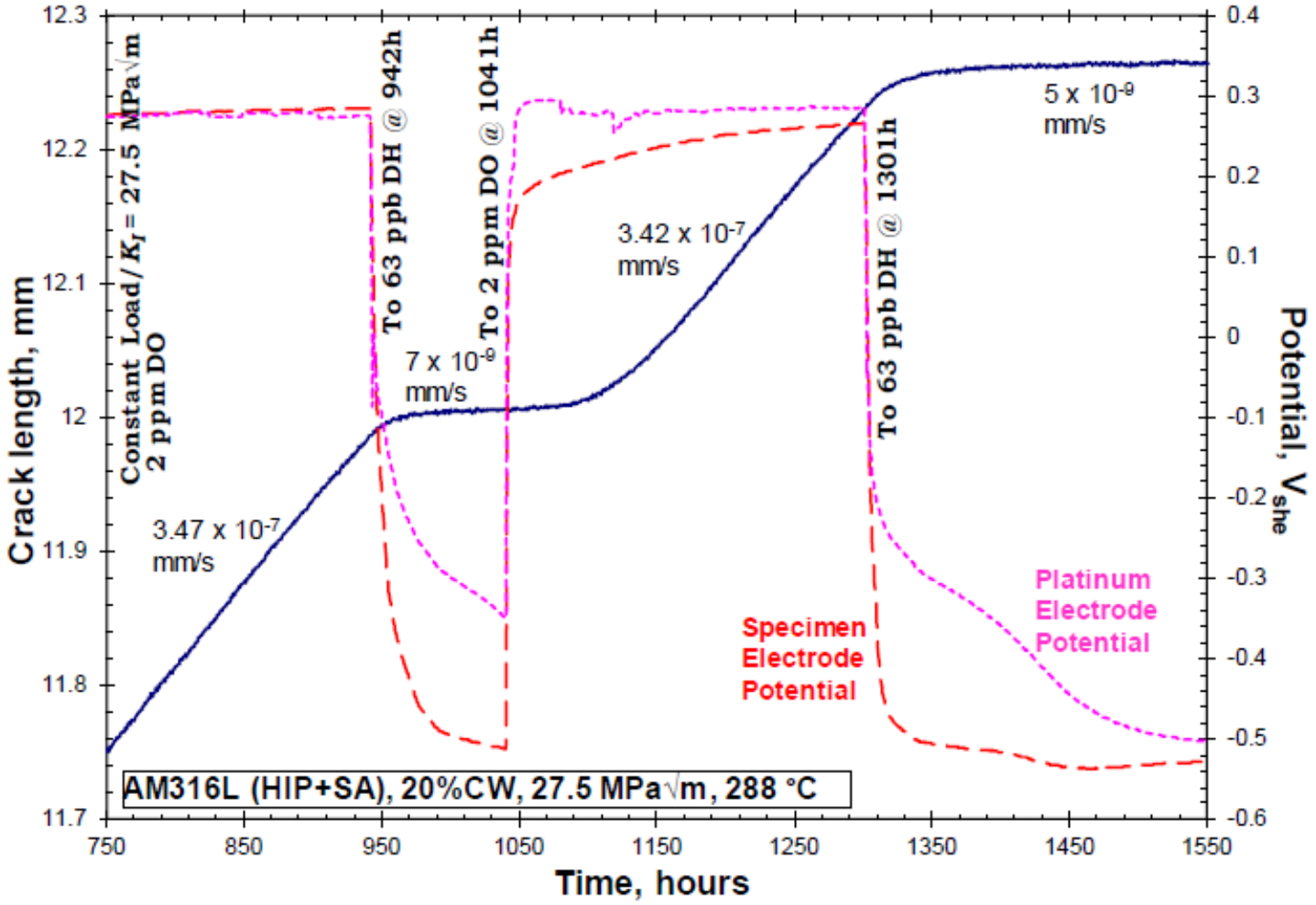
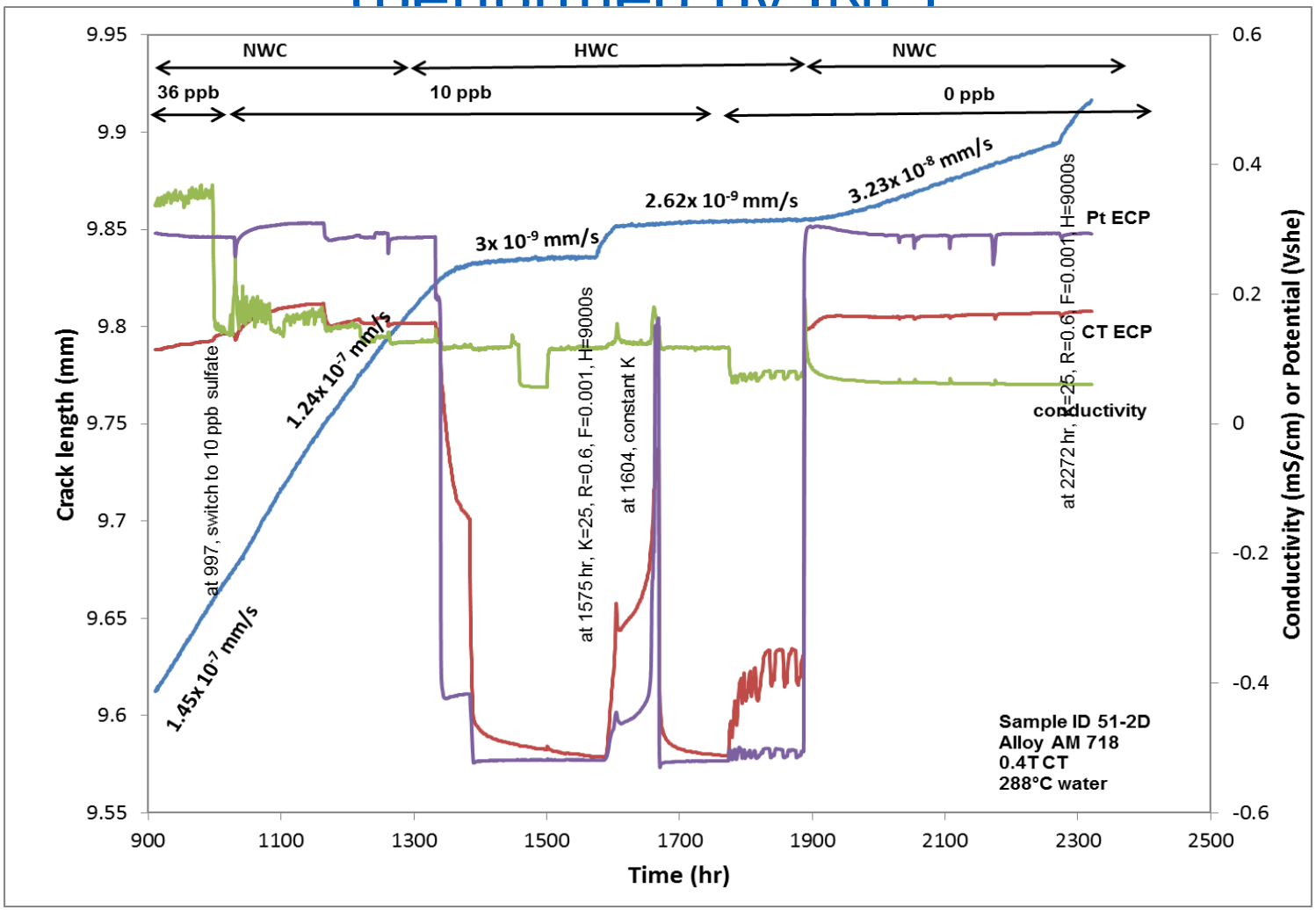
316L CGR in NWC and HWC conditions (performed by GE)



