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STUDY OF THE EFFECT OF A NEW COMBINED INHIBITOR AND A PERMANENT MAGNETIC FIELD ON CORROSION AND SALT DEPOSITION

Abstract. This academic article encompasses the investigation results concerning, the composite acquired from the mixture of hydrated technical phosphatide, cubic thickness of polypropylene glycol, and sodium hexametaphosphate. According to the outcomes of laboratory researches, it was determined that the developed new composite provides not only prevention of equipment from corrosion, but also protection of those from salt deposition. Furthermore, as a result of the joint effect of a stable magnetic field of 280 kA/m, high protective efficiency was determined. Thus, the optimum consumption was found to be 150 mg/l. In this case, the protection effectiveness against corrosion and salt deposition accounted for 93% and 85% accordingly.

Commercial tests of the combined action of the reagent and the permanent magnetic field were carried out on the cooling system of compressors "Bibiheybatneft" OGED (Oil and Gas Extraction Department). In the field with the combined use of a magnetic field and inhibitors the protective effect is 90%, and the protective effect of salt deposition is 73%.

Keywords: oilfield equipment, salt deposition, inhibitor, aggression, composite, corrosion.

Introduction

At the oil and gas refineries and petrochemical plants, when water is heated due to the super saturation of water with salts, primarily calcium carbonate, on the heat exchange surfaces of the heat supply and hot water supply systems, circulating cooling systems, distillation desalination plants and evaporators, low-pressure steam boilers. Operation of the listed equipment is also hampered by the formation of iron oxide deposits with high corrosive water aggressiveness. Similar problems arise in oilfield equipment in oil production. Therefore, the development of a multifunctional reagent that effectively inhibits corrosion and salt deposition is an urgent task.

Corrosion and salt sedimentation processes occurring in oil extraction create difficulties in exploitation of wells and consequently this causes an increase in the cost of the extracted oil.

Salt deposits form on the exploitation line, pump-compressor tubes, valves, and pumps, as well as oil preparation equipment and therefore entirely cover the internal surface of the facilities, restrict flow of stream or bring to whole limitation in movement of steam [1, 2]. Furthermore, salt sediments inevitably contribute to corrosion and its enhancement [3, 4].

The feasible causes for salt sedimentations can become chemical incompatibility of the waters flowing into wells from various horizons (mixture of alkaline and hard waters), and excessive saturation of water-salt system throughout the period of change in hydraulic pressure and thermodynamic conditions. From this reason, the improvement of exploitation efficiency of wells operating in circumstance in which corrosion and salt deposition take place is one of the pressing issues [5,6].

Firstly, inhibitors against salt sedimentation are applied in preservation of submersible pumps operating in wells because precipitation of salts inside working pieces of facilities will have a profoundly negative impact on the operation of the equipment, the facilities will be out of order prematurely, and thereby the work of the equipment will extremely aggravate. Unambiguously, salt deposition decreases operation time of pumps by virtually three-five times [6]. Recently, an inhibitor against salt deposition are applied in oil reserves for protection of oilfield equipment from mineral salts mainly comprising calcium and magnesium carbonates [7]. A fundamental study of scale formation of calcium carbonate ($CaCO_3$) for producing oil wells has been carried out [8, 9].

It is imperative to select an effective inhibitor in accordance with the operating parameters of the wells and the chemical composition of layer water once choosing technology for prevention from corrosion and salt precipitation [10-12]. From this reason, production of effective inhibitors prepared from multicomponent mixtures for prevention against corrosion and salt deposition becomes necessary. To obtain synergetic effective composite, combination of inhibitors is investigated on the basis of certain principles and optimal analyses.

Even though each of these inhibitors made from several components have a certain power of influence, combination of those results in formation of synergetic effect and make an opportunity to deteriorate different influences simultaneously and have complex effects.

Results of laboratory researches

As a result of laboratory researches, new complex effective composite was prepared from the mixture of hydratedtechnical phosphatide (TP), sodium hexametaphosphateand $(NaPO_3)_6$,cubic thickness of polypropylene glycol (PPG).

In order to investigate protection effectiveness from corrosion of new complex effective composition, according to laboratory tests was conducted on U-shaped device with using aggressive layer water within the period of six hours and at temperature of 25C^0.

