

Degradation of RPV Boundary Components in Concentrated Boric Acid Solutions

Tasks 3:

Corrosion of Reactor Steels in Concentrated Boric Acid Solutions

BAC testing kickoff meeting for NRC Y6722 program on October 29-30, 2003

Argonne National Laboratory



*A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago*



Project Goals

Corrosion Tests

- 1. Ambient environment, 1 atm & T= 100°C BA solutions**
- 2. Molten H-B-O conditions**
- 3. High T(100 to 316°C) and P(1,300-1,800 psi)**

Determine the wastage rates:

A533 Gr B and Type 308 SS weld (diluted by A533Gr B).

- Flowing & quiescent O-bearing BA solutions**
- T = 100-316°C (212-600°F)**
- PWR (1000-wppm B + 2-wppm Li)**
- 3500-wppm B + 2-wppm Li**
- Higher concentration be decided base on above**

Milestones on BA solution Test (TASK #3)

- **Establish Test Equipment based on the results of Task#4**
- **Wastage tests:
A533Gr B and Type 308 SS weld under the following conditions.**
 - I. **Hi-T & P**
 - 288°C, 1300 psi and 316°C, 1800 psi**
 - 3500 wppm-B and a higher value TBD**
 - II. **Hi-T molten solution (235-316°C)**
 - III. **Low T (97.5°C) sat'd BA solutions**

Team/Resources

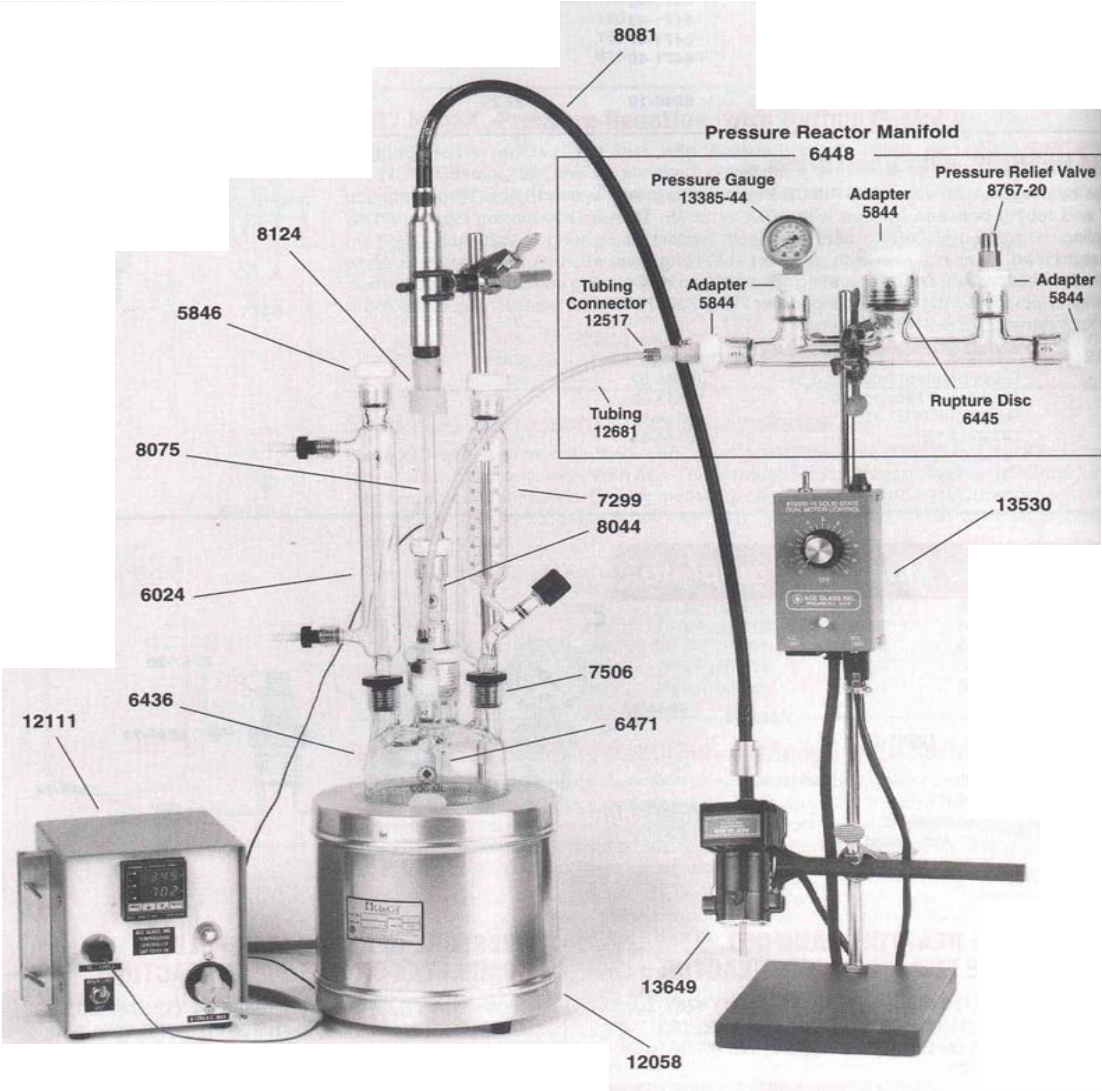
- **BAD-Team members (Monthly meeting)**

K. Natesan, O. K. Chopra, R. Clark, E. Listwan,
J.-H. Park, W. Shack, and W. Soppet

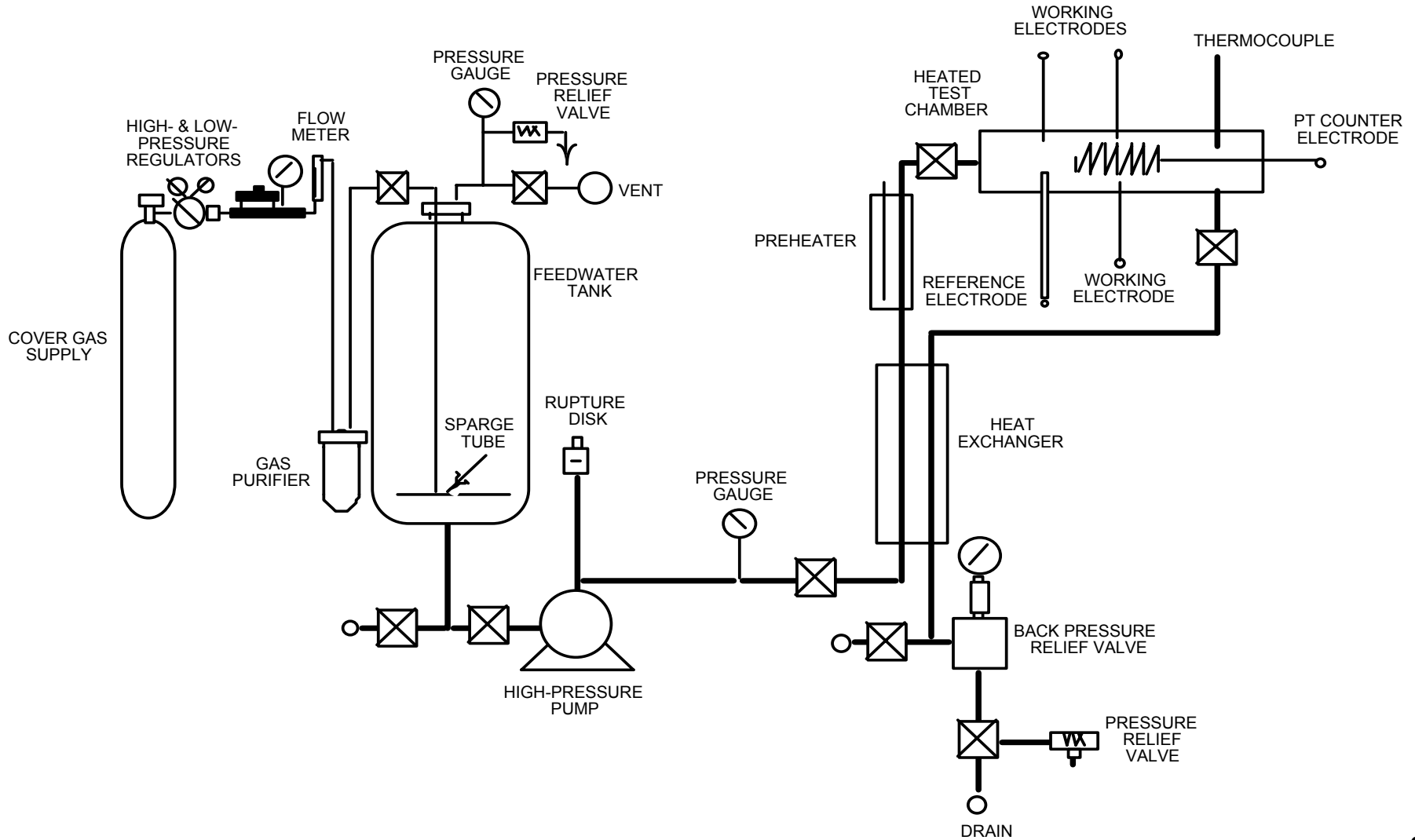
- **Resources allocated to this project**

