

Experimental Evaluation of Anticorrosion of a Standard 20# Gathering Pipeline by Injecting Oxygen-Reduced Air into Simulated In-Service Wells

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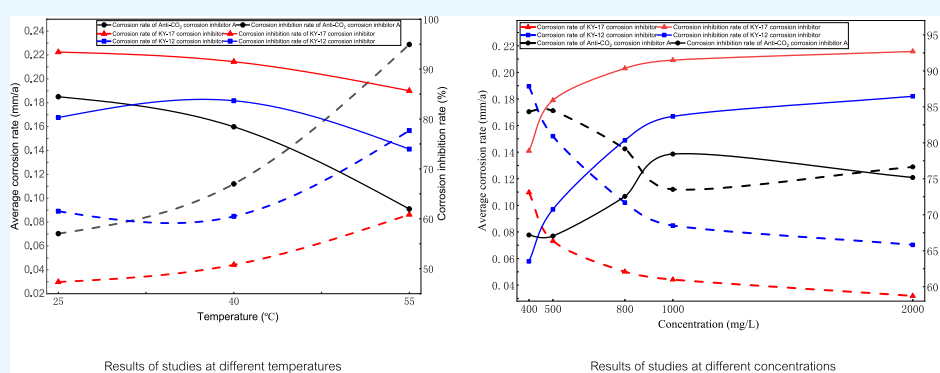


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ABSTRACT: Oxygen-reduced air flooding (ORAF) can effectively improve oil recovery in low-permeability reservoirs, but oxygen corrosion and CO₂ corrosion in downstream gathering pipelines are inevitable due to the existence of oxygen, which limits the popularization and application of ORAF. In this paper, research on the corrosion inhibitor is carried out for the gathering pipeline of an oilfield with ORAF in China. Under the conditions of a simulated onsite gathering pipeline, 6 kinds of anti-CO₂ corrosion inhibitors and 6 kinds of antioxygen corrosion inhibitors were selected to evaluate and screen the effects of 20# steel by the dynamic weight loss method. Two antioxygen corrosion inhibitors KY-12 and KY-17 and one anti-CO₂ corrosion inhibitor A were selected for the experiment. The corrosion inhibition rates of the three inhibitors reached 83.67, 91.49, and 78.44%, respectively, at a temperature of 40 °C and an inhibitor concentration of 1000 mg/L. Through the experimental evaluation of three primary corrosion inhibitors at different temperatures (25, 40, and 55 °C) and different concentrations (400, 500, 800, 1000, and 2000 mg/L), the KY-17 corrosion inhibitor with the best stability at different temperatures was selected, and the corrosion inhibition effect was the best at different concentrations, with the highest slow release rate reaching 92.7%. This conclusion has a good reference significance for the selection and dosage of corrosion inhibitors for downstream gathering pipelines of the ORAF oilfield.

1. INTRODUCTION

Reserves of low- and ultralow-permeability reservoirs are increasing annually in the world. Among the commonly used gas flooding methods (CO₂ flooding, N₂ flooding, flue gas flooding, natural gas flooding, and air flooding) for low-permeability reservoirs, oxygen-reduced air flooding (ORAF), as a production method with the advantages of abundant gas sources, environmental protection, energy conservation, and low investment cost, has been gradually popularized at home and abroad.^{1–3} ORAF is used to treat air to achieve a safe oxygen content range (oxygen concentration ≤ 10%) and inject it into the formation. The low-temperature oxidation reaction between crude oil and O₂ in the formation generates a large amount of heat and CO, CO₂, and CH₄ gases, which form the flue gas drive in the reservoir and have a certain mixed phase. This can promote the decrease of viscosity and

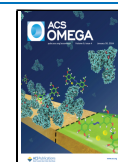
interfacial tension and the expansion of crude oil and thus help to improve oil recovery in the oilfield.⁴ However, due to the low-temperature oxidation reaction, light components in crude oil decrease and heavy components increase.⁵ The incomplete oxygen accelerates the corrosion of the injection system and the production system as a whole, especially the corrosion of the downstream gathering pipeline.⁶ Therefore, the corrosion of the gathering pipelines on exposure to oxygen and carbon dioxide seriously restricts the development of ORAF. With the

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increase in service life, the internal corrosion of gathering pipelines is becoming more and more serious.⁷ Crude oil leakage often occurs, which pollutes the environment and even causes high safety risks and serious economic losses. Liang et al.⁸ found that material properties are not the main reason for oil pipeline failure accidents, and leakage is mainly caused by spot corrosion perforation on the inner wall of the pipeline. Cai et al.⁹ found that dissolved oxygen in the transportation medium has a serious influence on the corrosion perforation of gathering pipelines.

