Experimental Guidelines for Generating High Quality Data on SCC on Alloy 690 in Hot Water

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Experimental Issues in SCC

SCC is an unusually complex experimental area in physical science

Many overlapping disciplines make SCC studies among toughest

Among the critical factors of good experiments are:

1. *Broad knowledge of mechanics, chemistry, electrochemistry, metallurgy, radiation damage, physical measurements*
2. *Excellence not only in 5 or 10 experimental areas, but in all "twenty";*
   Don't focus just on just mechanics or chemistry issues

Important Experimental Issues

Our ability to obtain reproducible CGR data depends on:

1 – Must transition from TG fatigue precrack to IG SCC

2 – Loading control/stability including constant K, dK/da

3 – Pressure pulse dampening & seal friction

4 – Crack length resolution & accuracy (need <10 μm)

5 – Temperature control (need <0.2 °C fluctuation)

6 – Water chemistry control (need <0.1 μS/cm outlet)

7 – Reference electrode accuracy & reliability

8 – Stability of test conditions over long times (& patience)

9 – Wise management of testing / specimen response
(we cannot simply "dunk" a specimen in water)

10 – Perhaps also ability to make changes "on-the-fly"

ICG-EAC 1998 SCC Experimental Guidelines

1. *Stress intensity (K)*
2. *Test preliminaries*
3. *Test temperature*
4. *Inlet and outlet solution conductivity*
5. *Inlet and outlet oxygen & hydrogen*
6. *Corrosion potentials*
7. *Flow rate*
8. *Continuous crack monitoring*
9. *“No growth” data*
10. *Material characteristics*
11. *Individual crack length vs. time*
12. *Accelerated testing & interpretation*

Repercussions of Weak Experiments

Our inability to obtain reproducible CGR data causes:

1 – CGR scatter by ~1000X

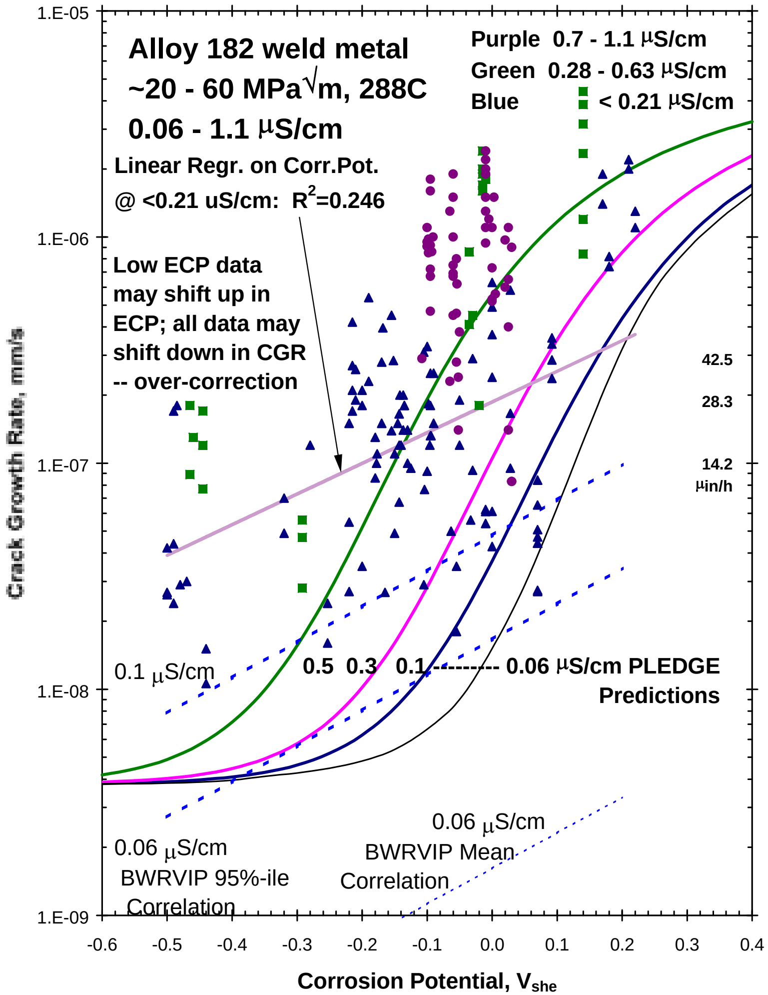
2 – Inability to define dependencies with statistical confidence from our collective data

