

Study of the effectiveness of the new inhibitor in different aggressive media

Badanie skuteczności nowego inhibitora w różnych środowiskach o dużej aktywności chemicznej

Huseyn R. Gurbanov¹, Gulahmad M, Talybov², Mehpara B. Adygezalova¹, Yu X. Zhang²

¹ Azerbaijan State Oil and Industry University

² Azerbaijan Technical University

ABSTRACT: The corrosion protection effect of the new S-1 reagent in media with the pH values of 2.0, 4.0, 6.0, as well as carbon dioxide and hydrogen sulfide added separately and combined to the mentioned media, was first tested under laboratory conditions. The protective effect of reagent S-1 was weak in the corrosion medium without hydrogen sulfide and carbon dioxide. However, as the acidity of the medium and the concentration of the reagent increases, the corrosion protection efficiency of the inhibitor also increases. The highest effect is observed at pH = 2.0 and reagent concentration of 30 mg/l. The corrosion protection effect of the reagent reaches 97% under these conditions. In the media with pH = 4.0 and pH = 6.0 without carbon dioxide and hydrogen sulfide, the protective effect of the inhibitor at the optimal concentration of 30 mg/l is 66% and 64%, respectively. In the medium with added carbon dioxide, the protective effect of inhibitor S-1 decreases at pH = 2.0 and, on the contrary, increases at the values of pH = 4.0 and pH = 6.0. Also, as the pressure of carbon dioxide in the medium increases, the protective effect of inhibitor S-1 increases. When hydrogen sulfide is added to the medium, it causes an increase in the corrosion rate and the protection efficiency of inhibitor S-1. However, in the medium without inhibitor, the increase of hydrogen sulfide concentration only up to $C_{\text{H}_2\text{S}} = 400$ mg/l is accompanied by an increase in the corrosion rate at all values of pH. The addition of 1000 mg/l of hydrogen sulfide to the corrosion medium leads to the decrease in the corrosion rate in the medium without inhibitors and a slight decrease in the protective effect at the concentration of the inhibitor $C_{\text{inh}} = 10$ mg/l. As the concentration of inhibitor S-1 increases in the medium with the addition of carbon dioxide and hydrogen, its corrosion protection effect also increases. In the range of $C_{\text{inh}} = 10\text{--}30$ mg/l, when $P_{\text{CO}_2} = 0.5$ atm and $C_{\text{H}_2\text{S}} = 200$ mg/l, the protective effect is estimated at 38–99%, and when $C_{\text{H}_2\text{S}} = 1000$ mg/l, it is estimated at 17–79%. At $P_{\text{CO}_2} = 1.0$ atm, the value of protective effect is 22–95% and 14–76%, and finally at $P_{\text{CO}_2} = 2.0$ atm, the value of the corrosion protection effect of inhibitor S-1 is estimated at 44–92% and 15–75%, respectively. The coexistence of carbon dioxide and hydrogen sulfide in an aggressive medium leads to an increase in the protective effect of inhibitor S-1 compared to the medium containing only carbon dioxide, and reduces it in comparison to the medium with hydrogen sulfide. An increase in carbon dioxide pressure in the presence of hydrogen sulfide causes a decrease in the protective effect of inhibitor S-1. The protective effect of inhibitor S-1 is lower in the medium with hydrogen sulfide concentration of 1000 mg/l compared to a concentration of 200 mg/l. This case is also observed in the carbon dioxide free medium.

Key words: carbon dioxide, hydrogen sulfide, corrosion, protective effect, inhibitor, pH, reagent, corrosion rate, concentration.