The use of corrosion inhibitors as an environmentally friendly, efficient, and low-cost anticorrosion method has been paid more and more attention in the production and development of oil and gas fields at home and abroad.^{10,11} According to the characteristics of oilfield recovery and production increases, it takes a long time to study CO₂ corrosion inhibitors in oilfields all over the world. There are mainly five kinds of CO₂ corrosion inhibitors: (1) imidazoline and its derivatives: Zhang et al.¹² studied 2-undecyl-1-ethylamino-1-ethylcarboxyl quaternary imidazoline corrosion inhibitors at temperatures of 25 and 40 °C, respectively, with a CO₂ content of 3% and an Na₂SO₄ content of 3% in saturated sodium chloride solution. The inhibition effect is over 90% when the dosage is 80 mg/L. The research progress of imidazoline corrosion inhibitors is remarkable, but there are still some problems in the research of long-chain alkyl imidazoline corrosion inhibitors. The main reason is that these imidazoline corrosion inhibitors cannot achieve ideal results in a high-temperature environment, and further research and development are needed to improve the high-temperature resistance of imidazoline corrosion inhibitors. (2) Organic amines: Cruz-Zabalegui et al.¹³ explained the protective behavior of a nonionic Gemini surfactant obtained by a chemical reaction between amine and waste avocado oil on X52 steel at 50 °C with a CO₂ content of 3% in saturated sodium chloride solution. The corrosion inhibition protection rate was higher than 90% at a concentration of 10 mg/L. Li et al.¹⁴ studied the corrosion inhibition performance of rosin amine corrosion inhibitor, a renewable forest product resource, under the conditions of a high temperature of 80 °C, a pressure of 1 MPa, and a CO₂ content of 1% in saturated sodium chloride solution and found that it had a good protective effect on N80 hanging pieces when the dosage was 20 mg/L, and the corrosion inhibition effect reached over 80%. (3) Schiff bases: Kra et al.¹⁵ found that the protective effect of the salicylaldehyde–chitosan Schiff base was about 80% when adding 60 mg at 65 °C and 3.5% CO₂ in a saturated sodium chloride solution. From the point of view of environmental protection, high performance, and harmlessness, scholars have recently focused on research on Schiff base green corrosion inhibitors. (4) Natural extracts: Singh¹⁶ and others introduced the protective effect of Ginkgo biloba extract on J55 steel at 25 °C with 3.5% CO₂ content in saturated sodium chloride solution. The results showed that the corrosion inhibition effect on the steel surface was 87% when the amount of extract reached 250 mg/L. Zhao¹⁷ et al.¹⁷ studied the corrosion inhibition and protection effect of Ginkgo biloba extract on the N80 steel surface in saturated carbon dioxide solution. The results showed that the corrosion inhibition and protection efficiency reached 84.8% when the extract concentration was 60 mg/L. (5) Synergistic compound reaction of corrosion inhibitors: Zhao et al.¹⁸ carried out the compound synergistic reaction of imidazoline and cysteine at 60 °C with 3% CO₂

content in a saturated sodium chloride solution. When adding 50 mg/L imidazoline and 10 mg/L cysteine, the protection rates on the surface of metal materials reached 22.3 and 41.1%, respectively. However, the corrosion inhibition protection rate obtained by compounding these two corrosion inhibitors reached 90.9%, which greatly improved the performance. Research on CO₂ corrosion inhibitors started earlier, and many kinds of corrosion inhibitors have been discovered up to now. In oilfield anticorrosion, the effects of corrosion inhibitors are quite different for different corrosion types. It is worth paying attention to and studying the high-efficiency corrosion inhibitors developed in different environments, such as with sulfur, oxygen, and carbon dioxide coexisting.

With the long running time of the oilfield, the content of oxygen dissolved in the pipeline increases. Through the research on oxygen corrosion, many achievements have been made in its protection and prevention, and the research on antioxygen corrosion inhibitors has been gradually developed. Shi et al.¹⁹ obtained a Mannich base from the materials benzylamine, acetophenone, and acetic acid and then compounded the obtained Mannich base with several ready-made surfactants such as AEO and AEO-3P to prepare a new antioxidant and corrosion inhibitor. It was found that the combination of amino and benzene rings on the corrosion inhibitor molecule gave rise to a p- π -conjugated system, which had a good adsorption force for carbon steel. Finally, the corrosion inhibition performance of the inhibitor was evaluated by the electrochemical method and the weight loss method in the laboratory. In a solution with low dissolved oxygen content (≤ 1.0 mg/L), the corrosion inhibition performance can reach 92.57%. Hu et al.²⁰ reported a corrosion inhibitor for the harmful corrosion caused by the coexistence of oxygen and carbon dioxide in flue gas drive for enhanced oil recovery in an oilfield. In 1% sodium chloride solution with a carbon dioxide partial pressure of 0.02 MPa and a dissolved oxygen content of 3 mg/L, 500 ppm corrosion inhibitor BEP was added, which had a good corrosion inhibition and protection effect on carbon steel. The corrosion inhibitor BEP can form a P–O–Fe bond with iron atoms on the metal surface, and the P–Fe bond interacts with iron and corrosion products to produce a barrier layer, thus exhibiting protective performance. In brief, although scholars have made great progress in the research on antioxygen corrosion inhibitors, and many effective antioxygen corrosion inhibitors have been obtained through synthesis and compounding, there are still a series of problems, such as rare types of antioxygen corrosion inhibitors, poor corrosion inhibition performance of a single type, and high economic cost. Considering the different production and operation environments of the oilfield, there is an urgent need to develop or identify antioxygen and corrosion inhibitors that can protect steel under these working conditions.