3 – Mechanisms and modeling disagreements

4 – Inefficient progress in understanding/quantifying SCC

5 – A necessary emphasis on experimental observations and engineering data to resolve confusion vs. probing new, key phenomena & enhancing understanding

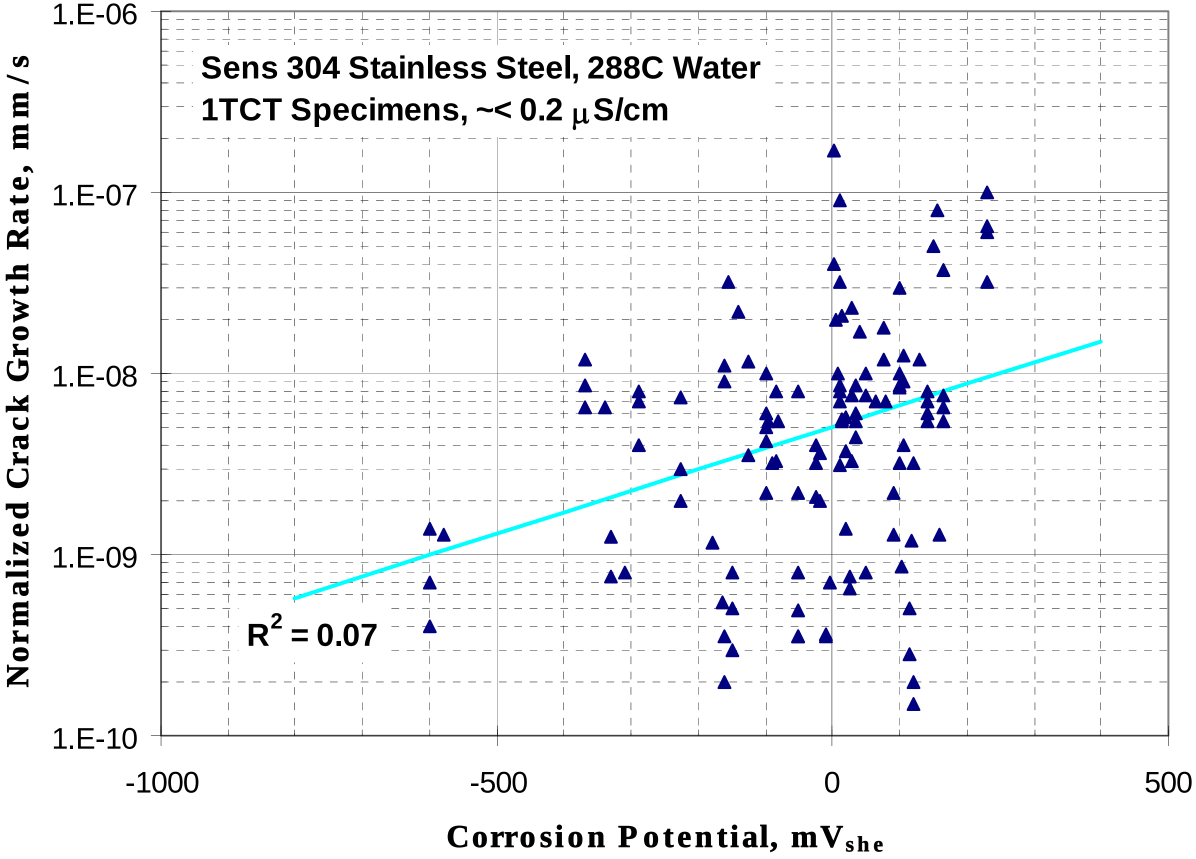
SCC Testing & Data Base Issues



Historical data shows large scatter due to testing problems

Scatter is related to testing problems, so the "mean" of the data ≠ the mean SCC response

