

# Improving The Efficiency Of Heat Exchange Equipment Using Corrosion And Scale Inhibitors

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**Abstract:** Background of the problem. The efficiency of heat exchange equipment in a closed indoor water supply depends on corrosion and the deposition of mineral salts on their surface. This is due to a decrease in the values of heat transfer coefficients between the aqueous medium and the wall of the heat exchangers. In this regard, the prevention of mineral deposits in water systems and corrosion of carbon steel pipes and equipment is one of the most important tasks. The problem, so far, has been solved with the use of scale inhibitors, which were imported from abroad for the oil refineries of our Republic, therefore, the development and implementation of new compositions of corrosion and scale inhibitors based on local raw materials is a solution not only to import substitution, but also to innovative technology. The aim of this work is to develop corrosion inhibitors and scaling based on analyzes of the electrochemical properties of water, with different ratios of activator ions present in the aquatic environment. Methodology. The degree of inhibitory protection  $Z = [100\% (ic' - ic) / ic']$ , where  $ic'$  and  $ic$  are the corrosion rates in the absence and presence of an inhibitor, evaluated by polarization curve (PC) methods (PI-50-1 potentiostat, potentials - on the scale of N.V.E.) and polarization resistance (PS) (P-5035 corrosion meter), measured on electrodes from Art. 20 with a purity of the air-oxidized surface  $Rz \leq 10 \mu m$ , characterized by the ratio of the area (S) to the volume of the solution (V),  $cm^2 / cm^3$ , not more than 1:10 (for PC and PS  $S = 0.5$  and  $25 cm^2$ ). Gravimetric measurements (GI) were carried out under static and dynamic conditions (stirring, 300 rpm) for  $\leq 30$  days on samples from Art. 20 ( $Rz \leq 20 \mu m$ ,  $s = 26.9 cm^2$ ;  $S / V = 1:20$ ). The inhibition of the scaling process was determined using the operating instructions on an ISO-1 device. Scientific novelty. It was established that the concentration of chemicals affecting the corrosive properties of water found in natural waters should not exceed, after their purification, standards in accordance with GOST 2877-82. The nature of the course of corrosion depends on the ions present in the corrosive medium, mainly anions. Received data. The effectiveness of the use of corrosion and scale inhibitors GPMSC and IONX-1 relative to imported HEDPA was determined. When the value of the corrosion rate for GPMSh is 0.0000064287; IONX-1 - 0.0000083722; and OEDPC - 0.0000245186. The effectiveness of the inhibition of scaling for GPMS - 91.76%; for IONX-1 - 89.41%; and for an imported scale inhibitor of HEDPK - 94.11%.

**Index Terms:** Corrosion, corrosion rate, concentration, inhibitor, scaling, heat exchange, equipment.

## 1. INTRODUCTION

Low-carbon structural steel used in heat exchange equipment, in water supply systems, during prolonged contact with mineralized, oxygenated air, is exposed to corrosion and scale formation, economic losses from which due to a decrease in the heat transfer coefficient between the wall and the cooled medium and due to accidents and caused by their production downtime often exceeds the cost of equipment to be replaced. That is why the development of methods of protection in these systems of steel against scale formation corrosion, especially inhibitory ones, as they do not require large investments, is relevant [1]. The use of corrosion inhibitors and scaling involves the study of interfacial equilibrium in a heterogeneous system at the metal-solution interface, which is impossible

without electrochemical methods [2].

## 2 METHODS OF RESEARCH

### 2.1 FEATURES:

- the influence of the composition of the water used on its corrosiveness and scale;
- the optimal concentrations of corrosion inhibitors and scaling are established, which are necessary for use in the composition of the used water, internal water supply of the Ferghana Oil Refinery.