ORAF has a more complex corrosion environment because of the involvement of oxygen. At the same time, there are few studies on the corrosion prevention of the gathering pipeline downstream of ORAF. Aiming at the phenomenon that a domestic oilfield adopts the ORAF technology to improve oilfield production, but the downstream gathering pipeline is seriously affected by corrosion, a kind of corrosion inhibitor suitable for this gathering environment was selected by a dynamic hanging piece corrosion weight loss experiment, and the optimal dosage of was found. The conclusion is a good

reference for the selection and dosage of corrosion inhibitors for downstream gathering lines in ORAF oilfields.

2. PIPELINE ANTICORROSION SIMULATION EXPERIMENT

Through the anticorrosion experimental simulation of the internal situation of the ORAF gathering pipeline, specific experimental methods and experimental steps are carried out as follows.

2.1. Experimental Conditions. The ionic composition of the formation water in an oilfield with ORAF in China is K^+ and Na^+ 13290.55 mg/L, Ca^{2+} 10767.09 mg/L, Cl^- 44837.16 mg/L, Mg^{2+} 1845.24 mg/L, and HCO_3^- 134.51 mg/L. The total salinity is 70874.55 mg/L. In this oilfield, 5% oxygen-reduced air is injected into the formation for oil displacement, and the oxygen content in the actual produced fluid increases continuously with the gas injection year. After the gas injection year reaches 2 years, the oxygen content in the produced fluid tends to be stable at about 3%. According to Henry's Law,^{21–23} the oxygen content in the produced liquid in the gathering pipeline is simulated by controlling the oxygen partial pressure above the liquid; that is, the oxygen partial pressure accounts for 3% of the total pressure. With the continuous oxidation reaction in the formation, the CO_2 content in the produced fluid also increases, but the maximum content is not higher than 0.6%;⁸ therefore, in this simulation experiment, we selected 0.6% CO_2 content as the simulation condition. Based on the actual production situation of the oilfield gathering pipeline, the pressure and water cut when the corrosion is the most serious are selected, which are 3 MPa total pressure and 70% water cut, respectively. The performance of the corrosion inhibitor is usually greatly affected by temperature, so the experimental temperature is 25 °C at the normal transportation temperature of the gathering pipeline and 40 °C at the entrance of the gathering pipeline. Considering the performance factors of the corrosion inhibitor in a higher-temperature environment, 55 °C is selected as the experimental test temperature. Finally, according to the screening results of corrosion inhibitors, the corrosion inhibition performance of the selected corrosion inhibitors at different doses of 400, 500, 800, 1000, and 2000 mg/L was tested, and the best concentration was optimized (Figure 1).

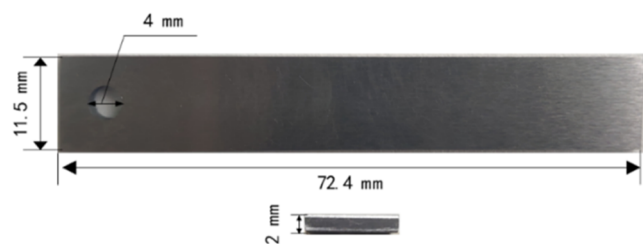


Figure 1. Schematic diagram of the hanging piece.

2.2. Experimental Materials and Pretreatment. Considering that the use of ORAF is utilized in oilfields that are already in production, 20# steel used in gathering pipelines is directly selected. Thus, a standard 20# corrosion hanging piece is used in the experiment. The main chemical compositions and size of the hanging piece are as presented in Table 1

In the preparation stage before the start of the experiment, the residual antitrust grease on the surface of the polished smooth hanging piece is wiped with filter paper. The hanging

Table 1. Main Chemical Components of 20# Steel^a

C	Si	Mn	P	S	Cr	Ni	Cu
0.2	0.22	0.36	0.014	0.007	0.04	0.03	0.08

^aMass fraction, %.

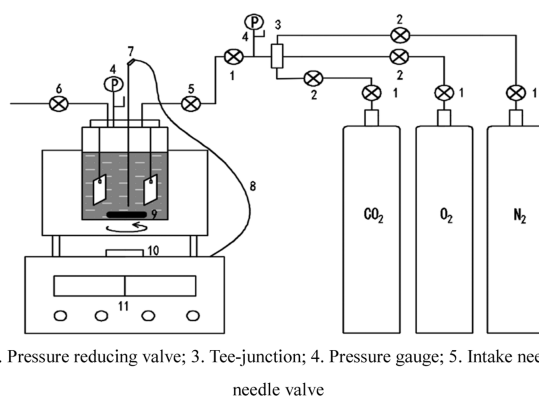
piece is soaked in absolute ethanol and acetone, respectively (the dosage of every 10 pieces is greater than or equal to 50 mL), and the hanging pieces in the reagent are wiped with absorbent cotton. Then they are taken out and put on filter paper. After treating the residual reagent with filter paper, it was placed in a drying oven for 24 h, and finally, the weight (accurate to 0.0001 g) and size (accurate to 0.02 mm) were measured and recorded for preservation.