STRESZCZENIE: Działanie antykorozyjne nowego odczynnika S-1 w agresywnych mediach o pH 2,0; 4,0; 6,0, a także dwutlenku węgla i siarkowodoru dodawanych osobno lub łącznie do tych mediów, zostało najpierw zbadane w warunkach laboratoryjnych. Działanie ochronne odczynnika S-1 było słabe w środowisku korozyjnym bez siarkowodoru i dwutlenku węgla. Jednak wraz ze wzrostem kwasowości medium i stężenia odczynnika wzrasta również skuteczność inhibitora w ochronie przed korozją. Najlepsze działanie antykorozyjne odnotowano przy wartości pH = 2,0 i stężeniu odczynnika 30 mg/l. Skuteczność ochronna odczynnika wynosi wówczas 97%. W medium o pH = 4,0 i pH = 6,0 bez dwutlenku węgla i siarkowodoru skuteczność ochronna inhibitora przy optymalnym stężeniu 30 mg/l wynosi odpowiednio 66 i 64%. W medium z dodatkiem dwutlenku węgla działanie ochronne inhibitora S-1 maleje przy wartości pH = 2,0 i odwrotnie wzrasta przy wartościach pH = 4,0 i pH = 6,0. Ponadto, wraz ze wzrostem ciśnienia dwutlenku węgla w środowisku wzrasta skuteczność ochronna inhibitora S-1. Dodanie siarkowodoru do medium powoduje wzrost tempa korozji i skuteczności ochronnej inhibitora S-1. Jednak w medium bez inhibitora wzrostowi stężenia siarkowodoru nawet do tak niskiej wartości jak $C_{\text{H}_2\text{S}} = 400$ mg/l towarzyszy wzrost tempa korozji przy wszystkich wartościach pH. Dodanie 1000 mg/l siarkowodoru do medium korozyjnego prowadzi do zmniejszenia tempa korozji w medium bez inhibitorów i nieznacznego zmniejszenia działania ochronnego przy stężeniu inhibitora $C_{\text{inh}} = 10$ mg/l. Wraz ze wzrostem stężenia inhibitora S-1 w medium z dodatkiem dwutlenku węgla i siarkowodoru,

Corresponding author: M. Adygezalova, e-mail: mehpara.adigozalova@asoiiu.edu.az

Article contributed to the Editor: 09.05.2023. Approved for publication: 11.07.2023.

zwiększa się również jego działanie antykorozyjne. W zakresie $C_{inh} = 10\text{--}30$ mg/l, gdy $P_{CO_2} = 0,5$ atm i $C_{H_2S} = 200$ mg/l, skuteczność ochronną szacuje się na 38–99%, natomiast przy $C_{H_2S} = 1000$ mg/l na 17–79%. Dla $P_{CO_2} = 1,0$ atm skuteczność ochronną wynosi od 22–95% do 14–76%, a przy $P_{CO_2} = 2,0$ atm skuteczność antykorozyjną inhibitora S-1 szacuje się odpowiednio na 44–92% i 15–75%. Jednoczesne występowanie dwutlenku węgla i siarkowodoru w agresywnym medium zwiększa skuteczność ochronną inhibitora S-1 w stosunku do medium zawierającego tylko dwutlenek węgla i zmniejsza ją w porównaniu do medium z siarkowodorem. Wzrost ciśnienia dwutlenku węgla w obecności siarkowodoru powoduje zmniejszenie skuteczności ochronnej inhibitora S-1. Ulega ona także zmniejszeniu w środowisku o stężeniu siarkowodoru 1000 mg/l w porównaniu do stężenia 200 mg/l. Ten przypadek obserwuje się również w środowisku bez dodatku dwutlenku węgla.

Słowa kluczowe: dwutlenek węgla, siarkowodór, korozja, działanie ochronne, inhibitor, pH, odczynnik, tempo korozji, stężenie.

Introduction

The rapid development of the oil and gas industry requires increasing the operational efficiency of wells in oil production. In this regard, corrosion protection of underground and above ground oilfield facilities remains relevant in order to stabilize oil production and increase the operational efficiency of wells. In an attempt to stabilize and increase oil production in most oil fields, many technical and technological measures such as injecting water and gas into the field, changing the type of wells operation, in particular switching to rod pump and depth pump methods, thermally affecting the formation, injecting chemical reagents and many other have been taken. As a result of these measures, oil fields are enriched with aggressive substances, and the amount of oxygen, carbon and hydrogen-sulfide gases increases significantly leading to accelerated corrosion. The studies conducted have shown that the main reason for the corrosion of underground and above ground facilities in oil and gas mines is the presence of corrosive elements in formation waters produced together with oil, including sulfur and oxygen compounds, hydrogen-sulfide and carbon dioxide, as well as mineral salts dissolved in formation waters (Morris and Sharp, 2002; Semenova et al., 2002; Plotnikova and Shein, 2013; Menshikov and Shein, 2016, 2018).

