Effect of H₂S on CO₂ Corrosion of Mild Steel in High-Temperature Supercritical CO₂ Conditions

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The effect of H_2S on the aqueous corrosion behavior of mild steel was evaluated at high-pressure and high-temperature (HPHT) conditions at a partial pressure of CO_2 of 12 MPa and a temperature of 160°C. The corrosion rate of steel samples was determined by electrochemical and weight loss measurements. The surface and cross-sectional morphology and the composition of the corrosion product layers were analyzed by using surface analytical techniques (scanning electron microscopy, energy-dispersive x-ray spectroscopy, and x-ray diffraction). Results showed that the corrosion rate decreased with time and no significant difference was observed in the presence of 1,000 ppm and 2,000 ppm of H_2S at HPHT CO_2 conditions. Surface and cross-sectional analyses revealed that the corrosion process was governed by the formation of FeCO₃ regardless of the presence of H_2S . Furthermore, the corrosion behavior of mild steel in these conditions did not depend significantly on flow velocity.

KEY WORDS: carbon steel, corrosion, H₂S, high temperature supercritical carbon dioxide

INTRODUCTION

The presence of large quantities of CO_2 (from 25% to 89%) in gas fields has imposed increased challenges on the economics of project development and subsequent operations.¹ A major issue in developing those fields is corrosion and materials technology because of aggressive environments (i.e., high CO_2 contents and/or presence of H_2S) with high pressures and high temperatures (HPHT).² Although corrosion-resistant alloys have been available as a materials selection option for these severe environments, carbon and low alloy steels are still widely used as tubing materials due to their strength, availability, and $cost.^{3-7}$

The increment of temperatures and CO_2 pressure in production wells may lead to CO_2 in a supercritical state if the temperature and pressure are over 31.1°C and 7.38 MPa, respectively.⁸ Corrosion issues in supercritical CO_2 environments relating to carbon capture and storage, enhanced oil recovery, and deepwater oil and gas production applications have recently been investigated at relatively low temperatures (<90°C),⁹⁻¹³ and it has been understood that aqueous corrosion mechanisms in high-pressure CO_2 are similar to those in lowpressure CO_2 conditions.¹⁴

On the other hand, there has been relatively less research on corrosion at high temperatures above 100° C,¹⁵⁻¹⁶ regardless of the used CO₂ pressure. In the temperature range from 90° C to 250°C, general corrosion rates of carbon steel (CS) have been shown to decrease with the increasing temperature being strongly dependent on the development of magnetite (Fe₃O₄) as a protective corrosion product because of its fast formation kinetics at high temperatures.¹⁷⁻¹⁸ This indicates that high temperatures can have a significant effect on the corrosion rate through the formation/transformation of corrosion product layers. Similar effects have been also found in high-temperature H₂S corrosion, yet the understanding of the associated corrosion mechanism is very limited.¹⁹⁻²¹

There are only a few studies currently available in the literature for aqueous corrosion in high-temperature supercritical CO_2 environments with H_2S related to downhole conditions. However, corrosion behavior in these type of environments at high temperatures has not been well characterized or understood yet. The objective of the present study was to characterize and analyze the aqueous corrosion behavior of CS in high-temperature supercritical CO_2 in the presence of H_2S .

EXPERIMENTAL PROCEDURES

2.1 | Material

The test specimens were machined from UNS K03014⁽¹⁾ CS with two different geometries: cylindrical type with 5 cm² exposed area for electrochemical measurements, and rectangular type with a size of 1.27 cm × 1.27 cm × 0.254 cm for surface analysis. The chemical composition of the used CS was shown in Table 1. The specimens were ground sequentially with 250-, 400-, and 600-grit silicon carbide paper, rinsed with

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⁽¹⁾ UNS numbers are listed in *Metals & Alloys in the Unified Numbering System*, published by the Society of Automotive Engineers (SAE International) and cosponsored by ASTM International.

Table 1. Chemical Composition of the Used CS (wt%, balance Fe)									
С	Cr	Mn	Ρ	S	Si	Cu	Ni	Мо	AI
0.065	0.05	1.54	0.013	0.001	0.25	0.04	0.04	0.007	0.041

deionized (DI) water, cleaned with isopropyl alcohol in an ultrasonic bath for 60 s, and then dried.