2.3. Experimental Apparatus and Methods. The experiment was carried out in a high-temperature and high-pressure magnetic stirring tank, and the apparatus is shown in Figure 2. First, the inner container of the stirring tank is purged with nitrogen to discharge impurities and gases in the container. The prepared formation water solution is injected, and a pipette is used to add the corrosion inhibitor solution with completed concentration to the inner container of the stirring tank. The pretreated corrosion hanging piece is hung in the inner container of the reaction kettle. Immediately, the reaction kettle is tightened, and the inlet and outlet valves on the kettle cover are opened at the same time. N_2 with a purity higher than 99.99% is slowly introduced into the kettle to remove the aqueous formation solution and excess gas in the kettle. After aeration for 2 h, the inlet and outlet valves on the kettle cover are closed. CO_2 gas with the lowest partial pressure, O_2 gas with intermediate partial pressure, and N_2 gas with high purity are introduced in turn for pressurization. Finally, the reaction kettle is put into the heating furnace, and the heating time, rotating speed, and heating and insulation temperature are set.

After 120 h, the hanging pieces were treated according to the standard GB/T 25147-2010. First, the test corrosion hanging piece was taken out, and the macroscopic morphology and corrosion product adhesion of the corrosion hanging piece were recorded. The surface was immediately rinsed with distilled water, the remaining oil stains on the surface of the hanging piece were cleaned with acetone, and the hanging piece was soaked in absolute ethanol for 5 min. Then, it was taken out and put on filter paper, the surface of the hanging piece was blow-dried with cold air, and images obtained were recorded. Immediately, the weighed hanging pieces were put into the prepared pickling solution (450 mL of distilled water, 45 mL of concentrated hydrochloric acid with a mass fraction of 31–38%, and 3.5 g of hexamethylenetetramine) and then put into an ultrasonic cleaning machine for cleaning. After cleaning, the hanging pieces were placed in NaOH solution (60 g/L) for 30s, dehydrated in anhydrous ethanol, and then dried and weighed. Finally, the corrosion rate of the tested hanging piece and the corrosion inhibition rate of the corrosion inhibitor^{24,25} were calculated, and the calculation process was as follows.

The equation for calculating the uniform corrosion rate of hanging pieces is as follows:

$$r_{\text{corr}} = \frac{8.76 \times 10^4 (M - M')}{ST\rho} \quad (1)$$



1. Control valve; 2. Pressure reducing valve; 3. Tee-junction; 4. Pressure gauge; 5. Intake needle valve; 6. Exhaust needle valve
7. Thermocouples; 8. Heating device; 9. Rotor; 10. Brushless motor; 11. Controls

Figure 2. Schematic diagram of the apparatus.

Among them, r_{corr} is the uniform corrosion rate of the hanging piece surface, mm/a; M is the mass of the hanging piece before the experiment, g; M' is the quality of the hanging piece after the experiment, g; S is the surface area of the hanging piece, cm^2 ; T is the experimental time, h; and ρ is the density of the hanging piece, g/cm^3 .

The equation for calculating the corrosion inhibition rate of the corrosion inhibitor is as follows:

$$\eta = \frac{\Delta m - \Delta m'}{\Delta m} \times 100\% \quad (2)$$

wherein η is the corrosion inhibition rate of the corrosion inhibitor, Δm is the mass difference of the hanging piece corrosion before adding the corrosion inhibitor, g; and $\Delta m'$ is the mass difference of the hanging piece after adding the corrosion inhibitor, g.

3. RESULTS AND DISCUSSION

According to the production practice of the ORAF oilfield, the corrosion inhibitor developed and used for the anticorrosion of gathering pipelines is analyzed. Six kinds of anti- CO_2 corrosion inhibitors were selected, which are CO_2 self-developed 1, CO_2 self-developed 2, CO_2 corrosion inhibitor C developed by Sichuan Research Institute, CO_2 corrosion inhibitor developed by Jingmen Chemical Industry, CO_2 corrosion inhibitor B for a wellbore, and CO_2 corrosion inhibitor A used in the oilfield. Six kinds of antioxidant corrosion inhibitors are selected, which are KY-1, KY-12, KY-17, ACA-6, A-type antioxidant corrosion inhibitor, and the deoxidizer used in the oilfield. The primary chemical agents and appearance characteristics of the corrosion inhibitors are shown in Table 2. Twelve corrosion inhibitors are selected for preliminary screening, and then the anticorrosion performance of the hanging piece with the selected corrosion inhibitors at different temperatures and concentrations is tested.