- Equipment purchased from Ace Glass and,
- Installed/assembled ANL ET(212) G-137
- Samples fabricated by ANL Central Shop (212 and 372)
- X-ray crystallography by ANL Anal. Lab (205)
- Bulk chem. analysis by Conam Kawin Inc., Glendale Hts, IL

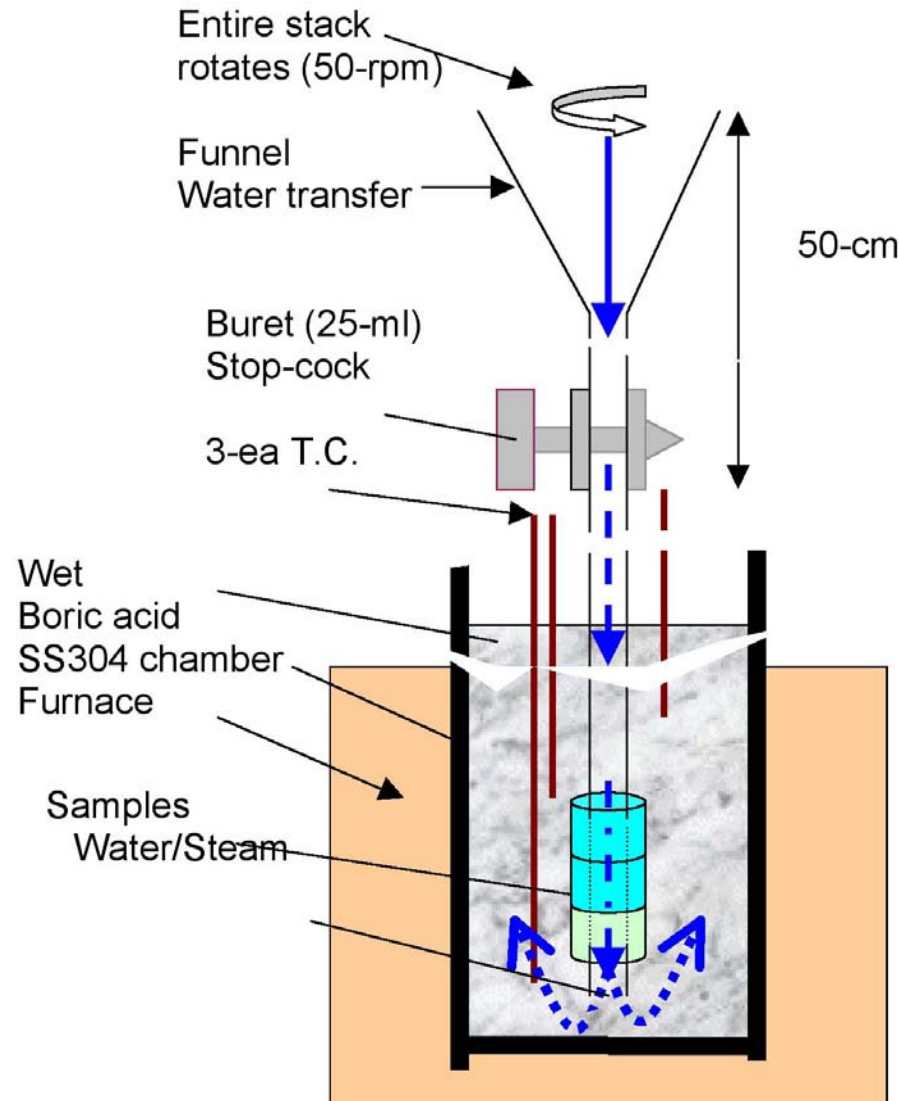
Measurement of Wastage for A533Gr B @ 97.5°C