The degree of contact between the aggressive medium and the metal surface determines the probability of occurrence of the process resulting in the corrosion of the facilities. The composition of the well product is rich in methane and its homologues, which do not have a high degree of corrosive aggressiveness. However, if it contains a small amount of H_2S or CO_2 , corrosive aggressiveness begins to increase rapidly. The solubility of gases in liquids, including water, is directly proportional to pressure. As the pressure in the production wells is high, the gases existing in the wells are also dissolved in the production product. Therefore, the increase of the partial pressure in the column intensifies the corrosion process accordingly (Vagapov., 2002; Chirkunov et al., 2007; Gurbanov and Abdullayeva, 2018; Gurbanov et al., 2019a). The presence of CO_2 in the medium is primarily related to the metamorphism of sedimentary rocks in the formation. Organic compounds

are broken down by high pressure or by bacteria to produce CO_2 . CO_2 is not aggressive to oilfield facilities in anhydrous conditions, but corrosive aggressiveness increases rapidly when there is even a little moisture in the medium. Thus, CO_2 dissolves well in water and turns into weak carbonic acid. Due to the reaction of CO_2 with water in the fields, the pH value increases and reaches 4–5. On the other hand, in recent years, there has been an increase in corrosion damage caused by hydrogen sulfide gas. Generally, in addition to electrochemical and sometimes chemical corrosion occurring at a high rate in the hydrogen sulfide medium, hydrogen embrittlement of steel also occurs (Tsygankova et al., 2005, 2006; Chirkunov et al., 2007; Tsygankova and Kuznetsova, 2007; Tsygankova, 2008; Dubinskaya et al., 2013; Gurbanov and Abdullayeva, 2018; Gurbanov et al., 2019a, 2019b; Miralamov et al 2019; Kuznetsov and Vagapov, 2000; Talybov et al., 2020).

Thus, the factors mentioned above once again indicate that the protection of oil and gas industrial facilities from the corrosion process caused by the impact of hydrogen sulfide and carbon dioxide is an urgent and pressing. For this reason, the search for effective inhibitors for protection from the mentioned corrosion processes, their research in laboratory conditions and their selection for application in mining conditions is one of the important issues raised before research scientists.

The goal of the work is to study the protective effect of the new reagent at different pH values and in media with different corrosive agents.

Workflow

In order to determine electrochemical corrosion resistance of St3 steel, laboratory studies were conducted at room temperature using polished samples with dimensions of $20 \times 12 \times 2$ mm. At this time, an aggressive corrosion medium was prepared under hydrogen chloride in the medium with pH = 2.0, 4.0, 6.0 and 5.0, 8.0 g/l NaCl, and in aggressive media with carbon dioxide and hydrogen sulfide added to that media separately and simultaneously. In laboratory conditions, hydrogen sulfide in the required amount of 50, 100, 200, 400 and 1000 mg/l was

obtained by means of $\text{Na}_2\text{S} + 2\text{HCl} = 2\text{NaCl} + \text{H}_2\text{S}$ reaction between dry Na_2S salt and HCl in the precalculated amount. To create 0.5, 1 and 2 atmospheric pressure of carbon dioxide, using Y.I. Kuznetsov method, plastic containers equipped with a nipple valve were used. Carbon dioxide was injected from a cylinder with manometric pressure control. Corrosion experiments were conducted according to generally accepted methodology and for a period of 24 hours.