3.1. Performance Evaluation and Screening of Corrosion Inhibitors. According to the dynamic hanging piece corrosion weight loss test, 12 corrosion inhibitors were evaluated. The experimental temperature was 40°C , the dosage of the corrosion inhibitor was 1000 mg/L, and the corrosion rate of the hanging piece and the corrosion inhibition rate of the corrosion inhibitor were obtained. Figure 3 shows that the corrosion rate of the blank group hanging piece without the corrosion inhibitor was 0.5194 mm/a at a temperature of 40°C . According to the experimental results,

Table 2. Main Chemical Agent and Appearance Characteristics of the Corrosion Inhibitor

number	name of corrosion inhibitor	main chemical agent	appearance characteristics
1	KY-1 corrosion inhibitor	modified imidazolines	reddish brown liquid
2	0.15% deoxidizer	triazinethiones	white crystal
3	KY-12 corrosion inhibitor	triazine derivatives	white powder
4	A-type corrosion inhibitor	imidazolines	reddish brown liquid
5	KY-17 corrosion inhibitor	modified imidazolines	brown liquid
6	ACA-6 corrosion inhibitor	heterocyclic compounds	reddish brown liquid
7	anti- CO_2 corrosion inhibitor A	quaternary ammonium salts	reddish brown liquid
8	anti- CO_2 self-developed 1	organic amines	reddish brown liquid
9	anti- CO_2 self-developed 2	imidazolines	reddish brown liquid
10	corrosion inhibitor for wellbore	imidazolines	reddish brown liquid
11	Sichuan Research Institute	alkyne alcohols	brown liquid
12	Jingmen Chemical Industry	organic phosphide	brown liquid

the corrosion rates of the hanging piece were controlled at 0.1120, 0.0442, and 0.0848 mm/a by the three corrosion inhibitors CO_2 inhibitor A, KY-17 inhibitor, and KY-12 inhibitor, respectively. The corrosion inhibition efficiency reached 75%, which were 78.44, 91.49, and 83.67%, respectively, and the corrosion inhibition effect was much higher than those of other corrosion inhibitors. It can be concluded that the protection of antioxidant corrosion inhibitors on 20# steel was better than that of the anti- CO_2 corrosion inhibitor under the working conditions of the gathering pipeline.

In addition, as can be seen in Figure 4, corrosion of the blank hanging piece is serious, and a large number of corrosion products cover the surface of the hanging piece. After cleaning, the hanging piece had completely lost its metallic luster, and the corrosion trace was obvious. Compared with the blank group, the corrosion phenomenon of the hanging piece surface is weakened after adding these three corrosion inhibitors. The corrosion severity follows the order blank group > CO_2 inhibitor A > KY-12 > KY-17, which is basically consistent