Corrosion tests facility in High-T & P of BA solutions at T up to 316°C

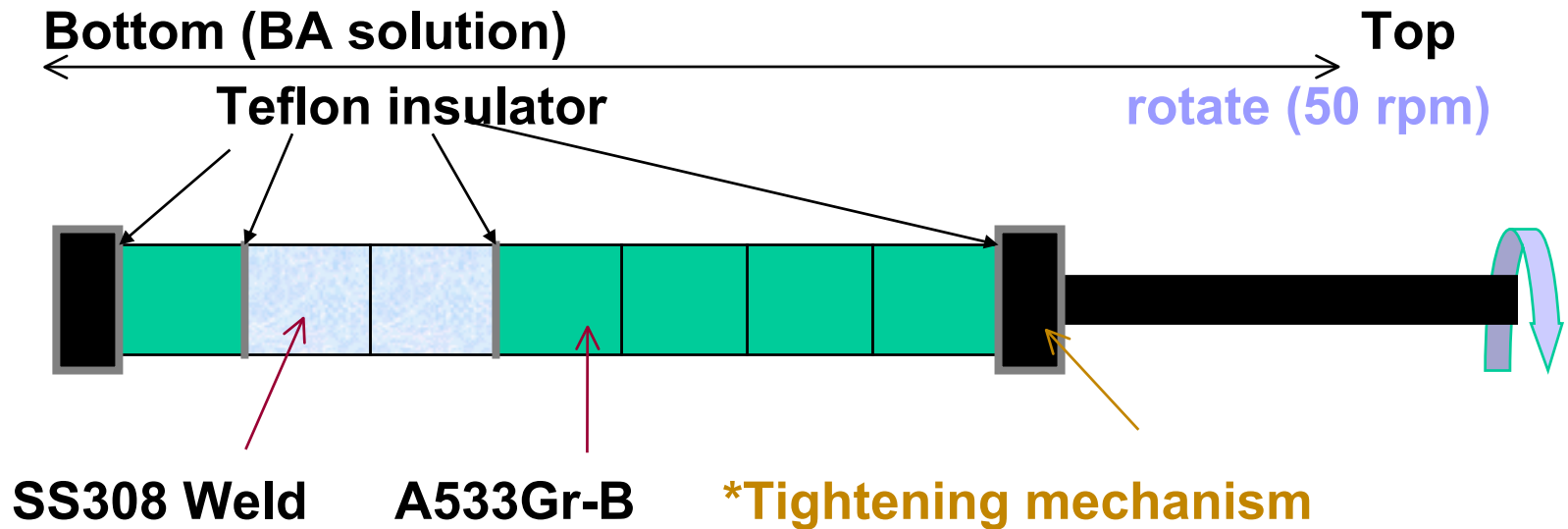


Wastage test apparatus for the molten system



Wastage test sample assembly in solution

Sample: 6.5 gram, OD (0.50"), ID (0.275"), length (0.5")
plug shape



*Stack inside leak-tight filled with rubber tube between shaft

Analysis

Corrosion rates

Dimension measurement

Wt. measurement

Microstructure/phase(s)

Surface and cross section

SEM/OM

X-ray crystallography

Thermodynamic evaluation

Based on the above results

Procedures

1. Wastage test in saturated BA at 97.5°C (completed):

- **Sample stack to be exposed and rotated.**
- **Samples to be taken out one by one at scheduled time, $t = 24\text{h}, 76\text{h}, 100\text{h}, 311\text{h}, 411\text{h}$.**

2. Wastage test at 288 & 316°C (in progress):

2-1) Test at 288°C, 1300 psi, 1,000 h

BA(1) 3,500-wppm-B

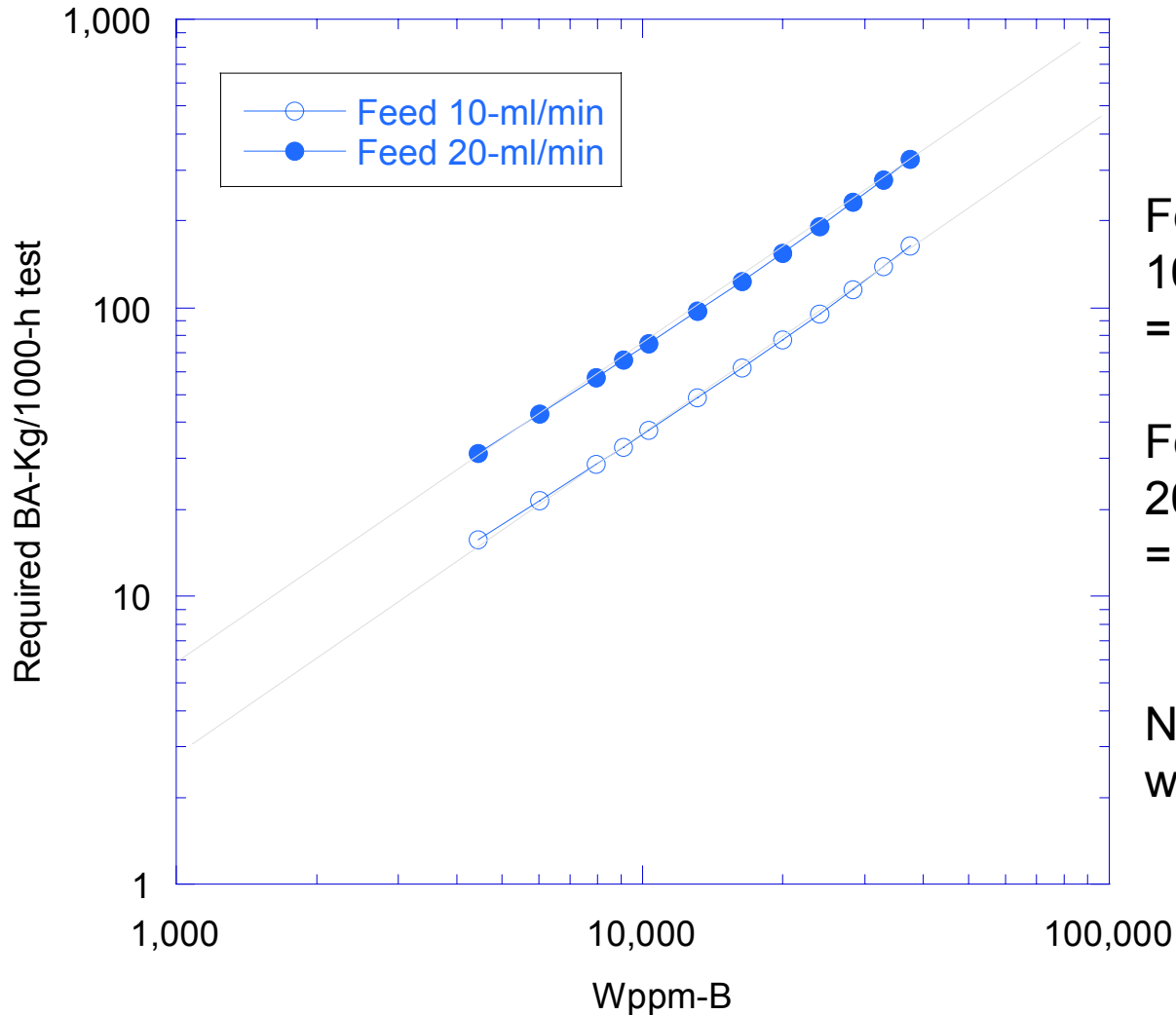
BA(2) Higher value TBD

2-2) Test at 316°C, 1800 psi, 1,000 h

BA(1) 3,500-wppm-B

BA(2) Higher value TBD

Amount of Boric Acid for the 1000-h tests?