2.2 | Autoclave Setup

The corrosion experiments were conducted in a 7.5 L autoclave (UNS N10276) which contained a CS working electrode, an HPHT Ag/AgCl reference electrode, a platinum-coated niobium counter electrode, and an HPHT ZrO_2 -based pH electrode. A schematic of the experimental setup was shown in Figure 1. The test solution was a 1 wt% NaCl aqueous



FIGURE 1. Schematic diagram of the autoclave used for the tests under HPHT conditions.

electrolyte prepared using DI water. An impeller was used to stir the solution and generate flow velocities of about 1 m/s and 1.7 m/s (1,000 rpm and 1,700 rpm, respectively) around the metal specimens during the tests.

2.3 | Methodology

The experimental procedure is outlined in Figure 2. Initially, 6 L of 1 wt% NaCl solution was placed in the autoclave and purged with a high flow rate of CO₂ for about 3 h to minimize dissolved O₂ content. The specimens were then placed in the autoclave while purging with CO₂ to avoid air ingress. After closing the autoclave, additional purging with CO₂ or a mixture of $CO_2/10\%$ H₂S was performed for 1 h to 2 h to ensure the saturation with CO₂ or CO₂/H₂S and further deaeration and, subsequently, the temperature was increased to the testing temperature of 160°C. The used procedure assured that the test solution was not contaminated by O2,²² which was confirmed by an Orbisphere[†] O₂ sensor measuring less than 5 ppb of dissolved O₂. Once the test temperature was reached, the working H₂S partial pressure for the CO₂/H₂S conditions was achieved by pressurizing with a mixture of $CO_2/10\%$ H₂S. Finally, the working partial pressure of CO₂ was then attained by injecting this gas with a booster pump.

Corrosion rates of specimens were evaluated with time by linear polarization resistance (LPR) measurements. The working electrode was polarized at $\pm 10 \text{ mV}_{OCP}$ with a scan rate of 0.125 mV/s. The polarization resistance (R_p), obtained from the LPR technique, was used to calculate the corrosion current density (i_{corr}) by using the Stern-Geary equation:

$$i_{corr} = \frac{B}{R_p} = \frac{\beta_a \times \beta_c}{2.3 \times R_p \times (\beta_a + \beta_c)},$$
 (1)

where β_a is the anodic Tafel slope and β_c is the cathodic Tafel slope. The B value, used in this study, was 23 mV which has been used for CO_2/H_2S corrosion.^{22-23} Then, the i_{corr} was converted into corrosion rate using:



FIGURE 2. Experimental procedures used to evaluate the corrosion behavior in HPHT CO_2 environments with H_2S .

Table 2. Conditions for Corrosion Tests						
	pCO ₂ (MPa)	H₂S (ppm _v)	Temperature (°C)	Rotation Speed (rpm)	Duration (h)	
1	12	0	160	1,000	62	
2	12	1,000	160	1,000	62	
3	12	2,000	160	1,000	90	
4	12	2,000	160	1,700	90	

Corrosion rate (mm/y) =
$$\frac{0.00327 \times i_{corr} (\mu A/cm^2) \times EW}{density (g/cm^3)}$$
 (2)

where EW is the equivalent weight in grams and 0.00327 is a constant factor used for dimension and time conversion.



FIGURE 3. Comparison of corrosion rate with different H_2S concentrations at 12 MPa CO₂ and 160°C: (a) LPR corrosion rate and (b) WL corrosion rate.

The corrosion rates were also determined by the weight loss (WL) method at the end of the tests. In each test, two rectangular samples were simultaneously exposed to the environment to obtain an average corrosion rate. After the test,

Table 3. Measured Initial and Final Solution pH at 12 MPa CO_2 and $160^{\circ}C$

	Initial pH	Final pH
0 ppm H ₂ S	4.3	4.8
1,000 ppm H ₂ S	4.2	4.7
2,000 ppm H ₂ S	4.4	4.8





FIGURE 4. (a) SEM surface view and (b) EDS analysis of the corrosion product formed at 12 MPa and 160°C.

the specimens were cleaned for 5 min in Clarke solution (20 g antimony trioxide + 50 g stannous chloride and hydrochloric acid to make 1,000 mL). The specimens were then rinsed with DI water, dried, and weighed to 0.1 mg. The WL corrosion rate was calculated by the following equation:²⁴

Corrosion rate (mm/y) =
$$\frac{8.76 \times 10^4 (\text{mm} \cdot \text{h/cm} \cdot \text{y}) \times \text{WL}(\text{g})}{\text{area}(\text{cm}^2) \times \text{density}(\text{g/cm}^3) \times \text{time}(\text{h})}$$
(3)

The solution pH was measured at the beginning and end of the tests by using the commercial HPHT ZrO₂-based pH electrode and the HPHT Ag/AgCl reference electrode. The electrodes were calibrated prior to testing by using H₂SO₄ (5×10^{-4} m) and NaOH (1×10^{-4} m) solutions at the testing temperature (160°C) in order to obtain the relationship between



FIGURE 7. XRD surface analysis of the CS sample exposed to 12 MPa CO_2 at 160°C.