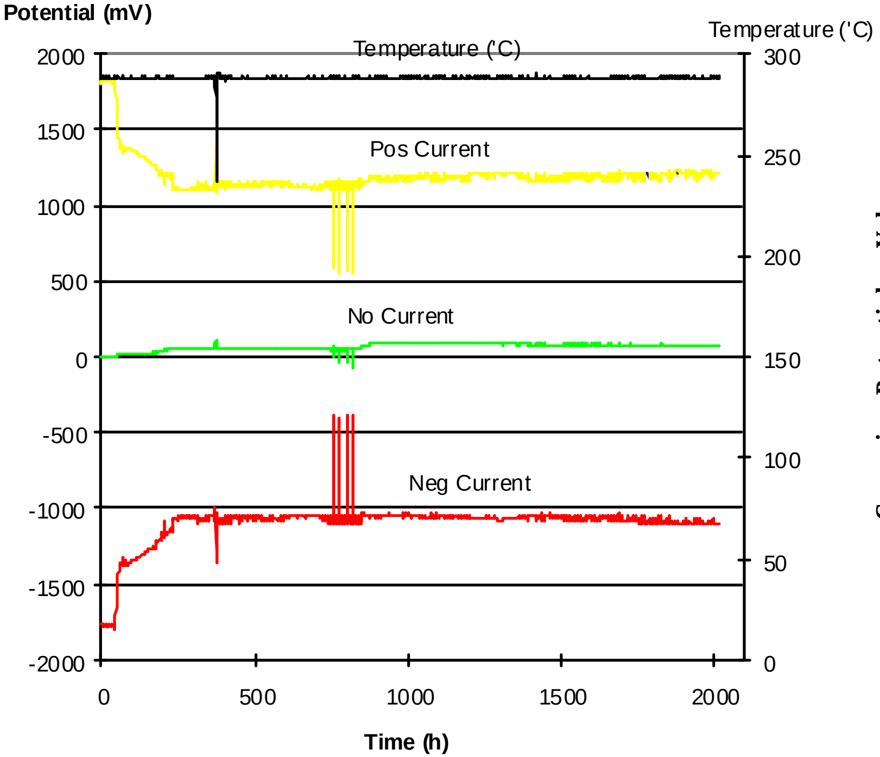
SCC Testing & Data Base Issues



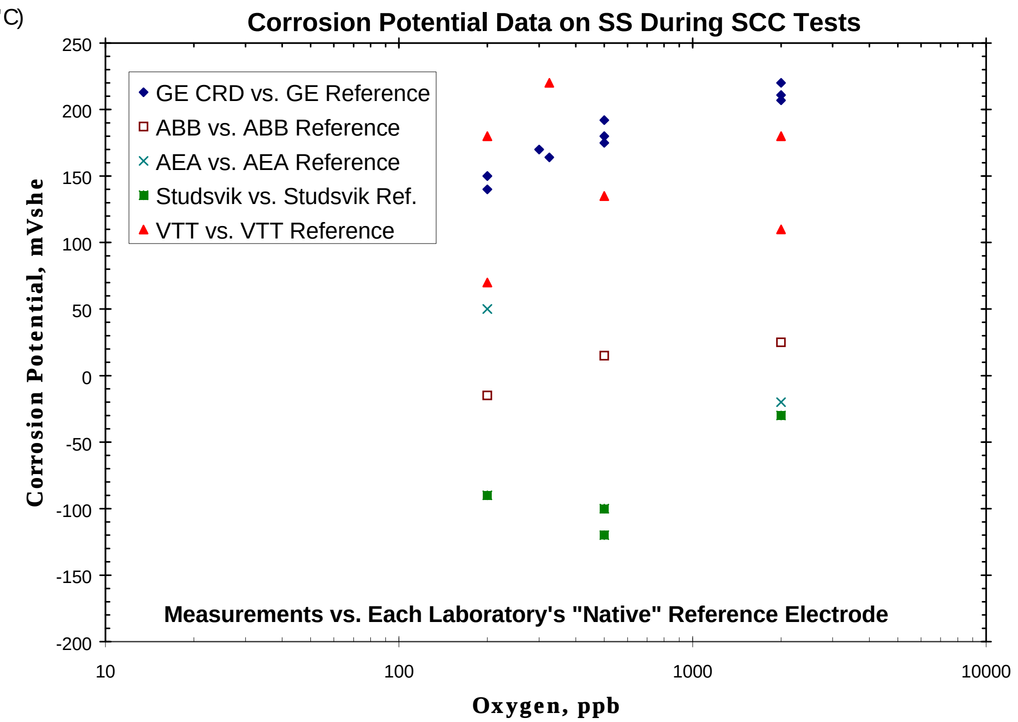
Even with best empirical model, scatter produces very poor statistical fit, $R^2 \approx 0.07$