The corrosion rate was calculated according to the following mathematical formula.

$$K = \frac{m_1 - m_2}{S \cdot \tau} \quad (1)$$

A mathematical expression used to calculate the retardation factor:

$$\gamma = \frac{K_0}{K_{inh}} \quad (2)$$

The protective effect of reagent S-1 was calculated by the following formula:

$$Z = \frac{K_0 - K_{inh}}{K_0} 100\% \quad (3)$$

Based on the corrosion rate, the penetration depth is determined as follows.

$$K_p = \frac{8760K_m}{\rho} \cdot 10^{-3} \text{ [mm/year]} \quad (4)$$

In the research process, $\text{C}_{11}\text{H}_{11}\text{Cl}_2\text{IO}$ (1,2-dichloro-4 {2-iodo-1[(prop-2-en-1-yl)oxy]-ethyl}benzene was synthesized in a similar way from 3,4-dichlorostyrene, allyl alcohol and crystalline iodine). Yield 66.8%, mt 97–99°C (from EtOH). IR spectrum, ν [cm]: 1: 3080, 3010, 1640, 1630, 1515, 1360–1340, 1270, 845, 560. NMR spectrum, ^1H , δ [ppm]: 3.20 d.d (1H, CH_2I , $J = 10.3, 5.8$ Hz), 3.47 d.d (1H, CH_2I , $J = 10.3, 5.8$ Hz), 4.03 d.d (2H, CH_2O , $3J = 5.7, 4J = 1.5$ Hz), 4.42 d.d (1H, CH, $J = 5.8, 9.0$ Hz), 5.18 d.d.t (1H, H_2C , $J_{cis} = 10.37, 2J = 4J = 1.6$ Hz), 5.25 d.d.t (1H, H_2C , $J_{trans} = 17.3, 2J = 4J = 1.7$ Hz), 5.88 d.d.t (1H, CH, $J_{cis} = 10.4, 2J = 4J = 1.6, J_{trans} = 17.3$ Hz), 7.28 d.d (1H, C_6H_3 , $J = 8.3, 0.5$ Hz), 7.53 d.d (1H, C_6H_3 , $J = 8.8, 2.6$ Hz), 7.66 d.d (1H, C_6H_3 , $J = 2.6, 2.6$ Hz). NMR spectrum, ^{13}C , δ [ppm]: 55.3, 69.9, 80.5, 114.0, 117.4, 127.8, 131.9, 131.1 (C^2), 132.6 (C^1), 134.9, 159.6. Found [%]: C 37.22; H 3.18; Cl 19.47, I 35.55. $\text{C}_{11}\text{H}_{11}\text{Cl}_2\text{IO}$. Calculated [%]: C 37.01; H 3.11; Cl 19.86; I 35.55 of organic origin and chemical composition was used as a chemical reagent against corrosion (Talybov et al., 2020).

Experimental part

First, the protective effect of the new reagent was investigated under laboratory conditions in the medium without the

addition of hydrogen sulfide and carbon dioxide. The obtained results are presented in Table 1.

As it can be seen (Table 1), the protective effect of reagent S-1 is weak in the corrosion medium without hydrogen sulfide and carbon dioxide. However, as the acidity of the medium and the concentration of the reagent increase, the corrosion protection effect of the studied S-1 reagent increases. The highest effect is observed at the value of $\text{pH} = 2.0$ and at reagent concentration of 30 mg/l. The corrosion protection effect of the reagent reaches 97% under these conditions. At the optimal concentration of S-1 reagent of 30 mg/l, the protective effect is 66 and 64% at $\text{pH} = 4.0$, and $\text{pH} = 6.0$ respectively.

Table 1. Protective effect of inhibitor S-1 at different pH values

Tabela 1. Ochronne działanie inhibitora S-1 przy różnych wartościach pH

$K_0 \cdot 10^6$ [g/sm ² · h]	Inhibitors concentration [mg/l]	10	15	20	25	30
	pH	Protective effect, Z [%]				
29.0	2.0	17.2	87	93	95	97
14.3	4.0	34.8	39	47	53	66
7.1	6.0	23.1	24	34	54	64

The protective effect of inhibitor S-1 in the presence of carbon dioxide was studied in a weak acidic medium.