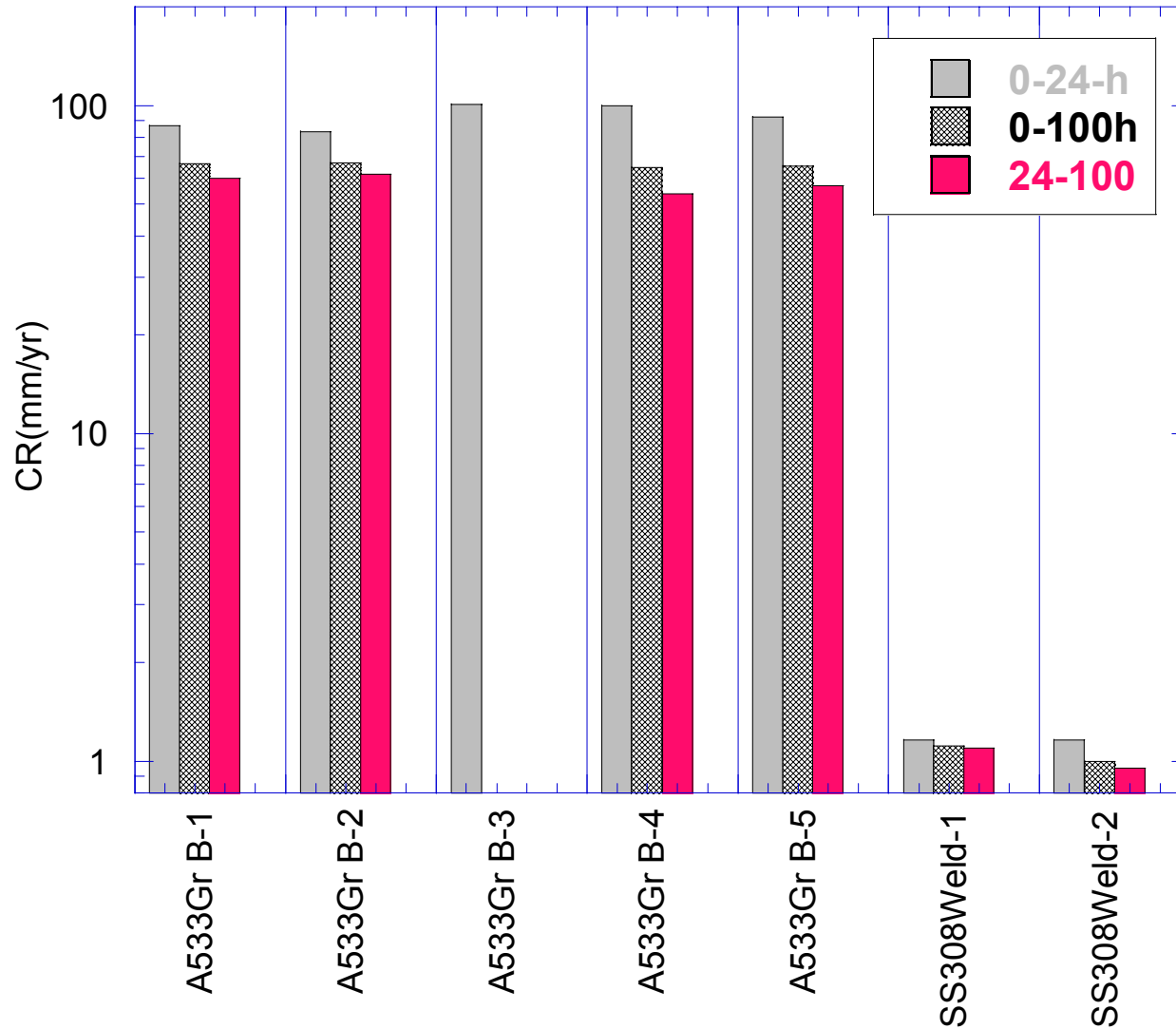


Feed 10-ml/min:
 $10\text{-ml/min} * 60 * 1000\text{min}$
= 600-liters solution

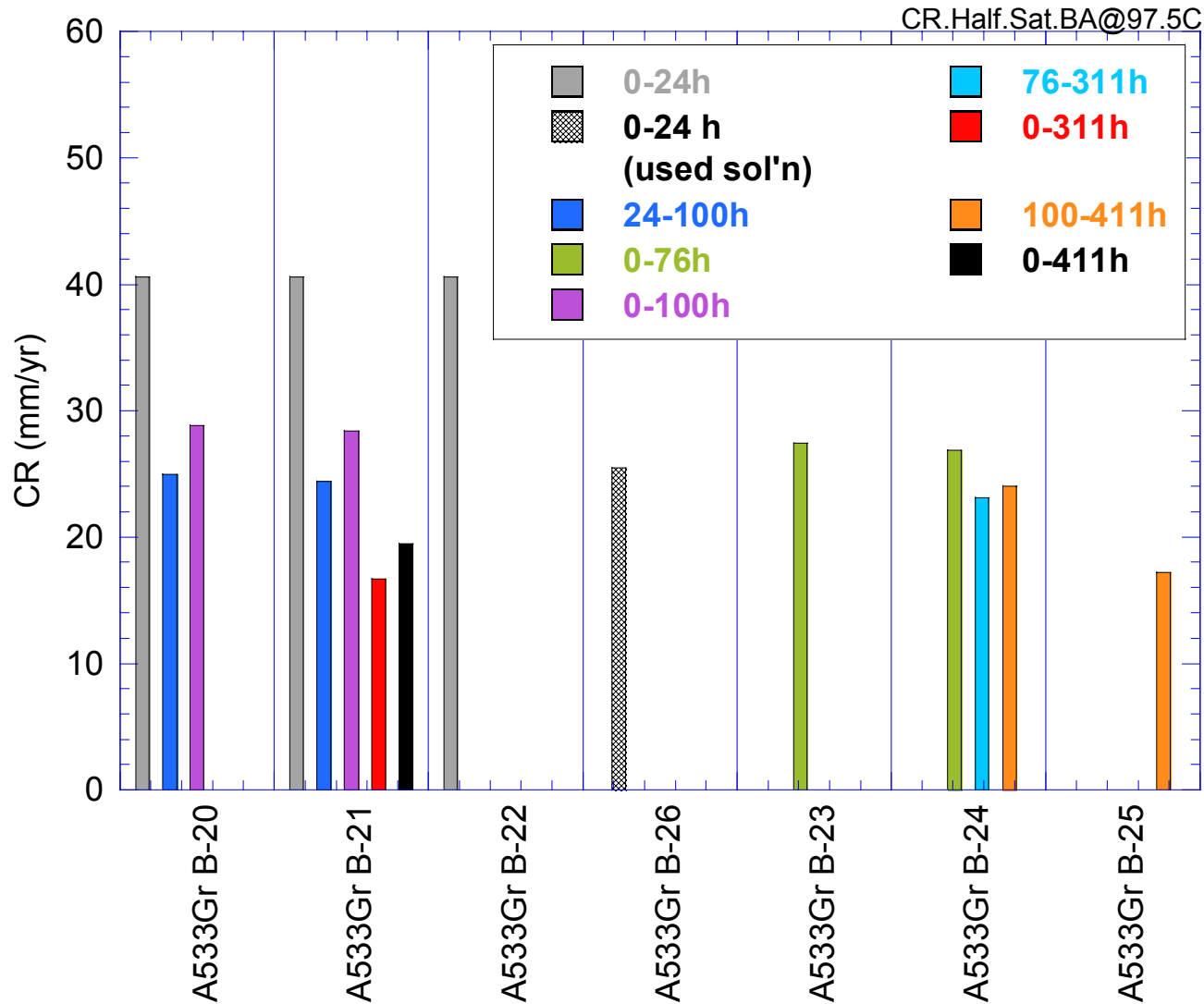
Feed 20-ml/min:
 $20\text{-ml/min} * 60 * 1000\text{min}$
= 1200-liters solution