Statistics can't overcome bad experiments

Experimental Error: Corrosion Potential



Effect of dc potential drop on ECP



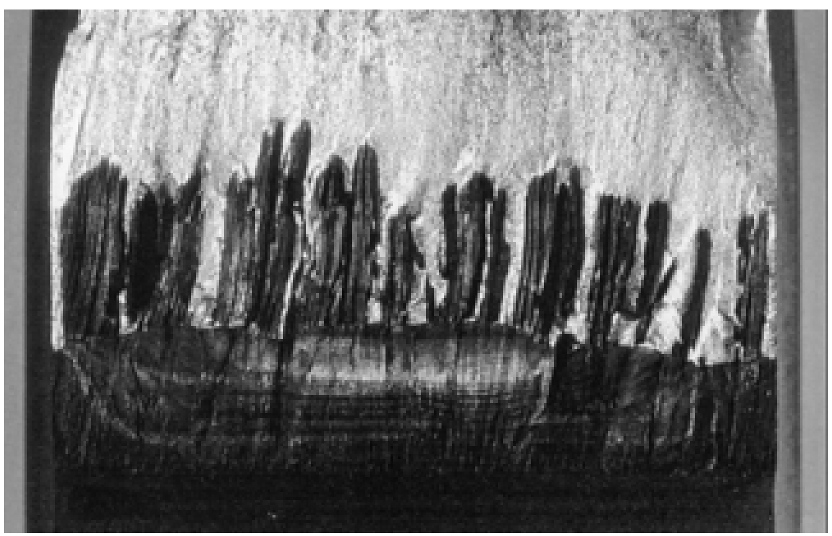
ECP of identical 304SS & water by 5 labs