As it can be seen from Table 2, as the pH value increases in the medium without inhibitors ($\text{pH} = 2.0, 4.0, 6.0$), the corrosion rate varies depending on the pressure of carbon dioxide. Thus, the corrosion rate at 0.5 atmosphere first decreases and then increases. At 1.0 atmospheres, the rate first increases, then decreases, and finally at 2.0 atmospheres, the corrosion rate gradually decreases.

At all pH values and carbon dioxide pressures of 0.5, 1.0, and 2.0 atmospheres, the protective effect increases as the concentration of the inhibitor increases. However, at the same concentration of the inhibitor, the situation is different when the pH and carbon dioxide pressure change. Thus, when $C_{inh} = 10$ mg/l, at $\text{pH} = 2.0$, the protective effect increases and then decreases as the pressure increases. At $\text{pH} = 4.0$, the protective effect decreases and then increases, at $\text{pH} = 6.0$ the protective effect decreases and then increases. As the pressure increases, the protective effect increases and then decreases when $C_{inh} = 15$ mg/l, $\text{pH} = 2.0, \text{pH} = 4.0$. When $\text{pH} = 6.0$, the protective effect increases as the pressure increases. When $C_{inh} = 20$ mg/l, $\text{pH} = 2.0, \text{pH} = 4.0$ the protective effect increases with increasing pressure and then decreases. When $\text{pH} = 6.0$, the protective effect increases as the pressure increases. The protective effect increases as the pressure increases when $C_{inh} = 25$ mg/l, $\text{pH} = 2.0, \text{pH} = 6.0$. At $\text{pH} = 4.0$, the protective

effect increases and then decreases as the pressure increases. Finally, the protective effect increases as the pressure increases at the values of $C_{inh} = 25$ mg/l, pH = 0, pH = 4.0, pH = 6.0 and the highest value is 91% at pH = 4 and carbon dioxide pressure of 2.0.

As it can be seen (Table 2), the protective effect of inhibitor S-1 decreases at the value of pH = 2.0 in carbon dioxide medium and on the contrary increases at the values of pH = 4.0 and pH = 6.0. Also, as the pressure of carbon dioxide in the medium increases, the protective effect of inhibitor S-1 increases.

Table 3 presents the results of laboratory experiments in the medium with the addition of hydrogen sulfide.

When hydrogen sulfide is added to the medium, it causes an increase in the corrosion rate and the protective effect of inhibitor S-1 (Table 3). However, in the inhibitor free medium, the increase of hydrogen sulfide concentration only up to $C_{H_2S} = 400$ mg/l is accompanied by an increase in the corrosion rate at all values of pH.

The addition of 1000 mg/l of hydrogen sulfide to the corrosion medium leads to the weakening of the corrosion rate in the inhibitor free medium and a slight decrease in the protective effect at inhibitor concentration of $C_{inh} = 10$ mg/l. As it can be seen (Table 3), since the concentration of inhibitor S-1 increases at all concentrations of hydrogen sulfide and at all values of pH, its corrosion protection effect also increases.

Table 2. Protective effect of S-1 inhibitor with the presence of CO₂

Tabela 2. Ochronne działanie inhibitora S-1 w obecności CO₂

P_{CO_2} [atm]	$K_0 \cdot 10^6$ [g/sm ² · h]	Inhibitors concentration [mg/l]				
		10	15	20	25	30
protective effect, Z [%]						
when pH = 2.0						
0.5	26.2	24.0	39.0	44.0	49.0	52.0
1.0	23.5	56.0	68.0	72.0	74.0	76.0
2.0	21.9	34.0	46.0	57.0	79.0	87.0
when pH = 4.0						
0.5	19.2	66.0	73.0	74.0	77.0	85.0
1.0	30.1	45.0	78.0	82.0	84.0	86.0
2.0	17.6	54.0	68.0	72.0	78.0	88.0
when pH = 6.0						
0.5	22.9	58.0	64.0	67.0	70.0	71.0
1.0	28.2	33.0	71.0	75.0	82.0	87.0
2.0	16.7	58.0	77.0	80.0	84.0	91.0