IN718 CGR in NWC and HWC conditions (performed by INL)



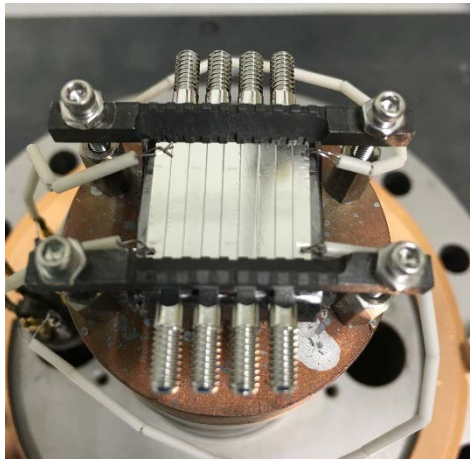
Results From AM NEET Program

https://www.osti.gov/servlets/purl/1431212

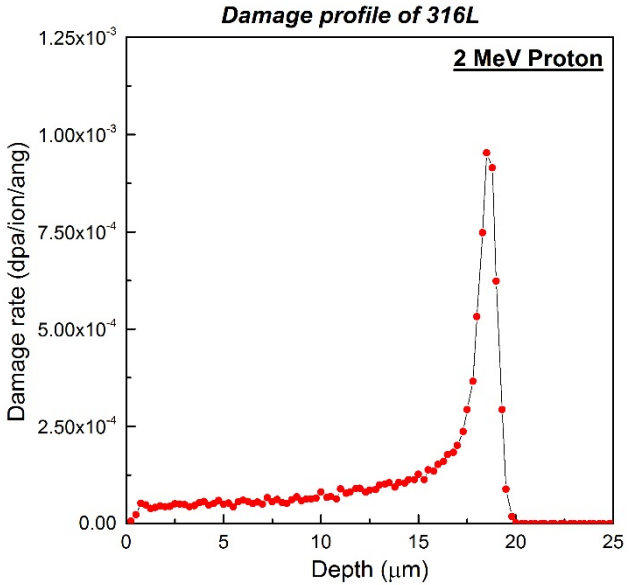
Experiment

- Irradiation

Parameter	2 MeV Proton	5 MeV Fe++ (QCAM316L only)
Dose (dpa)	5	100
Temperature (°C)	360	400
Damage rate (dpa/s)	1.6×10^{-5}	3.6×10^{-4}
Current (μA)	37	0.618