Transgranular Fatigue Precracking

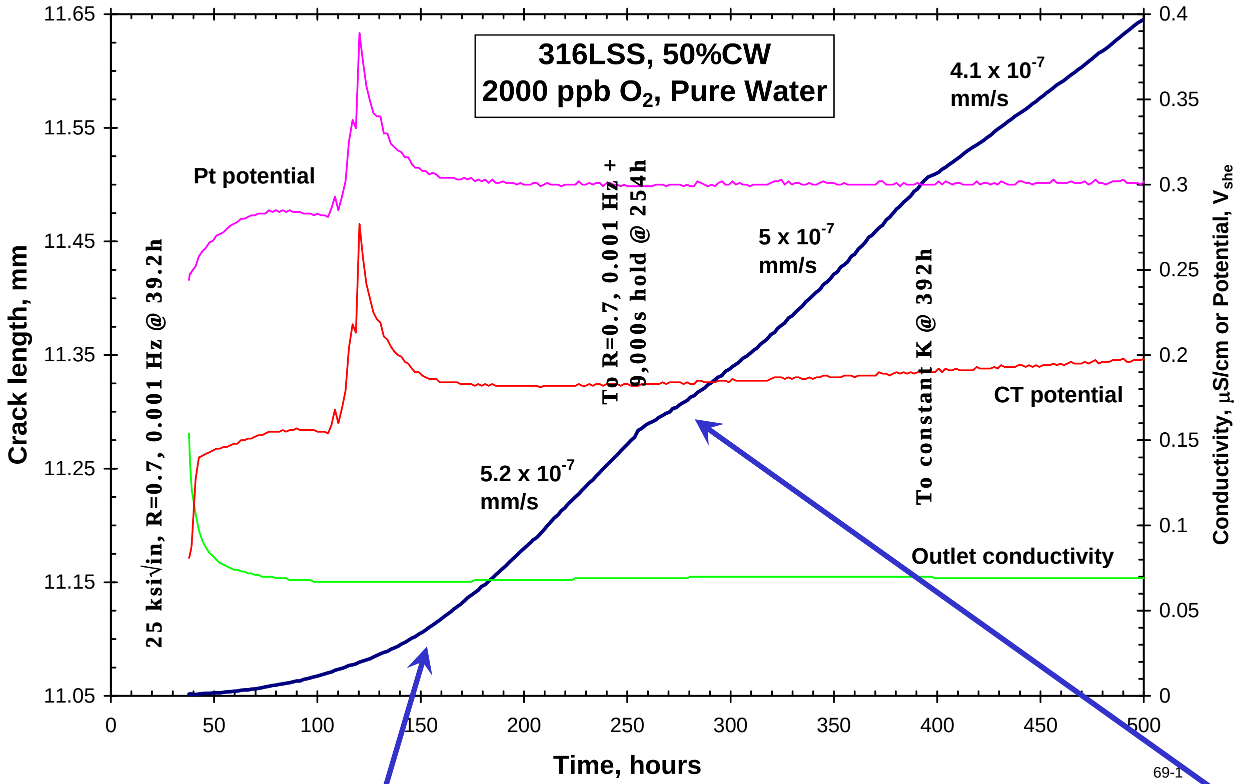
TG fatigue cracks very poorly simulate lab or field IGSCC