Note: normal
water tank 130 liter

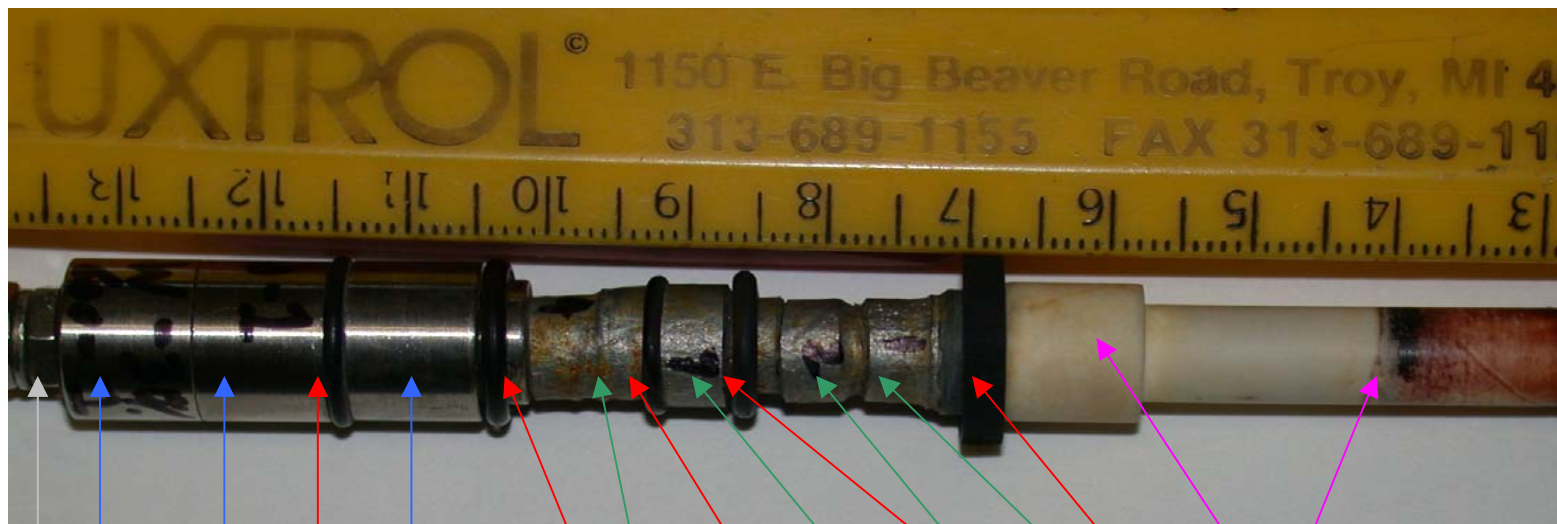
CR for A533-Gr. B & SS 308 in sat'd BA sol'n (40,514 wppm-B) at 97.5°C



Corrosion rates for A533-Gr. B half-saturated BA solution (20,257 Wppm-B) at 97.5°C



Sample stack view for A533Gr-B, A600, SS308 after exposure for 311 or 411 h in sat'd BA solution at 97.5°C



A B C D E F G H I J K L M N O

A: Screw tightening mechanism with flat O-ring at the bottom

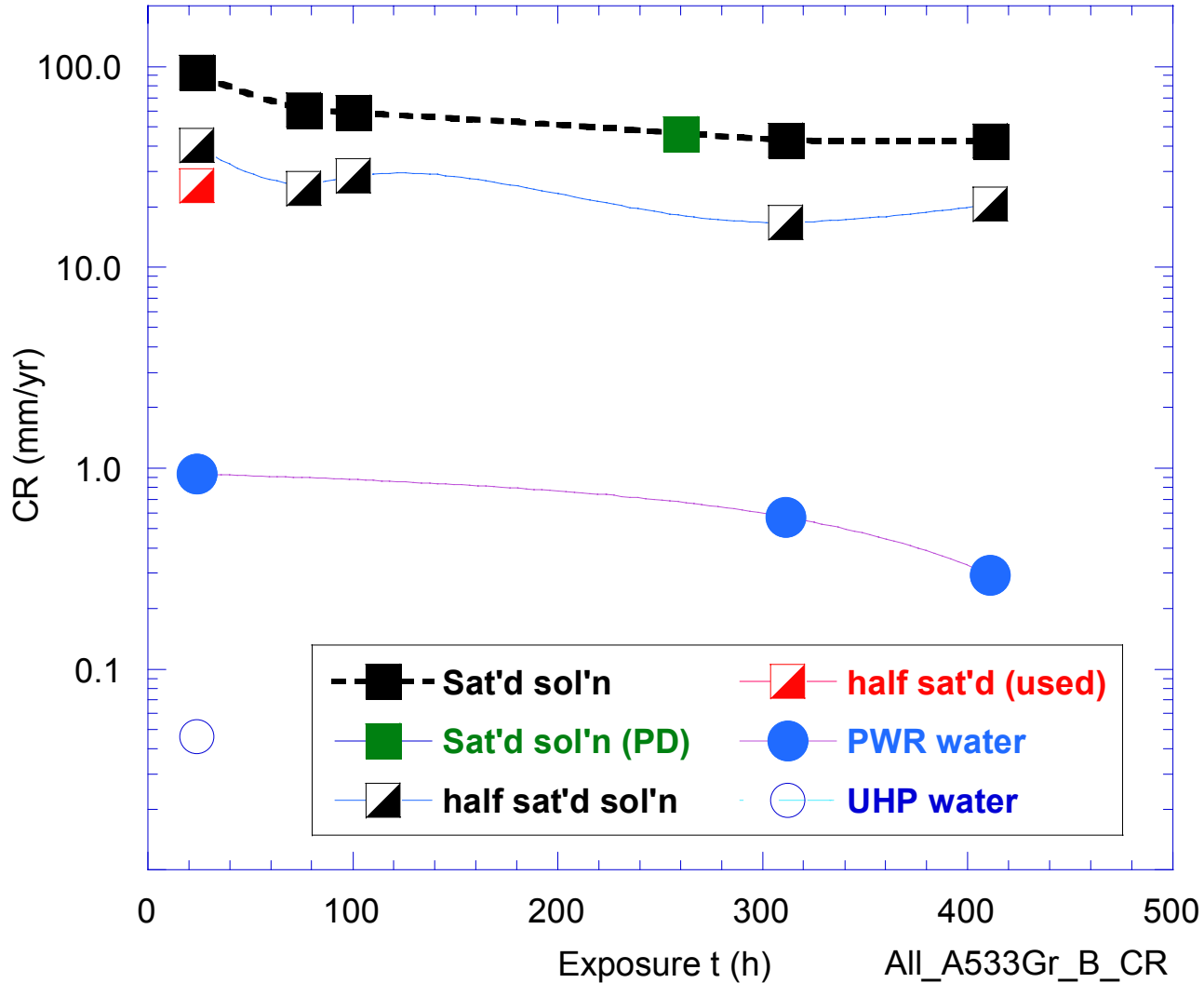
B: A600 (30%CW), **C:** A600-1, **E:** SS308 clad weld

D, F, H, J, & M: O-rings,

G, I, K, & L: A533Gr-B #1, 2, 4, & 7.

