Corrosion and Electrochemical Behavior of A Low Alloy Steel
in Boric Acid Solutions

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Leakage from piping and pressure vessels has resulted in varying degrees of external corrosion of PWR components in boric acid solutions.

The effects of solution composition, temperature and dissolved oxygen on corrosion and electrochemical behavior of A508III LAS in boric acid solutions at temperatures from 25 to 95°C were studied.

Helpful for understanding the fundamental factors and mechanism affecting the corrosion.
Experimental
A508-III LAS

I. Weight loss measurement

II. Electrochemical measurement
  • Open circuit potential
  • Dynamic potential scanning
  • Electrochemical impedance spectroscopy

III. Surface observations (SEM)

Results and Analysis

Temp
Concentration
DO

25°C——95°C

1x 1200 ppm B + 2 ppm Li
5x 6000 ppm B + 10 ppm Li
10x 12000 ppm B + 20 ppm Li

Aerated vs. DeAerated (with N₂)
Corrosion in aerated Solutions at Various Concentrations and Temperatures

pH values and corrosion rates

Corrosion rates for A508III steel in aerated boric acid solutions or boric acid with lithium hydroxide solutions at various temperatures

- pH values of test solutions at temperature of 25-95 °C
- Corrosion rate increased, reached a maximum value, and then decreased with increasing temperature.
Electrochemical behavior of A508III steel in aerated boric acid with lithium hydroxide solutions at 25 °C

- Increasing solution concentration increased the anodic current density. There were two potentials $E_2$ and $E_3$ at which the measured cathodic current density was zero, $E_1$ was the measured $E_{corr}$. 
Corrosion in aerated Solutions at Various Concentrations and Temperatures

Electrochemical behavior at 25 °C

EIS diagrams of A508III steel in aerated boric acid with lithium hydroxide solutions at 25 °C

- Increasing concentration of boric acid with lithium hydroxide solution decreased the EIS values.
Corrosion in aerated Solutions at Various Concentrations and Temperatures

Electrochemical behavior at 70 °C

Electrochemical behavior of A508III steel in aerated boric acid with lithium hydroxide solutions at 70 °C

- $E_{\text{corr}}$ was stable at about -0.2 V in 1200 ppm B + 2 ppm Li solution and it was about -0.65 V in more concentrated solutions. Neither current peak nor typical active-passive transition could be observed on the anodic polarization curves.
Corrosion in aerated Solutions at Various Concentrations and Temperatures

Electrochemical behavior at 70 °C

EIS diagrams of A508III steel in aerated boric acid with lithium hydroxide solutions at 70 °C

- The Nyquist plots exhibited two capacitive loops: one loop at high and intermediate frequencies and the other small one at low frequencies.
In 1200 ppm B + 2 ppm Li solution $E_{\text{corr}}$ could be stable at two levels: high potential of about -0.21 V and low potential of about -0.68 V. There were two potentials $E_2$ and $E_3$ at which the measured current was zero if $E_{\text{corr}} > -0.25$ V. There was only one corrosion potential in concentrated solutions.
Corrosion in aerated Solutions at Various Concentrations and Temperatures

Electrochemical behavior at 95 °C

EIS diagrams of A508III steel in aerated boric acid with lithium hydroxide solutions at 95 °C

Nyquist plots measured in 1200 ppm B + 2 ppm Li solution at two levels of $E_{corr}$ were close in the frequency range of 1M to 1 Hz, which were significantly different in the frequency range of 1 to 10m Hz.
Corrosion in aerated Solutions at Various Concentrations and Temperatures

Potential-pH diagrams analysis

The emergence of zero-current potentials in the cathodic polarization curves was mainly controlled by multiple elemental electrode reactions.

(a) 25 °C  
(b) 70 °C  
(c) 95 °C

The E-pH diagram of Fe-H₂O system and E_{corr} values in aerated solutions at 25, 70, 95 °C
Corrosion rates for A508III steel in aerated and deaerated 12000 ppm B + 20 ppm Li solutions at temperature of 50-95 °C

- In deaerated solutions, corrosion rates increased monotonically with increasing temperature. Corrosion rates in aerated solution at first increased with increasing temperature, reached a maximum value at about 75 °C, and then decreased with increasing temperature.
Temperature effect on corrosion rate in aerated solutions

- Solubility of oxygen in solution
- Diffusivity of oxygen in solution
- Reaction kinetics: anodic and cathodic
- Film properties
The SEM micrograph of the corrosion product films formed on A508III steel after immersion in 12000 ppm B+ 20 ppm Li solutions for 24 h at 95°C (a) aerated, (b) deaerated

The corrosion products formed in aerated solution were compacted and uniformly distributed. However, several cracks were observed in the micrograph of the films formed in deaerated solution.
Corrosion in aerated and deaerated Concentrated Solutions

The surface morphologies of the A508III specimens surfaces after removing the corrosion products formed in 12000 ppm B+20 ppm Li solutions.

- Main corrosion type was general corrosion.
Conclusions

• In aerated solutions, increasing the concentration of boric acid and lithium hydroxide increased the corrosion rates and anodic current densities, and decreased the electrochemical impedance values.

• Corrosion rates of A508III steel in deaerated solutions increased monotonically with increasing temperature in the range of 25-95 °C.

• Corrosion rates of A508III steel in aerated solutions showed a peak value at about 75 °C. This was related to the combinations of temperature and dissolved oxygen on corrosion and film properties.

• The corrosion product films formed in aerated solution at 95 °C were compact and uniformly distributed. The films formed in deaerated solution were not compact.
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