Morphology change, plastic zone, crack front pinning issues

Transition needed to IG crack and "monotonic" plastic zone



Typical SCC Crack Growth Data

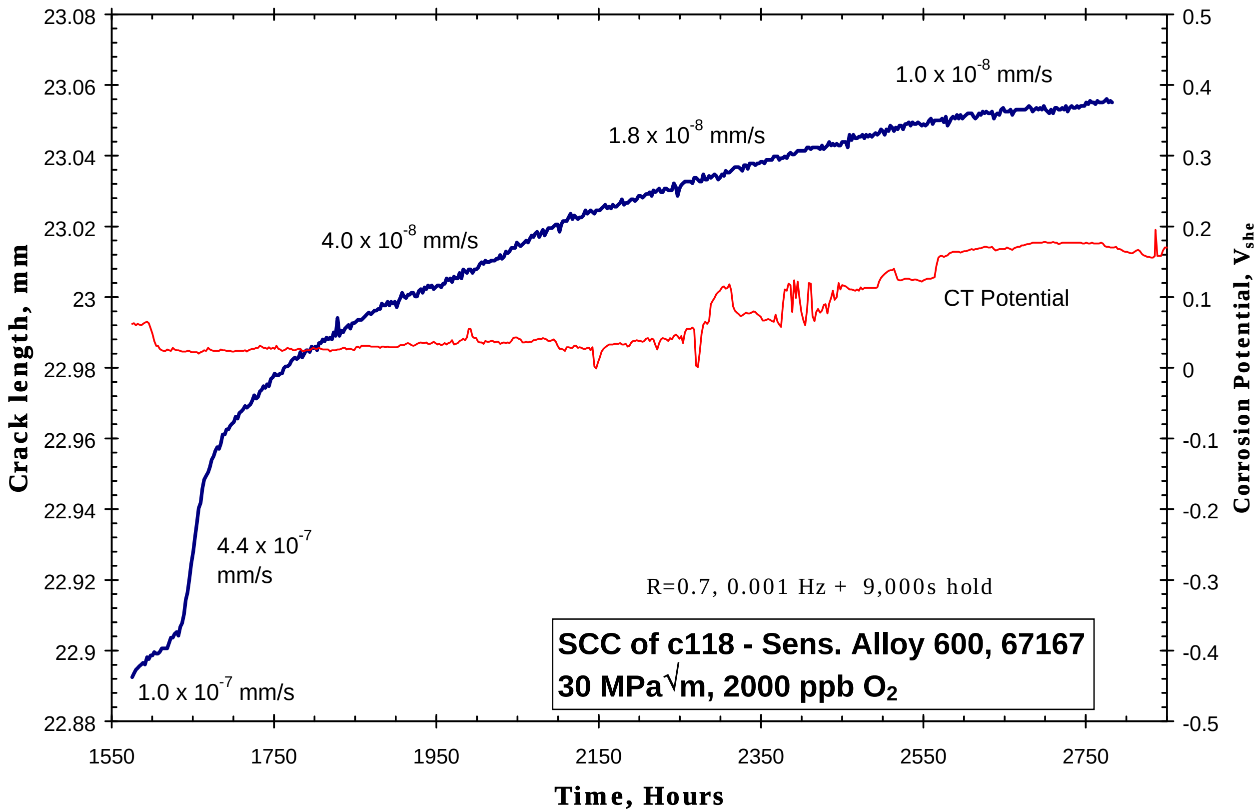


Compact tension (CT) specimen of annealed 316L SS +50% cold work by cross-roll at +140C

Transgranular fatigue pre-crack transitioned to IG SCC crack at constant K

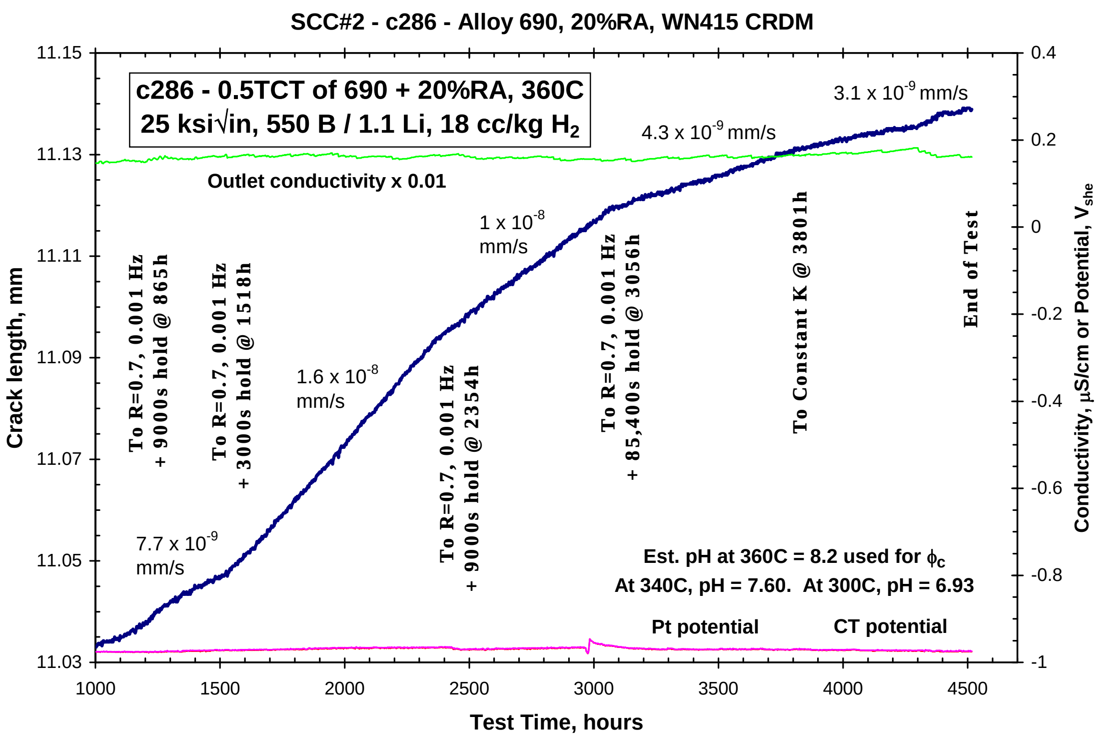
No recipe – must monitor & manage cracking behavior