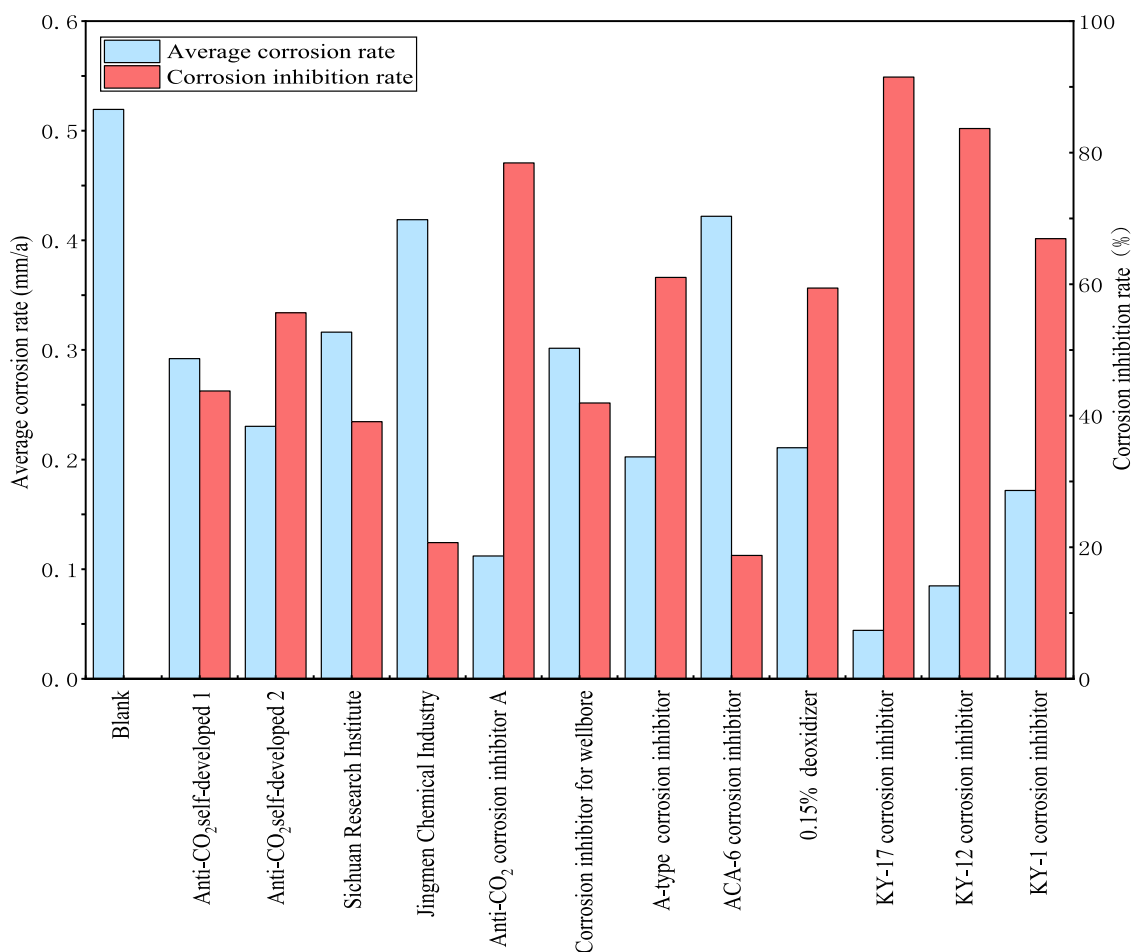


Figure 3. Average corrosion rate and corrosion inhibition rate of the hanging piece after adding the corrosion inhibitor.

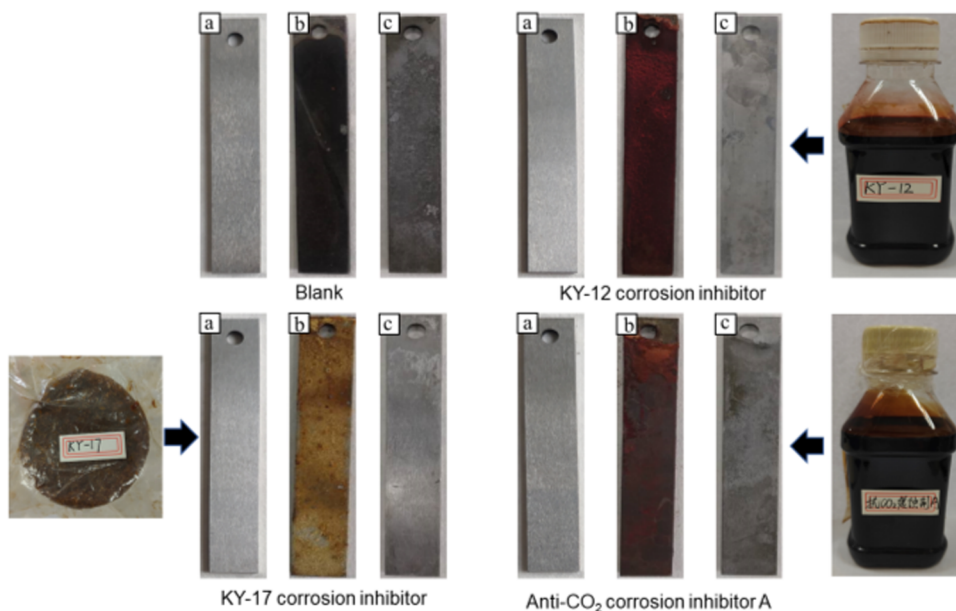


Figure 4. Schematic diagram before and after adding the corrosion inhibitor to the hanging piece: (a) before corrosion of a hanging piece; (b) before corrosion and cleaning of the hanging piece; and (c) after corrosion and cleaning of the hanging piece.

with the evaluation results. The red-brown adsorption protective layer on the surface of the hanging piece added with anti-CO₂ corrosion inhibitor A is loose and falls off easily, which cannot evenly cover the hanging piece surface and plays

a good protective role. After adding the KY-17 corrosion inhibitor, the surface of the hanging piece retains some metallic luster after cleaning off the dense yellow-brown adsorption protective layer, and the whole hanging piece is well protected.