Table 3. Protective effect of inhibitor S-1 in the presence of H₂S

Tabela 3. Ochronne działanie inhibitora S-1 w obecności H₂S

C_{H_2S} [mg/l]	$K_0 \cdot 10^6$ [g/sm ² · h]	Inhibitors concentration [mg/l]				
		10	15	20	25	30
protective effect, Z [%]						
when pH = 2.0						
50	60.1	47.0	83.0	88.0	89.0	93.0
100	75.4	38.0	90.0	93.0	94.0	95.0
200	123.5	47.0	91.0	92.0	93.0	94.0
400	199.0	45.0	80.0	82.0	85.0	90.0
1000	95.2	51.0	75.0	80.0	86.0	95.0
when pH = 4.0						
50	54.1	72.0	76.0	79.0	83.0	91.0
100	93.1	74.0	78.0	84.0	88.0	91.0
200	110.2	74.0	76.0	84.0	87.0	89.0
400	190.0	71.0	73.0	83.0	85.0	90.0
1000	82.1	76.0	79.0	85.0	84.0	91.0

cont. Table 3/ cd. Tabela 3

C_{H_2S} [mg/l]	$K_0 \cdot 10^6$ [g/sm ² · h]	Inhibitors concentration [mg/l]				
		10	15	20	25	30
protective effect, Z [%]						
when pH = 6.0						
50	54.1	72.0	76.0	79.0	83.0	91.0
100	93.1	74.0	78.0	84.0	88.0	91.0
200	110.2	74.0	76.0	84.0	87.0	89.0
400	190.0	71.0	73.0	83.0	85.0	90.0
1000	82.1	76.0	79.0	85.0	84.0	91.0

Table 4. Protective effect of inhibitor S-1 in CO₂ + H₂S medium (pH = 2.0)

Tabela 4. Ochronne działanie inhibitora S-1 w środowisku CO₂ + H₂S (pH = 2.0)

C_{H_2S} [mg/l]	$K_0 \cdot 10^6$ [g/sm ² · h]	Inhibitors concentration [mg/l]				
		10	15	20	25	30
protective effect, Z [%]						
$P_{CO_2} = 0.5$ atm						
200	63.6	38.0	94.0	97.0	98.0	99.0
1000	52.5	17.0	52.0	64.0	75.0	79.0
$P_{CO_2} = 1.0$ atm						
200	89.8	22.0	91.0	92.0	94.0	95.0
1000	40.3	14.0	52.0	54.0	69.0	76.0
$P_{CO_2} = 2.0$ atm						
200	41.6	44.0	89.0	91.0	90.0	92.0
1000	39.2	15.0	54.0	68.0	67.0	75.0

Thus, in the range of $C_{inh} = 10\text{--}30$ mg/l and pH = 2.0, the protective effect of the inhibitor is 47–93% at $C_{H_2S} = 50$ mg/l, 38–95% at $C_{H_2S} = 100$ mg/l, it ranges between 47–94% at $C_{H_2S} = 200$ mg/l, between 45–90% at $C_{H_2S} = 400$ mg/l, and it ranges between 51–95% at $C_{H_2S} = 1000$ mg/l. When pH = 4.0, the protective effect of the inhibitor ranges between 72–91% at $C_{H_2S} = 50$ mg/l, 74–91% at $C_{H_2S} = 100$ mg/l, 74–89% at $C_{H_2S} = 200$ mg/l, 71–90% at $C_{H_2S} = 400$ mg/l, 76–91% at $C_{H_2S} = 1000$ mg/l. When pH = 6.0, the protective effect of the inhibitor ranges between 64–89% at $C_{H_2S} = 50$ mg/l, 57–84% at $C_{H_2S} = 100$ mg/l, 71–83% at $C_{H_2S} = 200$ mg/l, 74–86% at $C_{H_2S} = 400$ mg/l and 73–88% at $C_{H_2S} = 1000$ mg/l.