FIGURE 5. SEM cross-sectional view of the corroded sample at 12 MPa CO_2 and 160°C.



FIGURE 6. SEM and EDS elemental mapping images of the cross section of the corrosion product layer produced after 60 h of exposure in 12 MPa CO_2 and 160°C.





FIGURE 8. (a) SEM surface view and (b) EDS analysis of the corrosion product formed at 12 MPa CO_2 and 160°C with 1,000 ppm H_2S .

potential and pH. After each test, the morphology and composition of corrosion products were analyzed with scanning electron microscopy (SEM), energy-dispersive x-ray spectroscopy (EDS), and x-ray diffraction (XRD). Table 2 shows the used test conditions.

RESULTS

Figure 3 shows LPR and WL corrosion rate data of CS exposed to 1 wt% NaCl at 12 MPa CO₂ and 160°C with 0 ppm, 1,000 ppm, and 2,000 ppm H₂S. The corrosion rate of CS for the condition without H₂S was about 5 mm/y at the beginning of the experiment and then slightly decreased with time, whereas the corrosion rates of CS with both H₂S concentrations started at much higher values and then decreased to similar values to those without H_2S after 20 h. WL corrosion rates show the same trend as seen for the LPR corrosion rates at exposure times longer than 20 h. It is worth mentioning that in previous work at lower temperatures (25°C and 80°C),²² the presence of 200 ppm of H₂S reduced the corrosion rate of CS almost 10 times under similar high-pressure CO₂ conditions. However, as shown in Figure 3, the presence of 1,000 ppm to 2,000 ppm H_2S at 160°C only increased the initial corrosion rate, and no significant effect of H₂S on the corrosion rate was observed at the end of the test.



at%	С	0	S	Fe
1	36.18	1.20	30.39	29.99
2	42.96	28.47	2.49	25.56
3	25.90	36.78	4.49	32.46
4	13.52	_	_	86.48

FIGURE 9. Cross-sectional SEM and EDS analysis of the corrosion product formed at 12 MPa and 160°C with 1,000 ppm H_2 S.

Table 3 lists the solution pH values at the beginning and the end of each test. The addition of H_2S did not affect the initial solution pH, indicating that the solution pH is mostly governed by the partial pressure of CO₂. For all of the tested conditions, the solution pH slightly increased during the tests implying a small change in the bulk water chemistry due to the release of Fe²⁺.

Figure 4 shows the surface morphology and chemical analysis of a CS sample after 60 h of exposure to the condition without H₂S. A uniform corrosion product was found covering the exposed surface. The EDS analysis shows that the corrosion product mainly consisted of iron (Fe), carbon (C), and oxygen (O). Figure 5 shows cross-sectional SEM images of the corroded sample exposed without H₂S. It can be seen that most of the surface was covered by a relatively thick and compact corrosion product layer (~30 µm). However, there were some locations where the corrosion product layer was thinner ($\sim 5 \,\mu$ m, Figure 5[b]). Cross-sectional EDS mapping analysis was conducted in order to identify the compositions of the corrosion product layer and their distribution as shown in Figure 6. The thick compact corrosion product layer was rich in Fe (blue mapping), C (red mapping), and O (green mapping). Scattered corrosion product particles containing higher relative O content were found above the thick main layer.

Figure 7 shows the XRD pattern of the sample surface exposed at 12 MPa CO₂ and 160°C without H₂S. This condition showed dominant iron carbonate (FeCO₃) diffraction patterns with some Fe₃O₄. Based on the obtained EDS mapping (Figure 6) and XRD results (Figure 7), it is identified that the thick and compact corrosion product layer was FeCO₃ and that some Fe₃O₄ was present possibly as scattered particles on top of the FeCO₃ layer. This would indicate that FeCO₃ is a more favored

[†] Trade name.