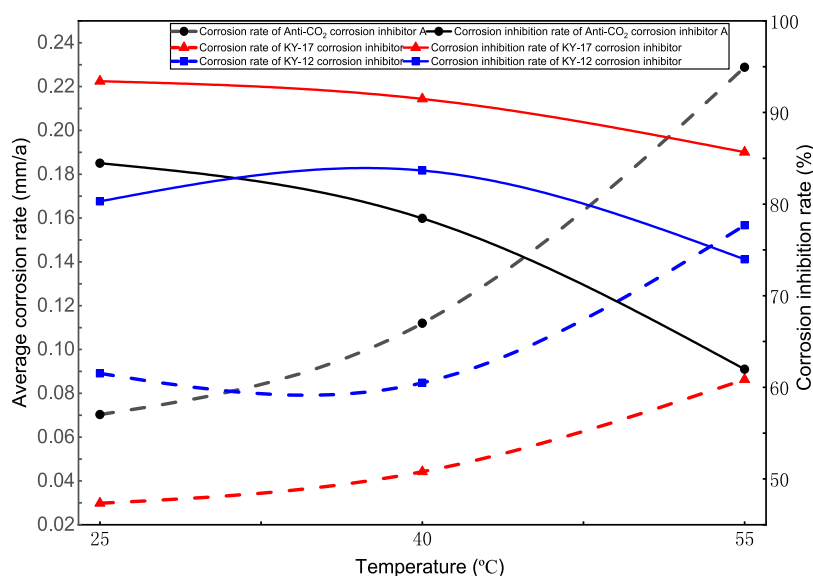


Figure 5. Corrosion rates and corrosion inhibition rates of the hanging piece after adding the corrosion inhibitor at different temperatures.

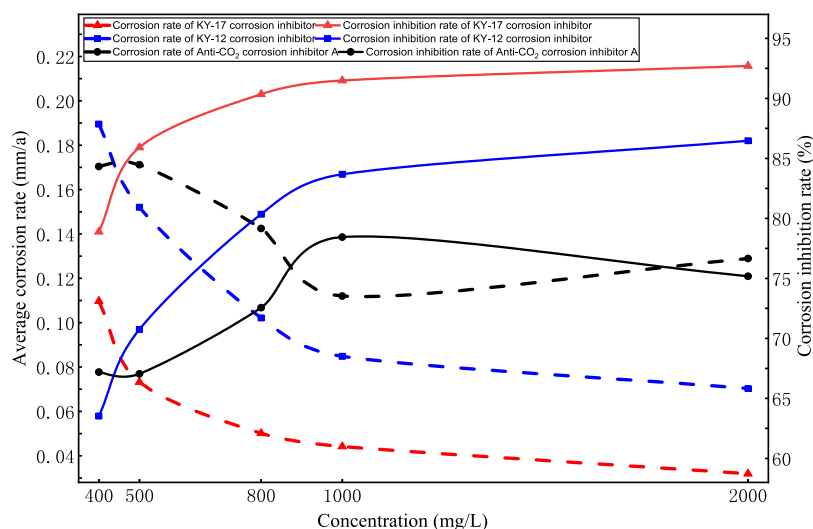


Figure 6. Corrosion rate and corrosion inhibition rate of the hanging piece after adding the corrosion inhibitor at different concentrations.

The KY-17 antioxidant and corrosion inhibitor used in the experiment is composed of the modified imidazoline inhibitor intermediate and small-molecule synergist, reducing agent, dispersant, inorganic compounds, and so on. The KY-17 corrosion inhibitor has multiple adsorption centers, which can not only consume dissolved oxygen in the corrosive medium but also form a dense protective film on the surface of the hanging piece by using the adsorption centers so as to inhibit the anodic corrosion of the hanging piece and protect the oil pipeline under the oxygen-containing environment in the ORAF gathering pipeline.

3.2. Effect of Temperature on the Corrosion Inhibitor Performance. According to the three selected corrosion inhibitors at different temperatures, 1000 mg/L was selected as the experimental concentration of the corrosion inhibitor, and the experimental temperatures were set to 25, 40, and 55 °C. First, the corrosion rates of the blank group hanging pieces at 25 and 55 °C were 0.4523 and 0.6019 mm/a, respectively. The temperature test experiment was carried out, and the average corrosion rate and corrosion inhibition rate of the hanging

piece after the addition of the above three corrosion inhibitors at various temperatures were obtained.

Figure 5 shows that the corrosion rate of the hanging piece is negatively correlated to the corrosion inhibition rate of the corrosion inhibitor. With an increase in the experimental temperature, the corrosion rate of the hanging piece surface increases, and the corrosion inhibition effect of the corrosion inhibitor decreases immediately. In the low-temperature region (25–40 °C), the corrosion inhibition effect of the three corrosion inhibitors decreased gently, and with an increase in temperature, the corrosion inhibition effect decreased steeply. Among them, the KY-17 corrosion inhibitor is the least affected by temperature, and the corrosion inhibition rate decreases by only 7.76% when the temperature increases by 30 °C, while the corrosion inhibition rate of CO₂ inhibitor A decreases sharply by 22.48% under the same conditions. At 55 °C, the corrosion rate of the KY-17 corrosion inhibitor is 0.0745 mm/a, which is still lower than the oilfield anticorrosion standard of 0.0760 mm/a. The corrosion inhibition rate of KY-17 is 85.66% at this temperature, and

the corrosion inhibition rate is always above 75%, which has strong protection ability for 20 # steel.