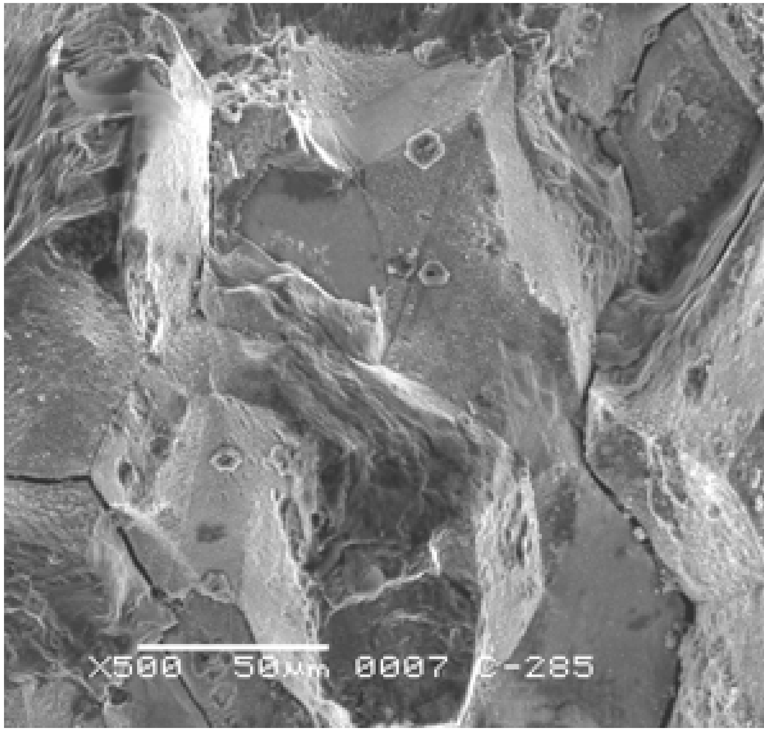
SCC Growth Not Always Well-Behaved



Even with the best experimental techniques, slowing or cessation of crack growth can be observed. This must be actively managed to avoid large scatter