FIGURE 10. Cross-sectional EDS line scanning of the corrosion product formed at 12 MPa CO_2 and 160°C with 1,000 ppm H_2S .

FIGURE 11. Cross-sectional SEM and EDS elemental mapping of the corrosion product formed at 12 MPa CO₂ and 160°C with 1,000 ppm H₂S.

corrosion product than Fe₃O₄ under the current experimental condition (12 MPa CO₂ and 160°C). This observation is also in line with the relatively high measured corrosion rate (>1 mm/y) that is compatible with a corrosion product mostly formed by FeCO₃, which is less protective than Fe₃O₄.^{17-18,25} Inspection of the corroded sample after removal of corrosion products indicated that the attack was uniform, showing a relatively rough surface with defects of a maximum depth of approximately 30 µm which

corresponded to maximum penetration rates approximately 4.4 mm/y similar to the measured average corrosion rate (~4 mm/y).

Figure 8 shows the surface morphology and chemical analysis of a CS sample corroded at 12 MPa CO_2 and 160°C with 1,000 ppm H₂S. A uniform corrosion product was found covering the exposed surface. In this case, the EDS analysis shows that the corrosion product mainly consisted of Fe and S.

FIGURE 12. (a) SEM surface view and (b) EDS analysis of the corrosion product formed at 12 MPa CO_2 and 160°C with 2,000 ppm H_2S .

Figure 9 displays the cross-sectional morphology and chemical analyses of the corrosion product formed at 12 MPa CO_2 and 160°C with 1,000 ppm H₂S. It is seen that the corrosion product presents a continuous two-layer structure; a thin (~10 µm) outer Fe- and S-containing layer and a thick (~25 µm) inner Fe-, C-, and O-containing layer. This was also

confirmed by the results from the EDS line scanning analysis and mapping analysis shown in Figures 10 and 11, respectively. It is worth noting that there is a small gap between the steel surface and the corrosion product. This gap could have been produced due to the poor adhesion of layers to the substrate and the action of intrinsic stresses in the corrosion product layer during or after the corrosion test, and/or the undermining effect of corrosion. In any case, this type of defect can consequently reduce the protectiveness of the formed corrosion product layer and increase the corrosion rate if happens while exposure.²⁶

Figure 12 shows the surface morphology and chemical analysis of a CS sample exposed at 12 MPa CO₂ and 160°C with 2,000 ppm H₂S. Similar to the case with 1,000 ppm H₂S, a uniform corrosion product was found covering the exposed surface. Some scattered small particles (<10 μ m) seemed to lay on top of the corroded surface. The EDS analysis shows that the corrosion product mainly consisted of Fe and S. Small amounts of C and O were also detected.

Figures 13 through 15 display the cross-sectional EDS analyses (point, line scanning, and mapping) of the corrosion product formed at 12 MPa CO_2 and 160°C with 2,000 ppm H₂S. As in the previous case with 1,000 ppm H₂S, the corrosion product presents a continuous two-layer structure with a thin outer Fe- and S-containing layer and a thick inner Fe-, C-, and O-containing layer. Furthermore, a gap is also found between the inner thick layer and the metal surface.

Figure 16 shows the XRD pattern of the sample surface exposed at 12 MPa CO₂ and 160°C with 2,000 ppm H₂S. This condition showed FeCO₃ and pyrrhotite (Fe_{1-x}S) diffraction patterns. This allowed the ready identification of the corrosion products formed in CO₂/H₂S conditions as Fe_{1-x}S for the outer layer and FeCO₃ for the inner layer. It is interesting to note that Fe₃O₄ was not detected in the corrosion products formed in CO₂/H₂S conditions and the predominant corrosion product was FeCO₃, the same as in the condition without H₂S.

Figure 17 shows the surface morphologies of CS samples after the removal of the corrosion products. Although a rougher surface was observed on the specimen exposed to 1,000 ppm H_2S compared to the specimen exposed to 2,000 ppm H_2S , the attack was found to be uniform for both specimens.