The above phenomenon is caused by the three corrosion inhibitors, which are all adsorptive corrosion inhibitors. In the low-temperature experimental environment, the adsorption layer formed by the adsorption of corrosion inhibitor molecules on the metal surface of the hanging piece is relatively tight; the corrosion rate of the hanging piece surface is low at this time, and the corrosion inhibition effect is better. When the temperature increases, the corrosion inhibitor molecules in the corrosive medium move faster, which makes it difficult to adsorb on the metal surface. With an increase in temperature, the molecular layer of the corrosion inhibitor adsorbed on the metal surface of the hanging piece separates quickly, which leads to the aggravation of the corrosion phenomenon on the hanging piece surface and the deterioration of the corrosion inhibition effect.^{26,27} However, KY-17 has good temperature resistance among the three corrosion inhibitors, and the corrosion inhibition effect does not decrease significantly.

3.3. Effect of Concentration on the Corrosion Inhibitor Performance. The anticorrosion effects of the three corrosion inhibitors on hanging pieces were evaluated experimentally under different concentrations. The experimental temperature was selected as 40 °C, and the concentrations of corrosion inhibitors were 400, 500, 800, 1000, and 2000 mg/L, respectively. The corrosion rate and corrosion inhibition rate of the hanging piece with different concentrations of corrosion inhibitors were obtained.

Figure 6 shows that the corrosion rate of the hanging piece surface decreases obviously with an increase in the concentration from 400 to 1000 mg/L after the three selected corrosion inhibitors are added into the corrosive medium. Among them, the KY-12 corrosion inhibitor is the most affected by the concentration, and the corrosion rate of the hanging piece decreases from 0.1895 to 0.0848 mm/a. Under different concentration gradients, KY-17 still has the best corrosion inhibition effect. When the concentration is 400 mg/L, the corrosion rate of the hanging piece is controlled at 0.1097 mm/a, and the corrosion inhibition rate reaches 75%. Compared with the other two corrosion inhibitors, the corrosion inhibition effect of CO₂ inhibitor A is slightly worse, and the corrosion inhibition rate reaches 75% only when the concentration is close to 1000 mg/L.

When the inhibitor concentration was increased from 1000 to 2000 mg/L, the corrosion rates of KY-12 and KY-17 corrosion inhibitors continued to decrease and the corrosion inhibition effect continued to increase, but the range of the two inhibitors was relatively gentle. Finally, the corrosion rates of KY-12 and KY-17 corrosion inhibitors were controlled at 0.0703 and 0.0319 mm/a, and the corrosion inhibition rates reached 86.47 and 92.7%, respectively. However, when the concentration of CO₂ inhibitor A reached 1000 mg/L, the corrosion inhibition effect decreased slightly, and the corrosion rate and corrosion inhibition rate of the hanging piece remained at 0.1289 mm/a and 75.18%, respectively.

The inhibition efficiency of KY-12 and KY-17 corrosion inhibitors increases with the corrosion inhibitor concentration because it is difficult for inhibitor molecules to form a complete and dense protective film on the surface of the hanging piece when the concentration of the corrosion inhibitor is low. However, with the increasing concentration of corrosion inhibitors, more corrosion inhibitor molecules are

adsorbed on the metal surface of the hanging piece, and the protective film formed on the metal surface of the hanging piece becomes more compact and complete. The corrosion rate decreases, and the corrosion inhibition rate increases.^{28,29} However, after reaching a certain concentration, the corrosion inhibitor molecular film basically covers the hanging piece, and the corrosion inhibition efficiency will increase very slowly if the corrosion inhibitor is added continuously. If the concentration is too high, it even inhibits the corrosion inhibition effect or leads to molecular film shedding,³⁰ which is similar to the situation wherein the corrosion inhibition rate of anti-CO₂ corrosion inhibitor A decreases.

Finally, as KY-17 is recommended as the corrosion inhibitor for the gathering pipeline in this oilfield, and considering the actual economy of oilfield production, the recommended amount of corrosion inhibitor is 1000 mg/L.

4. CONCLUSIONS

- (1) Based on the experimental evaluation of dynamic corrosion of the simulated ORAF pipeline, three of the 12 corrosion inhibitors selected at 40 °C and 1000 mg/L were KY-12, KY-17, and CO₂-resistant inhibitor A, and their corrosion inhibition efficiencies were 83.67, 91.49, and 78.44%, respectively. The three have a good protective effect on the pipeline material of ORAF, and the effect of the antioxidant corrosion inhibitor is better than that of the anti-CO₂ corrosion inhibitor.
- (2) According to the test results of dynamic corrosion experiments of the three corrosion inhibitors at different temperatures, the KY-17 corrosion inhibitor is the most stable at different temperatures. At 55 °C, it can still control the corrosion rate of the hanging piece at 0.0745 mm/a, and the corrosion inhibition efficiency remains at 85.66%.
- (3) The corrosion inhibition efficiencies of KY-12, KY-17, and CO₂ inhibitor A with different dosages were studied. The corrosion inhibition rate of KY-17 remains above 75%. Finally, KY-17 is selected as the corrosion inhibitor in this oilfield. Considering the economic cost, the best dosage of 1000 mg/L is recommended.

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Notes

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