As it can be seen (Table 4), since the concentration of inhibitor S-1 increases in the medium where carbon dioxide and hydrogen sulfide coexist, its protective effect also increases. In the range of $C_{inh} = 10\text{--}30$ mg/l, when $P_{CO_2} = 0.5$ atm and $C_{H_2S} = 200$ mg/l, the protective effect is rated between 38–99%, and when $C_{H_2S} = 1000$ mg/l, it is rated between 17–79%. At $P_{CO_2} = 1.0$ atm, the value of the protective effect is rated between 22–95% and 14–76%, and finally when $P_{CO_2} = 2.0$ atm, the protective effect of S-1 inhibitor is accordingly rated between 44–92% and 15–75%. Coexistence of carbon dioxide and hydrogen sulfide in an aggressive medium increases the

protective effect of inhibitor S-1 compared to the medium with carbon dioxide only, and reduces it compared to the medium with hydrogen sulfide (Table 4). An increase in carbon dioxide pressure in the presence of hydrogen sulfide causes a decrease in the protective effect of inhibitor S-1. The protective effect of inhibitor S-1 is lower in the medium of concentration of 1000 mg/l compared to concentration of 200 mg/l of hydrogen sulfide. This case is also observed in carbon dioxide free medium.

Conclusion

1. For the first time, as a result of experimental studies, it was determined that the optimal concentration of the protective effectiveness in the various aggressive environments of the new organic S-1 reagent is 30 mg/l.
2. As a result of numerous experiments, it was found that in the media without hydrogen sulfide and carbon dioxide, also in the media with the presence of hydrogen sulfide, there is an increase in acidity, in the media of carbon dioxide the increase of pressure and decrease of acidity increase the protective effect of inhibitor.

3. In the media with the presence of both hydrogen sulfide and carbon dioxide, the protective effect of S-1 reagent increases at low values of carbon dioxide pressure and hydrogen sulfide concentration.

Nomenclature

- K – the corrosion rate,
 Z – the protective effect,
 γ – the retardation factor,
 K_p – the penetration depth,
 m_1 – the pretest weight of the sample [g],
 m_2 – the weight of the sample after removing the corrosion product [g],
 S – the sample area [m²],
 τ – the test duration, hours,
 K_0 – a reagent free corrosion rate,
 K_{inh} – a corrosion rate in the presence of the reagent [g/sm² · h],
 K – corrosion rate [g/sm² · h],
 ρ – density of the studied metal [g/sm²],
 8760 – is a constant number of hours in a year.