In order to evaluate the effect of flow velocity on the corrosion behavior of CS at 12 MPa CO_2 and 160°C with H₂S, an additional test was conducted at a higher impeller rotation speed of 1,700 rpm. A comparison of the corrosion rates at

at%	С	0	S	Fe
1	66.76	6.74	13.04	8.04
2	27.85	0.63	35.81	34.73
3	49.06	21.89	4.70	23.64
4	27.10	10.80	23.44	37.52
5	18.40	-	-	81.60

FIGURE 13. Cross-sectional EDS analysis of the corrosion product formed at 12 MPa CO_2 and 160°C with 2,000 ppm H_2S .

different rotation speeds (1,000 rpm and 1,700 rpm) is shown in Figure 18. The corrosion rate decreased with time in both cases, and a slightly higher corrosion rate was measured for the case of 1,700 rpm compared with that of 1,000 rpm. Figure 19 shows the morphology and chemical analyses of the surface of the CS sample exposed with a rotation speed of 1,700 rpm. It is observed that a uniform corrosion product layer was also formed in this case. It is interesting to mention that

FIGURE 14. Cross-sectional EDS line scanning of the corrosion product formed at 120 MPa CO_2 and 160°C with 2,000 ppm H_2S .

FIGURE 15. Cross-sectional SEM and EDS elemental mapping of the corrosion product formed at 12 MPa CO₂ and 160°C with 2,000 ppm H₂S.

FIGURE 16. *XRD* surface analysis of the CS sample exposed to 2,000 ppm H_2S and 12 MPa CO₂ at 160°C.

scattered corrosion product particles of smaller size were present on top of the main corrosion product as compared to the previous case with a rotation speed of 1,000 rpm (Figure 12). EDS analyses indicated that Fe and S were the main constituents of both the top scattered particles and the corrosion product layer below (Figures 19[b] and [c]).

Cross-sectional images and EDS analyses (Figure 20) showed that the morphology and composition of the corrosion products formed at 1,700 rpm were similar to those formed at 1,000 rpm. This would indicate that the corrosion behavior of CS in the CO_2/H_2S condition did not vary significantly within the two tested flow velocities, which is also in line with the measured corrosion rates shown in Figure 18. This would also imply that water chemistry remains supersaturated with respect to FeCO₃ close to the metal surface even in conditions where mass transfer is accelerated by flow.^{17,27} No localized corrosion was observed after the removal of corrosion products for the sample exposed at 1,700 rpm (Figure 21).

FIGURE 18. Comparison of corrosion rates of CS at different impeller rotation speed, 12 MPa CO_2 and 160°C with 2,000 ppm H_2S .

DISCUSSION

It has been reported that a thin and continuous Fe₃O₄ layer can be formed on CS conferring almost instantaneous corrosion protection at high temperatures (>120°C).^{17,25,28} An increase in CO₂ partial pressure (from about 0.3 MPa up to ~3 MPa) has been found to make the formation of FeCO₃ more favorable compared to Fe₃O₄, and both corrosion products can coexist in different amounts offering fair corrosion protection (general corrosion rates <0.5 mm/y).¹⁸ However, in the present study, a relatively high corrosion rate (>1 mm/y) was measured at higher CO₂ partial pressure (12 MPa). According to the performed surface analyses, corrosion was mostly controlled by the formation of a relatively thick FeCO₃ layer. A similar corrosion behavior was observed when H₂S was added (1,000 ppm to 2,000 ppm), where an outer $Fe_{1-x}S$ layer was found to form but did not provide additional corrosion protection to the main FeCO₃ layer developed adjacent to the metal surface. It can be speculated that the increased concentration of carbonic

FIGURE 17. SEM images of corroded CS surfaces after removal of corrosion products: (a) 1,000 ppm H_2S and (b) 2,000 ppm H_2S .

FIGURE 19. SEM and EDS analyses of the corrosion product formed at 12 MPa CO_2 and 160°C with 2,000 ppm H_2S with an impeller rotation speed of 1,700 rpm: (a) SEM surface view, (b) EDS spectrum from the scattered corrosion product particles, and (c) EDS spectrum from the corrosion product layer.

FIGURE 20. Cross-sectional SEM and EDS elemental mapping of the corrosion product formed at 12 MPa CO_2 and 160°C with 2,000 ppm H_2S with impeller rotation speed of 1,700 rpm.

SCIENCE SECTION

FIGURE 21. SEM images of CS surface after removal of corrosion products (12 MPa CO_2 and 160°C with 2,000 ppm H₂S with impeller rotation speed of 1,700 rpm).

species in an aqueous environment could affect the thermodynamic stability of corrosion products such as Fe_3O_4 and FeS and/or alter its formation kinetics.