### 2.2 METHODOLOGY

When choosing a suitable preparation, various additives to the used water attract attention [1], as an effective and affordable means for the temporary protection of steel against corrosion and scale formation. Of particular interest is the study of the corrosion-electrochemical characteristics of carbon steel in water containing corrosion activating ions and purposefully calculating its protective concentration. It is known that with the same presence of corrosion activating ions: chloride and sulfate ions, carbonate hard water is non-aggressive due to screening of the metal surface with a film, and soft water is aggressive. That is why low carbon structural steel Art. 20 and a solution of sodium chloride (0-177 mg / l for chloride ions) and sodium sulfate (0-480 mg / l for sulfate ions) in distilled water, simulating extremely aggressive technical water GOST 2874-82. It was of interest to evaluate the effect of the temperature of the solution and the time of contact with it. The degree of inhibitory protection  $Z = [100\% (ic' - ic) / ic']$ , where  $ic'$  and  $ic$  are the corrosion rates in the absence and presence of an inhibitor, evaluated by polarization curve (PC) methods (PI-50-1 potentiostat, potentials - on the scale of N.V.E.) and polarization resistance (PS) (P-5035 corrosion meter), measured on electrodes from Art. 20 with a purity of

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the air-oxidized surface  $R_z \leq 10 \mu\text{m}$ , characterized by the ratio of the area (S) to the volume of the solution (V),  $\text{cm}^2 / \text{cm}^3$ , not more than 1:10 (for PC and PS  $S = 0.5$  and  $25 \text{ cm}^2$ ). Gravimetric measurements (GI) were carried out under static and dynamic conditions (stirring, 300 rpm) for  $\leq 30$  days on samples from Art. 20 ( $R_z \leq 20 \mu\text{m}$ ,  $s = 26.9 \text{ cm}^2$ ;  $S / V = 1:20$ ). The inhibition of scaling was determined using the operating instructions on an ISO-1 device.

### 3 RESULTS AND DISCUSSION

It was established by the GI method at  $20^\circ \text{C}$ , which at the same low concentrations, sodium chloride is more aggressive than sulfate. At the same time, with an increase in the concentration of one or another salt, from  $20 \div 30$  to  $250 \div 260 \text{ g / l}$ , the corrosion rate decreased from  $3.8 \cdot 10^{-2}$  and  $3.0 \cdot 10^{-2} \text{ g / m}^2 \cdot \text{hr}$ , respectively,  $5 \cdot 10^{-2}$  and  $0.5 \cdot 10^{-2} \text{ g / m}^2 \cdot \text{h}$ , which is explained by a decrease in oxygen solubility as the solution mineralizes. The increase, due to its mixing, the concentration of  $\text{O}_2$ , the depolarizer of the cathodic reaction, increased the corrosion rate (PC method) (Table 1). With an increase in the electrode rotation speed,  $i_k$  increased; regardless of the composition of the solution,  $i_k$  in the oxygen atmosphere was greater than in the helium atmosphere. The dependence of the corrosion rate of steel, determined by the PS method in 24 hours, on the speed of movement of low-mineralized (total content of chloride, sulfate ions of  $50 \text{ mg / l}$ ) aerated water was complex. Its initial increase,  $0.0-0.3 \text{ m / s}$ , facilitated the diffusion of oxygen to the surface due to a decrease in the thickness of the diffusion layer, which led to an increase in  $i_k$ . Its further increase,  $0.4-0.8 \text{ m / s}$ , led to a decrease in  $i_c$  due to the passivation of the metal surface due to the intensive supply of oxygen to it. Even greater mixing,  $0.8-1.0 \text{ m / s}$  and further in a turbulent mode, increased  $i_k$ , apparently due to cavitation destruction of the protective film on the metal. In highly mineralized water, corresponding in composition to solutions 2–4 of Table 1, the picture of the change in  $i_k$  from the mixing speed is different (Table 2) From the table. 2 follows the linear nature of the dependence  $i_k \sim \omega^{0.5}$ , which does not go from the origin, characteristic of the predominantly diffusion control of the slow stage of the cathodic reaction of the corrosion process. For corrosion with oxygen depolarization, this kind of kinetics is typical due to the poor solubility of molecular oxygen in aqueous solutions, which decreases with increasing temperature. Therefore, for example, with an increase in temperature from  $20$  to  $60^\circ \text{C}$ , the corrosion rate determined by the PC method increased from  $0.63 \times 10^{-2}$  to  $12.59 \times 10^{-2} \text{ mA / cm}^2$ . On the contrary, the time factor in a neutral medium led to the opposite effect - the accumulation of corrosion products on the steel surface and the inhibition of corrosion. Under these conditions, over time, the corrosion potential shifted to the negative region, which is explained by the difficulty of the cathodic reaction due to diffusion restriction of oxygen access to the cathode sections through the layer of corrosion products (Table 3).