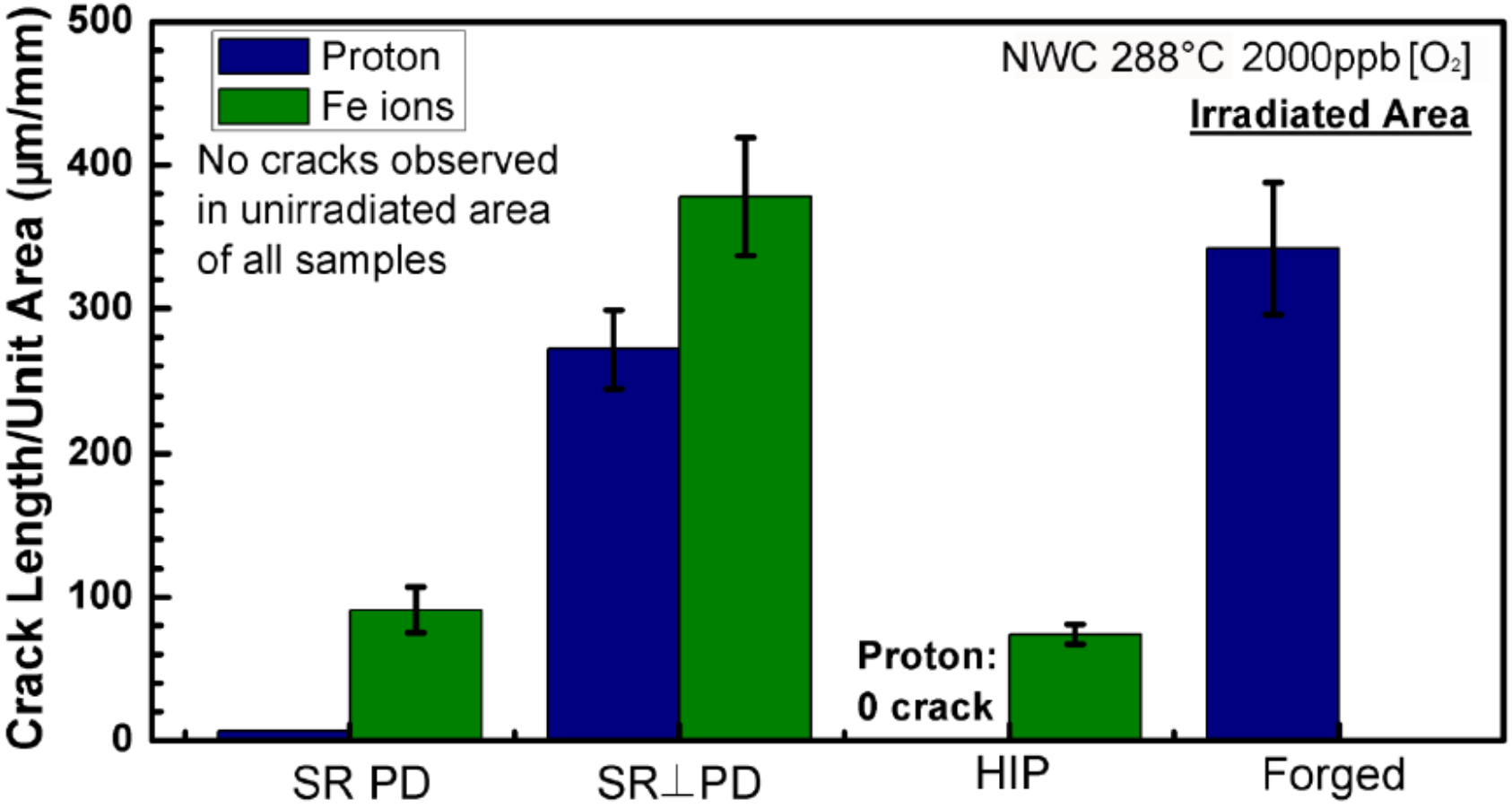


Irradiation stage



- Constant Extension Rate Tensile (CERT) test in BWR (NWC) environment
  - 288°C, 2000 ppb [O_2]
  - Slow strain rate: ~ 1×10^{-7} s^{-1}
  - Plastic deformation: ~ 4 %

Cracking susceptibility of GE materials



What's Next?

NRC and Material Licensing

- NRC has become active in the consideration of AM for nuclear with workshops, visits, and vendor discussions
- EPRI is doing some 316L AM development and testing work and is planning to submit an ASME code case
- GEH would like to obtain BWRVIP-84 review for AM material (future DOE proposal)
- It would be useful to connect the NSUF neutron test results with the proton and ion results

Questions?

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