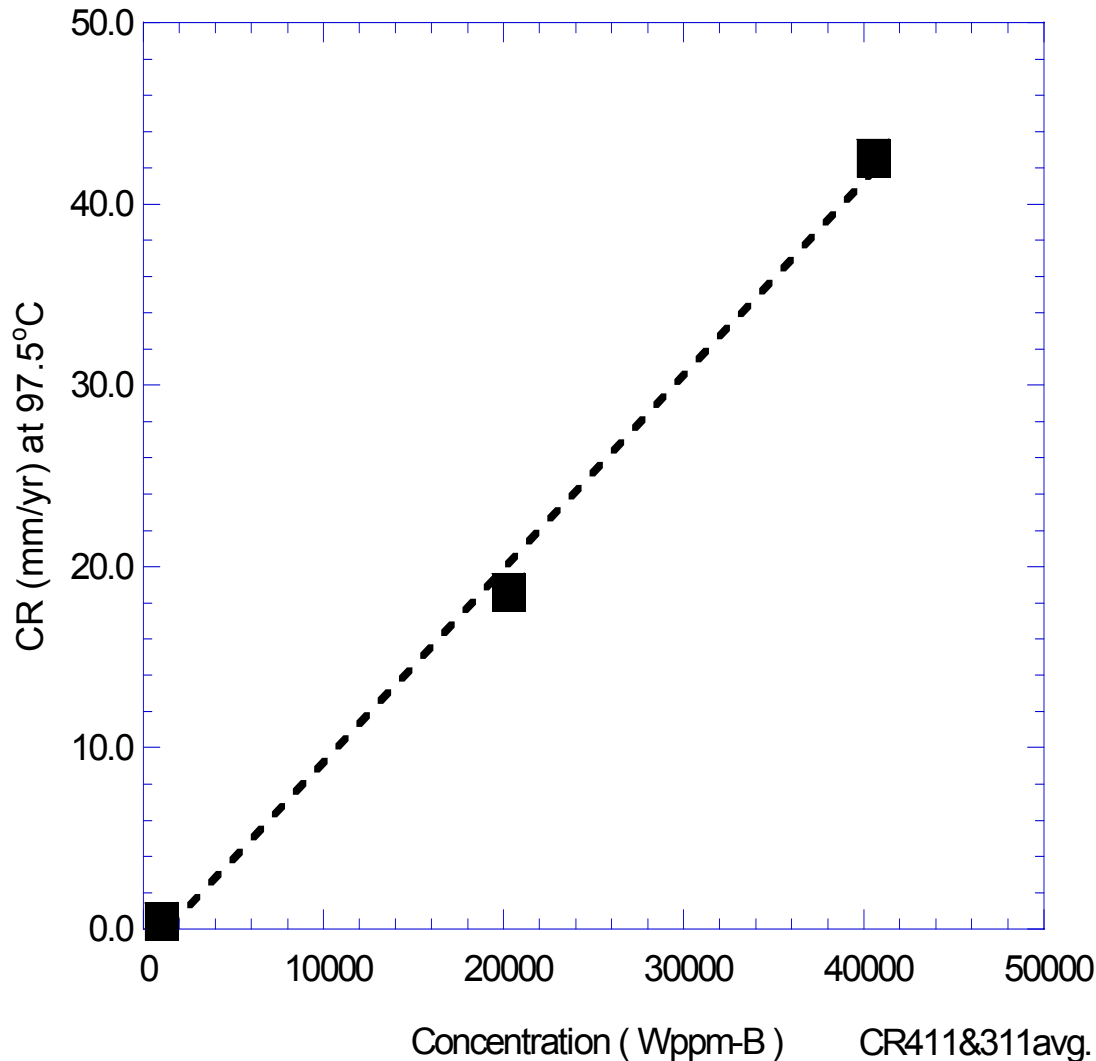
N & O: Alumina (N, in the sol'n & O, interface solution/vapor)

Corrosion Rates of A533Gr-B in various BA solutions at 97.5°C



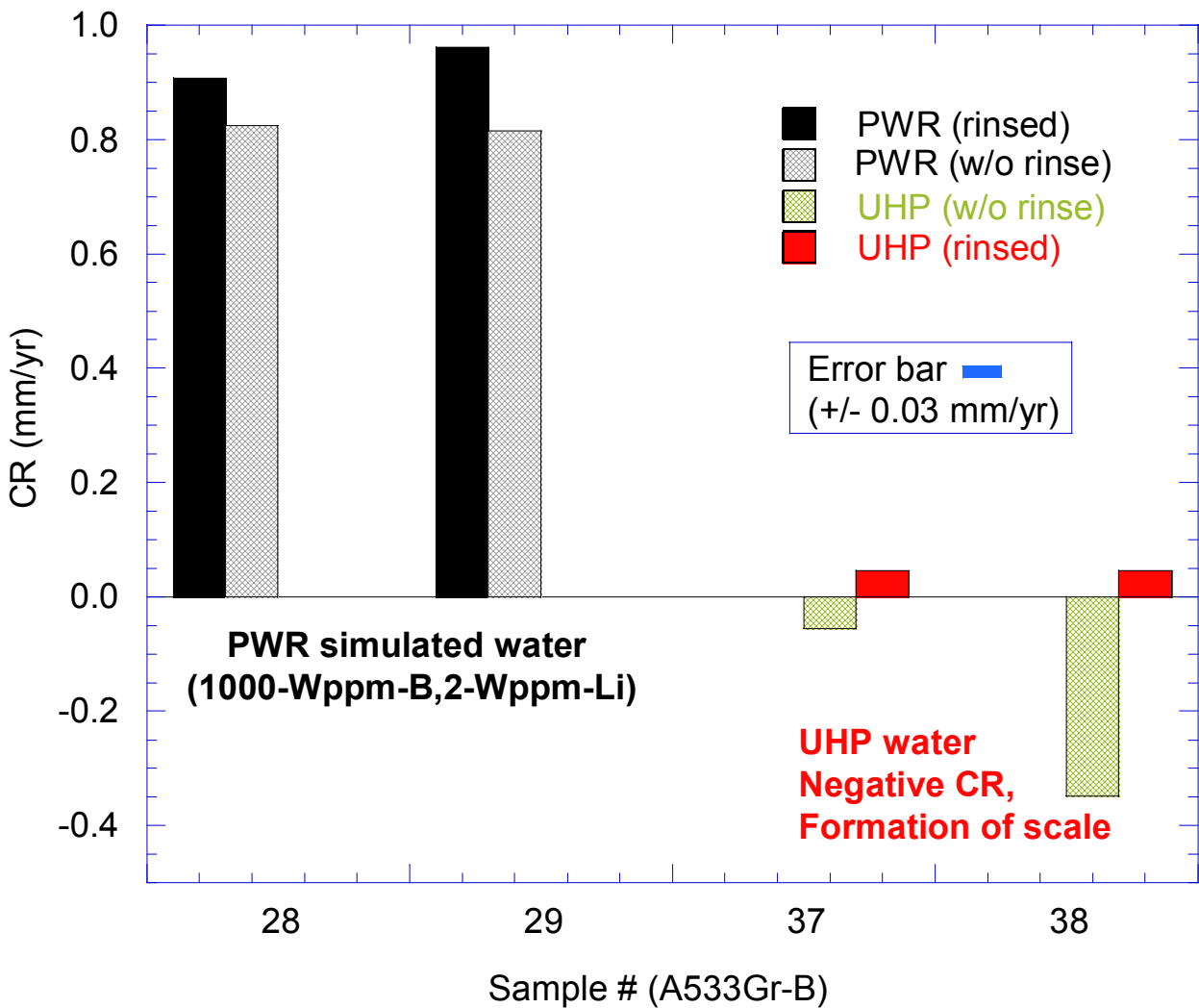
Note:
CR determined times
between 24 and 411 h.