**Table 1. Steel corrosion rate 20 in solutions of sodium chloride and sulfate ( $20^\circ \text{C}$ , atmosphere - air, helium,  $\omega$  - angular rotation speed, rpm)**

No. of solution and mode mixing rpm	Anion, mg / L		Gas saturation		$i_k$ , mA / $\text{cm}^2$
	Cl-	SO <sub>4</sub> <sup>2-</sup>	air	helium	
1( $\omega = 200$ )	-	-	-	-	8,0·10 <sup>-3</sup>
1( $\omega = 200$ )	-	-	-	-	1,5·10 <sup>-3</sup>
2( $\omega = 0$ )	-	480	+	-	22,0·10 <sup>-3</sup>
2( $\omega = 0$ )	-	480	-	+	10,0·10 <sup>-3</sup>
3( $\omega = 0$ )	177	-	+	-	39,5·10 <sup>-3</sup>
3( $\omega = 0$ )	177	-	-	+	25,0·10 <sup>-3</sup>
4( $\omega = 0$ )	177	480	+	-	55,0·10 <sup>-3</sup>
4( $\omega = 0$ )	177	480	-	+	35,0·10 <sup>-3</sup>

No. of solution	$i_c$ , mA / $\text{cm}^2$			
	Angular rotation speed ( $\omega$ ), (rpm)			
	0	750	1600	2600
2	22,5·10 <sup>-3</sup>	100·10 <sup>-3</sup>	160·10 <sup>-3</sup>	200·10 <sup>-3</sup>
3	39,5·10 <sup>-3</sup>	80·10 <sup>-3</sup>	140·10 <sup>-3</sup>	175·10 <sup>-3</sup>
4	55,0·10 <sup>-3</sup>	125·10 <sup>-3</sup>	175·10 <sup>-3</sup>	225·10 <sup>-3</sup>

**Table 2. The effect of the mixing rate of solutions of sodium chloride and sulfate on the corrosion rate of steel 20 (PC method,  $20^\circ \text{C}$ , natural aeration)**

No. of solution	$i_c$ , mA / $\text{cm}^2$			
	Angular rotation speed ( $\omega$ ), (rpm)			
	0	750	1600	2600
2	22,5·10 <sup>-3</sup>	100·10 <sup>-3</sup>	160·10 <sup>-3</sup>	200·10 <sup>-3</sup>
3	39,5·10 <sup>-3</sup>	80·10 <sup>-3</sup>	140·10 <sup>-3</sup>	175·10 <sup>-3</sup>
4	55,0·10 <sup>-3</sup>	125·10 <sup>-3</sup>	175·10 <sup>-3</sup>	225·10 <sup>-3</sup>

**Table 3. Time variation of the corrosion potential of steel St.20 in solution 3 (temperature  $20^\circ \text{C}$ , without stirring, natural aeration)**

Time, day / potential, mV											
0	0,04	0,25	1	3	8	10	14	16	20	25	30
-	-	-	-	-	-	-	-	-	-	-	-
0,26	0,37	0,39	0,39	0,40	0,41	0,41	0,42	0,42	0,43	0,44	0,45
5	6	3	7	1	2	8	4	7	0	5	8

Thus, the concentrations of chemicals that affect the corrosive properties of water found in natural waters or added to water during its treatment should not exceed the standards in accordance with GOST 2877-82, which are given in table No. 4.