A thermodynamic analysis using Pourbaix diagrams was conducted for the formation of corrosion products in the tested conditions. Details of construction of Pourbaix diagrams for Fe-CO₂-H₂O and Fe-H₂S-H₂O systems were investigated

FIGURE 22. Generated Pourbaix diagrams for the Fe-CO₂-H₂O system at 160°C with arbitrary 1 ppm of [Fe²⁺] and [Fe³⁺]: (a) 0.1 MPa of pCO_2 and (b) 12 MPa of pCO_2 .

FIGURE 23. Generated Pourbaix diagrams for the Fe-CO₂-H₂S-H₂O system at 160°C, 12 MPa CO₂ and 2,000 ppm H₂S with arbitrary 1 ppm of [Fe²⁺] and [Fe³⁺].

by Tanupabrungsun, et al.,²⁵ and Ning, et al.,²⁹ respectively. Figure 22 shows Pourbaix diagrams of Fe-CO₂-H₂O system at 160°C under different CO₂ partial pressures. A region of possible operating pH and potentials is indicated in all of the shown thermodynamic diagrams as a black rectangle. The estimated pH range was selected starting at the measured bulk pH up to about one additional pH unit to account for the effect of proton consumption and accumulation of ferrous ions close to the metal surface, while the potential range was based on the measured open-circuit potential (OCP) values. At low CO₂ partial pressure (0.1 MPa), both FeCO₃ and Fe₃O₄ are thermodynamically stable at 160°C (Figure 22[a]), which is consistent with the results reported in the literature.¹⁷ However, only FeCO₃ is suggested as a stable corrosion product at high CO₂ partial pressure (12 MPa) as shown in Figure 22(b), which agrees with the results of the present study (Figure 7). This would indicate that high CO_2 partial pressure makes the formation of FeCO₃ more favorable compared to the formation of Fe_3O_4 at high temperatures. It is worth mentioning that this behavior may not be entirely related to thermodynamic factors because the kinetics of corrosion product formation might also be influential.

Referring to the Pourbaix diagram generated for the tested condition with H₂S (Figure 23), Fe_{1-x}S (pyrrhotite) is predicted as the only stable phase, which was in fact detected in the experiments (Figure 16). However, as shown in Figures 13 through 16, composed corrosion products with a relatively thin outer Fe_{1-x}S layer and a thick FeCO₃ inner layer adjacent to the metal surface were observed from the experiments. This would imply that the formation of FeCO₃ could be kinetically more favored than the formation of Fe_{1-x}S at high CO₂ partial pressure. This can be particularly true when the mass transfer is increasingly limited by the initial formation of a FeS layer and there is a subsequent increase of pH and accumulated ferrous ions close to the steel surface leading to high supersaturation of FeCO₃. Under these circumstances, any change in mass transfer characteristics due to flow would have limited impact as the overall mass transfer process toward and away from the steel surface would be controlled by the slower ion transport through the formed corrosion product layer, which is in line with the corrosion rate results shown in Figure 18. Furthermore, the initial high corrosion rates measured in the conditions with 1,000 ppm and 2,000 ppm of H₂S could be related to the formation of the FeS layer at the beginning of the tests which did not provide any protection. However, the corrosion rate

started to decrease as kinetically more favorable $\ensuremath{\mathsf{FeCO}_3}$ formed on the surface.

It is believed that the kinetic preponderance of FeCO₃ over FeS is only feasible when large amounts of dissolved carbonic species (high pCO₂) and comparatively low H₂S concentrations are present. For example, it has been reported that FeS was the predominant corrosion product formed on CS at lower CO₂ partial pressure (0.69 MPa) and slightly lower temperature (120°C) with used H₂S/CO₂ partial pressure ratios ranging from 0.2 to 0.6.³⁰

CONCLUSIONS

The effect of H₂S (1,000 ppm to 2,000 ppm) on the aqueous corrosion behavior of CS was evaluated in supercritical CO₂ conditions (high-partial pressure of 12 MPa) at high temperature (160°C). The following conclusions are drawn: > Corrosion rate did not vary significantly in the presence of H₂S and showed values as high as approximately 3 mm/y after exposure times of 60 h or longer.

> The predominant corrosion product was FeCO₃ with and without the presence of H₂S, indicating that the formation of FeCO₃ is more favorable than that of FeS and Fe₃O₄ in the present conditions.

> No significant effect of flow velocity was observed on the corrosion behavior of CS in the presence of H_2S .

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