References

- Chirkunov A.A., Kuznetsov Yu.I., Tomin V.P., 2007. Inhibition of corrosion of low-carbon steel in soft waters by anavidin. *Corrosion: Materials, Protection*, 4: 18–23.
- Dubinskaya E.V., Vigdorovich V.I., Tsygankovich L.E., 2013. Inhibitor protection of steel in hydrogen sulfide environments. *TGU Bulletin*, 18(5): 2814–2822.
- Gurbanov G.R., Abdullayeva Z.A., 2018. Investigation of a multi-functional combined inhibitor for the oil and gas industry. *Journal Practice of Anticorrosive Protection*, 2(88): 16–20.
- Gurbanov G.R., Adygezalova M.B., Mammadly S.M., 2019a. Research on the effect of an inhibitor-bactericide for corrosion protection of oilfield equipment. *Azerbaijan Oil Industry*, 2: 38–42.
- Gurbanov G.R., Adygezalova M.B., Mammadly S.M., 2019b. Study of the protective properties of a universal corrosion inhibitor for the oil and gas industry. *Practice of Anticorrosion Protection*, 24(1): 29–48.
- Kuznetsov Yu.I., Vagapov R.K., 2000. On the protection of steel in hydrogen sulfide-containing media with a volatile inhibitor. *Zashchita Metallov*, 36(5): 520.
- Menshikov I.A., Shein A.B., 2016. Low corrosion protection carbon steel in acidic environments inhibitors of series SOLING. *Chemistry and Chemical Technology*, 59(2): 70–73.
- Menshikov I.A., Shein A.B., 2018. Protective properties of series solingors in acid hydrogen sulfide-containing environments. *Chemistry and Chemical Technology*, 61(7): 91–98.
- Miralamov G.F., Gurbanova G.R., Mammadly S.M., Gasimzada A.V., 2019. Laboratory the research new inhibitor for prevention of corrosion of the oil field equipment. *Herald of the Azerbaijan Engineering Academy*, 11.1.61 -70.
- Morris W.F., Sharp R.R., 2002. Race, Ethnicity, and Genomics: Social Classifications as Proxies of Biological Heterogeneity. *Genome Research*, 12(6): 844–850. DOI: 10.1101/gr.99202.
- Plotnikova M.D., Shein A.B., 2013. Inhibition of corrosion of mild steel in acidic and neutral environments. *Chemistry and Chemical Technology*, 56(3): 35–40.
- Semenova I.V., Florianovich G.M., Khoroshilov A.V., 2002. Corrosion and corrosion protection. Ed. I.V. *Fizmatlit*, 1–336.
- Talybov G.M., Azizbeyli A.R., Mammadbeyli E.G., Gurbanov G.R., 2020. Alkoxyhalogenation of dichlorostyrenes in unsaturated C3-alcohols. *Journal of Organic Chemistry*, 56(1): 47–51.
- Tsygankova L.E., 2008. Inhibition of corrosion and hydrogenation of carbon steel in H₂S and CO₂ containing environment. *Corrosion: Materials, Protection*, 2: 26–30.
- Tsygankova L.E., Kim Ya.R., Kichigin V.I., Vigdorovich V.I., 2005. Investigation of corrosion inhibition and the penetration of hydrogen into steel in formation water simulants. *Practice of Corrosion Protection*, 4(38): 29–38.
- Tsygankova L.E., Kuznetsova E.G., 2007. Anticorrosive protection of carbon steel in the reservoir water imitate in the presence of H₂S and CO₂. *Natural and Technical Sciences Series*, 12(5): 585–589.
- Tsygankova L.E., Mozharov A.V., Ivanischenkov S.S., Kosyanenko E.S., 2006. Phenolic bases of Mannich as inhibitors of corrosion and hydrogenation of steel in hydrochloric acid environments containing H₂S and CO₂. *Practice of Corrosion Protection*, 2(40): 49–60.
- Vagapov R.K., 2002. Inhibition of hydrogenation of steel in hydrogen sulfide-containing media by Schiff bases. *Protection of Metals*, 38(1): 32–37.



Prof. Huseyn Ramazan GURBANOV, Ph.D.
 Professor at the Department of Transportation and Storage of Oil and Gas
 Azerbaijan State Oil and Industry University
 16/21 Azadliq Ave, Baku AZ1010, Azerbaijan
 E-mail: huseyn.gurbanov@asoiu.edu.az



Mehpara Babaverdi ADYGEZALOVA,
 Ph.D. Candidate
 Associate Professor at the Department of Chemistry and Technology of Inorganic Substances
 Azerbaijan State Oil and Industry University
 16/21 Azadliq Ave, Baku AZ1010, Azerbaijan
 E-mail: mehpara.adigozalova@asoiu.edu.az



Prof. Gulahmad Mirahmad TALYBOV, Ph.D.
 Professor at the Department of Chemical Technology, Recycling and Ecology
 Azerbaijan Technical University
 25 G. Javida Ave, Baku AZ1073, Azerbaijan
 E-mail: gatalibov61@gmail.com



Yu Xin ZHANG, M.Sc.
 Doctoral student at the Department of Transportation and Storage of Oil and Gas
 Azerbaijan State Oil and Industry University
 16/21 Azadliq Ave, Baku AZ1010, Azerbaijan
 E-mail: zyx110708@gmail.com