Corrosion Rates vs. Wppm-B for A533Gr-B in BA solutions at 97.5°C

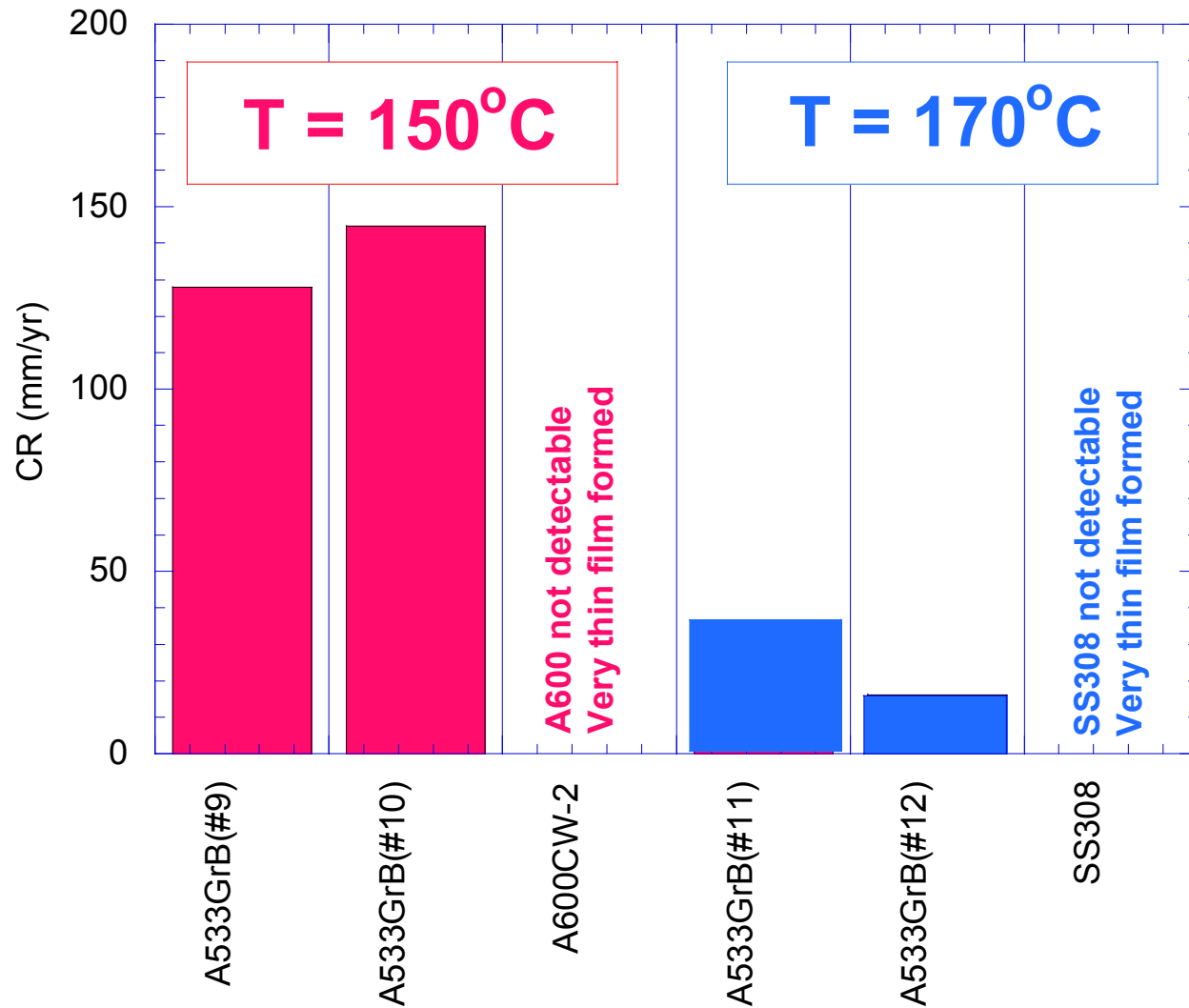


Note:
Corrosion rates based on
311 & 411 h exposure

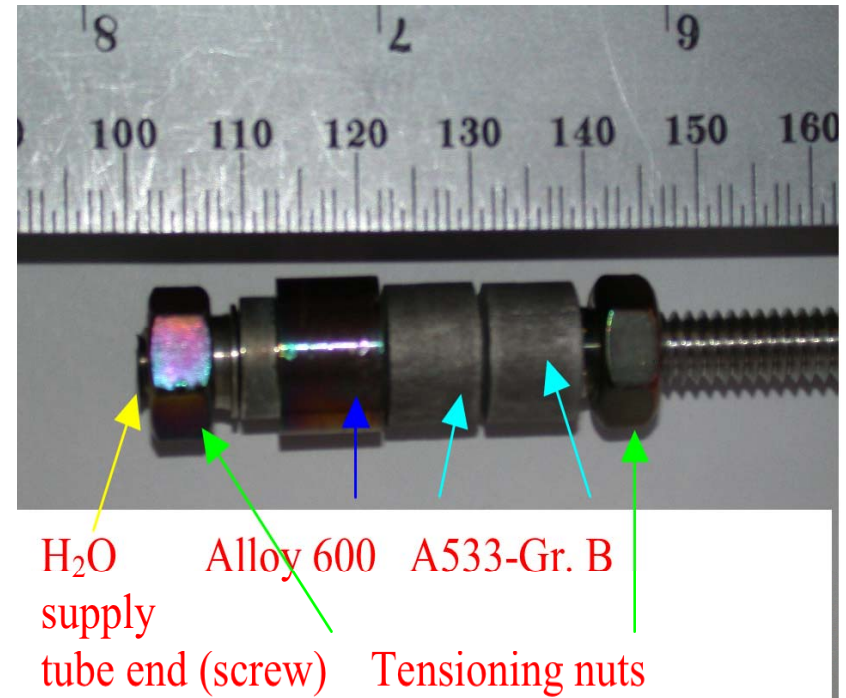
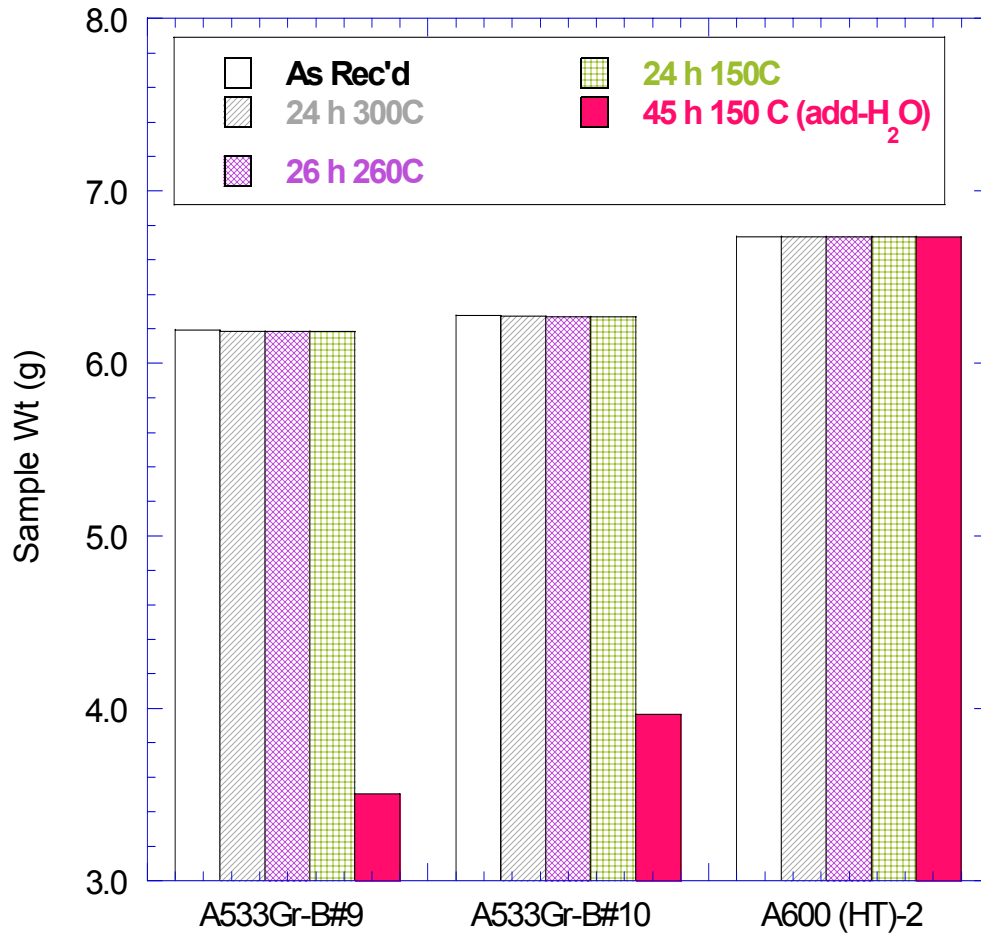
CRs of A533Gr-B in PWR & UHP-waters @97.5°C