**Table 4. Chemical concentration**

№	Name of indicator	Normative	Test method
1	PH value	6,0-9,0	It is measured with a pH meter of any model with a glass electrode with a measurement error not exceeding 0.1 pH
2	Iron (Fe), mg / $\text{dm}^3$ , no more	0,3	According to GOST 4011
3	Total hardness, mol / $\text{m}^3$ , no more	7,0	According to GOST 4151

4	Manganese (Mn), mg / dm <sup>3</sup> no more	0,1	According to GOST 4974
5	Copper (Cu <sup>2+</sup> ), mg / dm <sup>3</sup> , no more	1,0	According to GOST 4388
6	Residual polyphosphates (PO <sub>4</sub> <sup>3-</sup> ), mg / dm <sup>3</sup> , no more	3,5	According to GOST 18309
7	Sulfates (SO <sub>4</sub> <sup>2-</sup> ), mg / dm <sup>3</sup> , no more	500	According to GOST 4389
8	Dry residue, mg / dm <sup>3</sup> , no more	1000	According to GOST 18164
9	Chlorides (Cl <sup>-</sup> ), mg / dm <sup>3</sup> , no more	350	According to GOST 4245
10	Zinc (Zn <sup>2+</sup> ), mg / dm <sup>3</sup> , no more	5,0	According to GOST 18293

The most acute problem of protecting materials from corrosion and scale formation is in such material-intensive industries as transport, engineering and construction. In a number of cases, this led to the nature of the presentation of the material in the article, relying on relevant examples, and also draws attention to the specifics of corrosion and corrosion protection of materials used in these industries, while separately discussing the inhibition of scaling processes on the surface of heat exchange equipment. In this regard, the main attention is paid to those concepts and patterns that make up the "core of chemical knowledge", necessary to understand the essence of the processes that occur during the destruction of materials during corrosion and scaling. When we meet the word "corrosion" in scientific and technical literature, we habitually associate it with metal. The reason is obvious: for many centuries, it has been metal that has been the main engineering material. And until now, the scientific discipline "Material Science" is actually metal science. Most textbooks and teaching aids related to this subject pay little attention to non-metallic materials. However, at present, one of the main trends in the development of technology is the replacement of metal in many critical parts and machine components with chemically more resistant, lightweight, technologically advanced, and economical plastics, ceramics, and other non-metallic materials. Despite the obvious advantages of these materials, and over time they fail, they are destroyed by aggressive environmental factors [3]. Moreover, in many cases there is a complete analogy to the processes occurring during the corrosion destruction of metals. With this in mind, it is justified to study the general mechanisms of phenomena that underlie the processes of natural and technogenic destruction of various materials, and the associated change in the work of heat-exchange equipment in the direction of their work efficiency. Thus, we can assume that the nature of the course of corrosion depends on the ions present in the corrosive medium. The main effect on corrosion is exerted by anions, less commonly cations. The ions contained in the solution are divided into activators and inhibitors. If salt ions do not have an activating or inhibitory effect, then with increasing salt

concentration, the corrosion rate initially increases due to an increase in the conductivity of the solution, and then decreases due to a decrease in oxygen solubility [4-6]. The chemical composition of the water used from system LLA of the Ferghana Oil Refinery, water block No. 2 is shown in table No. 5. Corrosion and scaling inhibitors HPMS, IONX-1 were tested in comparison with the imported HEDPK scaling inhibitor (hydroxyethylidene diphosphonic acid) using the method on the ISO-1 scaling device [6], and the gravimetric method was used to determine the degree of corrosion inhibition [6-8]. The results are shown in table No. 6.

