Fireside Corrosion in Oxy-Combustion Demonstration Plant (FutureGen 2.0)

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FutureGen 2.0 Organizational Structure

Project Oversight

U.S. Department of Energy

FutureGen Alliance

Oxy-Combustion Repowering

CO₂ Pipeline & Storage Hub

B&W

Power Generation Group

Oxy-Combustion Boiler and GQCS

AIR LIQUIDE

ASU & CPU

Technology Providers

Power Generation Group

Oxy-Combustion Boiler and GQCS
Impact of Oxycombustion on Boiler Design

Convection Pass

Furnace

Meredosia Energy Center

Subcritical Boiler
FutureGen 2.0 Process Configuration

“Cool” Gas Recycle Process

ASU

Burners

Coal

Boiler

Steam; 2100 psia, 1000°F/1000°F

Recycle Heater

CDS

Secondary Recycle (SR) Fan

CPU

Air Intake

Recycle Damper

Stack Damper

Vent

To Storage

CPU Damper

CPU

Gas Reheater

DCCPS

ID Fan

Primary Recycle (PR) Fan

Recycle Damper

Gas Reheater

Vent

ASU
FutureGen 2.0 Fireside Corrosion Considerations

- Blend of 60% Illinois #6 + 40% PRB
- \( S = 2.1 \) wt.%
  \( Cl = 0.1 \) wt.%
- Un-staged combustion
- “Cool” gas recycling
- \( SO_2 = 2300 \) ppmv
  \( HCl = 100 \) ppmv
- Main steam \( T = 538^\circ C \) (1000^\circ F)
- Maximum SSH outlet bank metal \( T = 616^\circ C \) (1141^\circ F)
Coal Ash Corrosion on SH/RH

Perform laboratory corrosion tests (based on IL#6 coal)

- Temperature: 593-649°C (1100-1200°F)
- \( \text{SO}_2 \): 2200 ppmv
- \( \text{HCl} \): 300 ppmv
- Balance: \( \text{O}_2-\text{N}_2-\text{Ar}-\text{CO}_2-\text{H}_2\text{O} \)
- Deposit \( \text{Al}_2\text{O}_3-\text{SiO}_2-\text{CaO}-\text{Fe}_2\text{O}_3-\text{Fe}_2(\text{SO}_4)_3-\text{Na}_2\text{SO}_4-\text{K}_2\text{SO}_4-\text{CaCO}_3-\text{K}_2\text{CO}_3-\text{MgCO}_3-\text{Na}_2\text{CO}_3 \)
- 1000 hours, isothermal
Corrosion Rate of “Conventional” SH/RH Alloys

2200 ppm SO₂ and 300 ppm HCl

Temperature (F)

1080 1100 1120 1140 1160 1180 1200 1220

mpy

Max. Tds

347H

347HFG

304H

310HCbN
Acid Dew Point Corrosion

- 30 MWth Pilot-scale combustion facility (CEDF) burning PRB and lignite coals
- Primary and secondary condensates collected
  - Condensate pH = 2.2-2.8 from very low-sulfur coals
- Carbon steel and Corten exposed to condensate solutions at 110-190°F under CO$_2$/N$_2$/O$_2$ cover gas for up to 175 hours
- These alloys also exposed to sulfuric acid solutions of different concentrations up to 25 wt. %
Dew Point Corrosion Test Apparatus
Laboratory Dew Point Corrosion Test
Corrosion Rates vs. Temperature

PRB Condensate

**Carbon Steel - Primary Condensate**

\[
y = 0.6593x + 6.1083 \\
R^2 = 0.9879
\]

**Carbon Steel - Secondary Condensate**

\[
y = 0.8948x - 44.768 \\
R^2 = 0.9921
\]

**Corten - Primary Condensate**

\[
y = 0.4407x + 24.462 \\
R^2 = 0.9102
\]

**Corten - Secondary Condensate**

\[
y = 0.8893x - 58.104 \\
R^2 = 0.9877
\]
Corrosion Rate vs. Time

PRB Condensate

Carbon Steel

Corten
Corrosion Rate vs. Acid Concentration

Samples Fully Immersed in Sulfuric Acid

Carbon Steel

\[ y = 303.72x \]
\[ R^2 = 0.9871 \]

Corten

\[ y = 302.06x \]
\[ R^2 = 0.9923 \]
Ductwork Interior Surface Appearance

Gas T < Dew Point

Gas T > Dew Point
Conclusions

- Laboratory tests performed to evaluate fireside corrosion potential of FG2
- Conventional stainless steels may be used for highest temperature sections of SH/RH in subcritical oxy-fired boilers
- Dew point corrosion severe in recycle loop/back end if acid allowed to condense
- Gas temperature designed above dew point or use of coating is essential in recycle loop