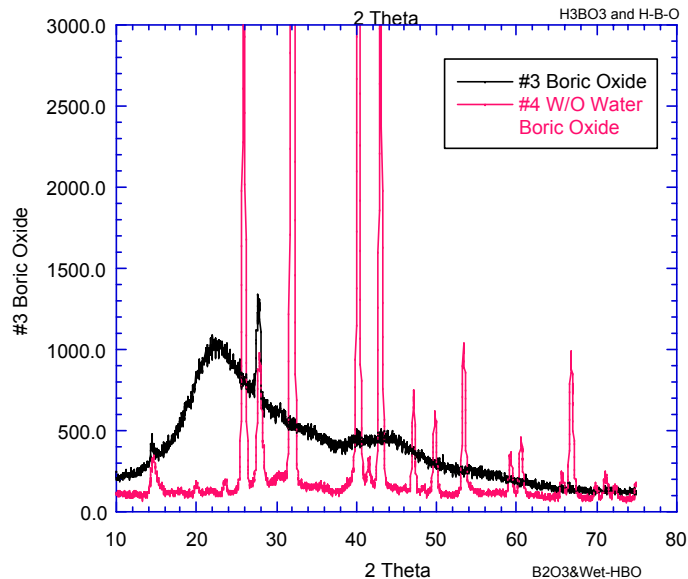
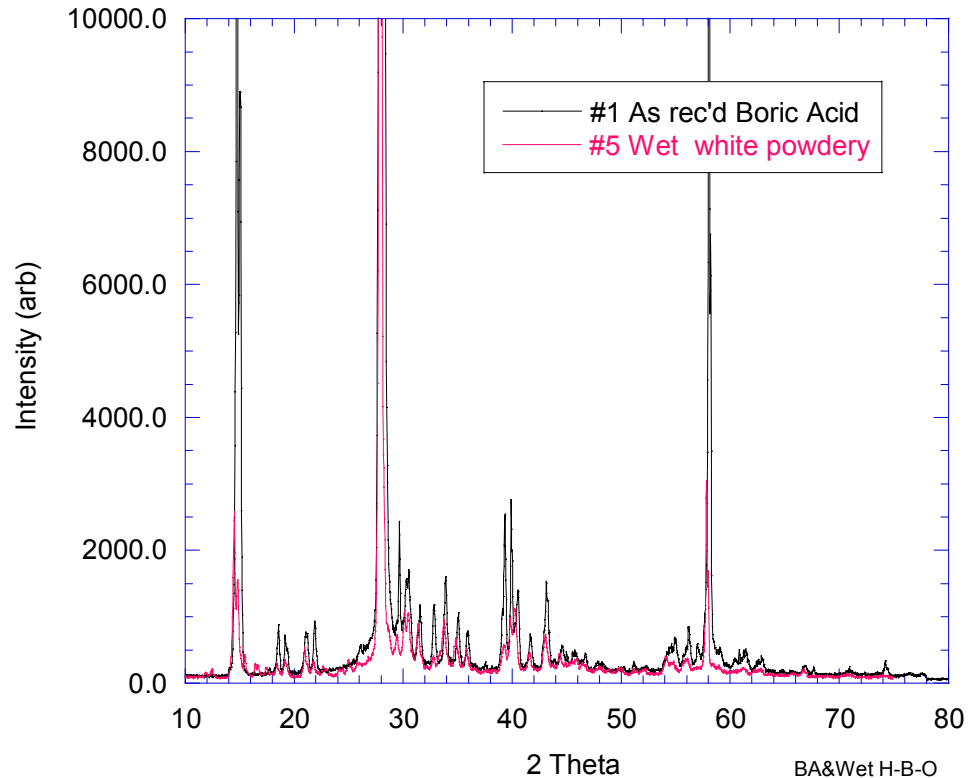
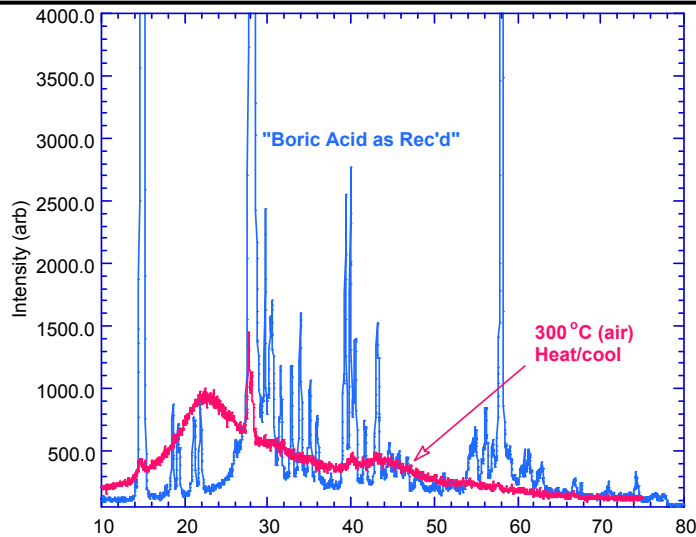
CR: A533-Gr. B, A 600, and SS 308 at 150°C & 170°C with H₂O additions in molten H-B-O.



Molten H-B-O wastage tests: A600 and A533-Gr. B with and without H₂O additions



X-ray spectrum for $B(OH)_3 \leftrightarrow HBO_2 \leftrightarrow B_2O_3$



Transformed by T & H₂O

$B(OH)_3 \leftrightarrow HBO_2 \leftrightarrow B_2O_3$

- **Wastage tests for the A533Gr B in the BA solution at 97.5°C were completed.**
 - CR value of 2-in/yr in the saturated solution was highest
 - CRs were shown linear relationship with the concentration of BA
 - Note: CRs for A600 & SS308 were negligible when compared with those of A533Gr-B.**
- **Wastage tests in the molten H-B-O at 150-290°C were performed.**
 - Without water addition, none of the metallic samples showed corrosion, except thin oxide scale formed on A600 & SS308.
 - With water addition, A533Gr B at 150°C showed the highest CR value, and higher the T the lower the CR.
- **Wastage tests in the Hi-T & P conditions to be conducted based on the scoping work from the Task#4**