Supporting Information for

Effect of Impurities on the Corrosion Behavior of CO₂ Transmission Pipeline Steel in Supercritical CO₂-Water Environments

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Text: Setup and procedures for the corrosion test.

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Experimental Section

A schematic diagram of the autoclave corrosion test system used in this study is presented in Figure S1 (a). Technical grade (ultra high purity) oxygen (O₂) and sulfur dioxide (SO₂) cylinders served as the O₂ and SO₂ sources which were directly added to the autoclave by adjustment of the partial pressures of each gas. High pressure CO₂ was added to the autoclave with gas booster pump to the desired working pressure.

The specimens were ground with 600 grit silicon carbide paper, cleaned with isopropyl alcohol in an ultrasonic bath, dried, and weighed using a balance with a precision of 0.1 mg. The electrolyte used in this work was deionized (DI) water. The weight loss experiments were performed in a 2000 psi static autoclave with 1000 ml volume (Figure S1 (b)). In each test, two specimens were simultaneously exposed to the corrosive environment in order to obtain an averaged corrosion rate. A 1 mm diameter hole at one end serves to hang the samples from a sample stand with a non-metallic wire inside the autoclave. The specimens were removed and cleaned for 5 min in Clarke solution (20 g antimony trioxide + 50 g stannous chloride and hydrochloric acid to make 1000 ml) (1). The specimens were then rinsed in distilled water, dried and weighed to 0.1 mg. The corrosion rate can be calculated by the following equation (2):

$$\text{Corrosion rate (mm/y)} = \frac{8.76 \times 10^4 (\text{mm} \cdot \text{hour/cm} \cdot \text{year}) \times \text{weight loss (g)}}{\text{area (cm}^2\text{)} \times \text{density (g/cm}^3\text{)} \times \text{time (hour)}} \quad (1)$$

Literature Cited

- (1) ASTM Standard G1-03, Standard practice for preparing, cleaning, and evaluating corrosion test specimens. In *Annual Book of ASTM Standards, Vol. 03. 02*; ASTM International: West Conshohocken, PA, 2003.
- (2) ASTM Standard G31, Standard practice for laboratory immersion corrosion testing of metals. In *Annual Book of ASTM Standards, Vol. 03. 02*; ASTM International: West Conshohocken, PA, 1994.

TABLE S1. Element Analysis for the Carbon steel (API 5L X65) and the 13Cr Steel (UNS S41000) Used in the Tests (wt. %)

	C	Mn	Si	P	S	Cr	Cu	Ni	Mo	Al	V
X65	0.065	1.54	0.25	0.013	0.001	0.05	0.04	0.04	0.007	0.041	-
S41000	0.13	0.49	0.23	0.012	0.005	12.74	0.009	0.112	0.017	-	0.038

TABLE S2. Test Matrix for CO₂-Saturated Water Phase

Material	CO₂ pressure (bar)	O₂ pressure (bar)	Temperature (°C)	Test period (hour)	
X65	80	0	50	24	120
	80	3.3	50	24	120
S41000	80	0	50	24	
	80	3.3	50	24	

TABLE S3. Test Matrix for Water-Saturated CO₂ Phase

Material	CO₂ pressure (bar)	O₂ pressure (bar)	SO₂ pressure (bar)	Temperature (°C)	Test period (hour)
X65	80	0	0	50	24
	80	1.6	0	50	24
	80	3.3	0	50	24
	80	5.1	0	50	24
	80	0	0.8	50	24
	80	3.3	0.8	50	24
S41000	80	0	0.8	50	24
	80	3.3	0.8	50	24

FIGURE S3. SEM images of the surface of 13Cr steel exposed in CO₂-saturated water with oxygen for 24 hours.

(a)

(b)

FIGURE S4. SEM images of the sample exposed in water-saturated CO₂ for 24 hours with different O₂ contents (after cleaning): (a) 80 bar CO₂, 50°C, (b) 80 bar CO₂, 5.1 bar O₂, 50°C.

(a)

(b)

FIGURE S5. SEM cross-sectional image of the sample exposed in water-saturated CO₂ for 24 hours: (a) 80 bar CO₂, 0.8 bar SO₂, 50°C, (b) 80 bar CO₂, 3.3 bar O₂, 0.8 bar SO₂, 50°C.

(a)

(b)

Figure S6. SEM images of the sample exposed in water-saturated CO₂ for 24 hours (after cleaning): (a) 80 bar CO₂, 0.8 bar SO₂, 50°C, (b) 80 bar CO₂, 3.3 bar O₂, 0.8 bar SO₂, 50°C.