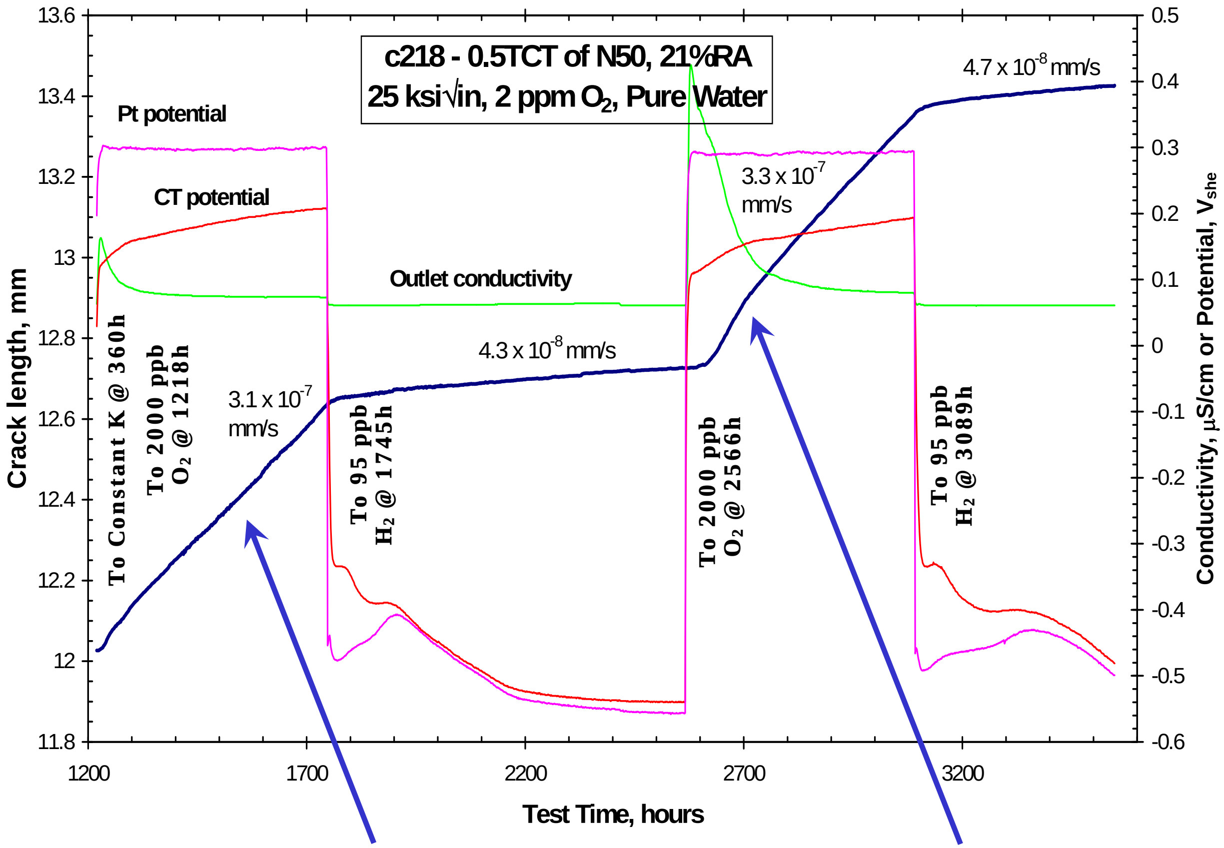
Alloy 690 and 152/52 Weld Metals





Good experiments are needed to define the "reality" of SCC susceptibility in resistant materials

Example of Crack Growth Data



Compact tension (CT) specimen of annealed XM-19 (Nitronic 50) +20% cold work by cross-roll at +140C

Usually acquire data by repeating the changes to demonstrate reproducibility, e.g., low ↔ high potential

Experimental Issues: 690 Emphasis

Ability to obtain high quality CGR data depends on:

1 – Crack length resolution & accuracy (need <10 μm)

Error = (Measured growth – dcpd) / (Measured growth)

2 – Must transition from TG fatigue precrack to IG SCC

Must monitor in-situ; no "recipe" is guaranteed to work

3 – Must manage specimen response, esp. for "no growth"

4 – Sufficient increment & crack front straightness

5 – K within validity; constant K preferred to data with cycling

Need loading stability & good pulse dampening

6 – Control & documentation of heat, treatment, microstucture, machining, precracking, surface, pre-oxidation, etc.

Experimental Issues: 690 Emphasis

7 – Test controls: temperature fluctuation <0.2 °C,

Water & gas chemistry, adequate refresh rate,

full flow demineralizers, measure corrosion potentials…

8 – Ability to make changes “on-the-fly”, e.g., for B/Li, H_2,

temperature, K, etc.

9 – Detailed reporting of: Material – heat, composition, heat treatment, processing/cold-work, microstructure, banding, inclusion, orientation….

Also, precracking, system design, loading, insulation, plots of crack depth & temperature & chemistry & potential vs. time, autoclave volume & refresh rate, post test fractography, dcpd error, etc.