**Table 5.** The chemical composition of the water used in the water supply systems of the Ferghana Oil Refinery.

Name	pH	Hardness mg.B eq / L	Sa ++ Mg.eq / l	Mg ++ Mg.eq / l	Alkalinity Mg.eq / l	Cl mg / l	PO <sub>4</sub> mg / l
II - water block							
I- cold	7,95	12,08	7,8	4,28	3,99	38,31	1,38
II - cold	7,95	27,9	20,2	7,7	5,46	73,9	1,92
IIa system	7,88	27,9	20,2	7,7	5,46	73,9	1,92
III system	8,22	15,2	11,72	3,48	5,36	45,45	0,88
Additives	8,16	12,55	9,15	3,4	5,17	42,34	1,41

The results on the inhibition of salt deposition on collector water (water block No. 2, system 3) of the IONX-1, GPMS and OEDFK preparations carried out on the instrument "Salt sediment indicator ISO-1" are summarized in table 6.

**Table 6.** Comparative effectiveness of inhibition of scaling by the reagents "GPMS", "IONX-1" and "OEDFK" on an ISO-1 device and the effectiveness of corrosion inhibition.

Inhibitor	Inhibitor concentration, mg / l	Volume of the titer of Trilon-B solution (0.025 n), ml	The amount of deposits on the electrode, (RSaCO <sub>3</sub> ), mg	Scale Inhibition Efficiency, (Eiso), %	Corrosion rate V <sub>k</sub> , g / m <sup>2</sup> h	Degree of protection, (Z) from corrosion, %
No inhibitor	-	8,5	10,625	0	0,0000205475	0
GPMS	20	0,8	1	90	-	-
	40	0,75	0,9375	91,17	-	-
	50	0,7	0,875	91,76	0,0000064287	68,71
IONX-1	20	1,05	1,3125	87,64	-	-
	40	0,95	1,1875	88,82	-	-

	50	0,9	1,125	89,41	0,000008 3722	59,25
OEDF K	20	0,6	0,75	92,94	-	-
	40	0,6	0,75	92,94	-	-
	50	0,5	0,625	94,11	0,000024 5186	0

#### 4 CONCLUSION

As the obtained results of the studies in table No. 6 show, scaling inhibitors — IONX-1 and GPMSH are effective, and when they are contained in collector water (water block No. 2, system 3) of the Ferghana oil refinery within 40–50 mg / l. the inhibition efficiency reaches 85% and 94%, respectively, and they can be competitive with an imported sedimentation inhibitor OEDPK, which, when kept at the same concentration of 40-50 mg / l, the inhibition efficiency reaches 95%. We examined the issues of the effect of water composition on corrosion when using cooling water in heat exchange equipment. The analysis of the surface protection of heat exchange equipment using corrosion inhibitors and scaling is carried out. Production tests of pilot batches of corrosion and scale inhibitors in the laboratory conditions of the Ferghana Oil Refinery were carried out. According to the results obtained, scale inhibitors - IONX-1 and GPMSH are effective, and when they are contained in collector water (water block No. 2, system 3) of the Ferghana Oil Refinery within 40-50 mg / l, the inhibition efficiency reaches 85% and 94%, respectively and they can be competitive with an imported inhibitor of sedimentation of OEDPK, in which when the content in the same concentration of 40-50 mg / l, the inhibition efficiency reaches 94%. Conclusion: According to the results obtained, the most effective inhibitor of corrosion and scaling is the GMSP whose value for inhibiting scaling is 91.76%, and for the effectiveness of corrosion protection is 68.71% and which can be recommended for implementation with the solution of the issue of import substitution. Implementation, which will increase the efficiency of the heat exchange equipment, after preliminary cleaning. Deserves consideration of the issue of introducing the corrosion and scaling inhibitor IONX-1, provided that the technical and economic indicators regarding the corrosion inhibitor and scaling are improved.

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