The corrosion rate is computed by the expression given below:

$$CR = \frac{m - m_1}{St} \tag{1}$$

where, CR – corrosion rate, g/m^2·hour; m – mass of the test specimen before the test, g; m_1 – mass of the test specimen after the test, g; S – the surface area of the witness specimen, m^2; t – test time, hours.

The effectiveness of the protective action of the inhibitor was characterized by the degree of protection IE, %.

$$IE = \frac{CR - CR_1}{CR} 100\% \tag{2}$$

where, CR and CR_1 –corrosion rates of the sample without inhibitor and with inhibitor.

Research methodology of composites against salt sedimentation principally consists of examination of precipitation of carbonate salts in laboratory conditions. On the other hand, protection effectiveness of composite against salt deposition is dependent upon amount of consumption in aggressive environment.

In order to determine intensity of salt deposition investigations were performed in underground water environment during the period of six hours and at the temperature of 65C^0. Consumption rate of the composite was in the range of 50 and 250 mg/l.

Intensity of salt deposition is determined by precipitation of calcium ion. Concentration of calcium ion is detected by means of titration method. As an aggressive environment, underground water containing abundant minerals was utilized.

The effectiveness of the reagent is defined by reduction in an amount of calcium carbonate present in the reagent solution for precluding precipitation of calcium carbonate into solid surface.

Reagent effectiveness is expressed with the assistance of the formula given in the following.

$$E_r = \frac{DR_0 - DR_1}{DR_0} \cdot 100\%$$

E_r – effectiveness of reagent in, %; DR_o – speed of salt deposition in water, mg/cm^2·hour; DR_1 – speed of salt deposition in the water containing reagent, mg/cm^2·hour.

The research results are shown in figure 1.

As it can be seen from figure1, results of laboratory researches have determined that optimal consumption of the composite in the environment is 200 mg/l. In this case, protection effectiveness values against corrosion and salt deposition are 94% and 87% respectively (0.73-0.044 g/m^2·hour and 0.0127-0.0016 mg/sm^2·hour).

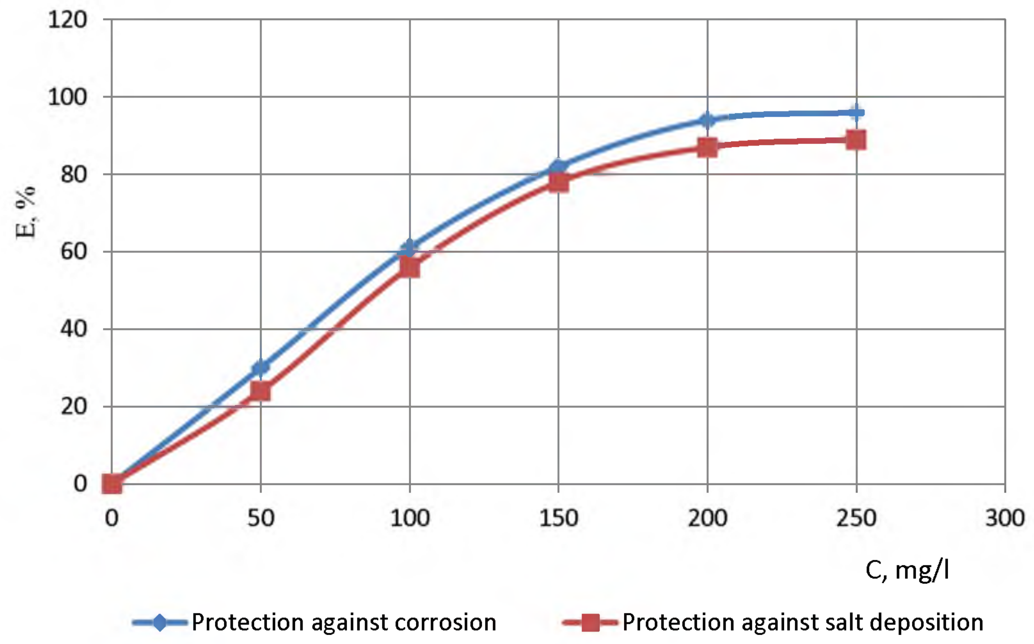

Figure 1 – Intensity of salt deposition and corrosion rate in underground water

To study the mechanism of the protective action of the reagent, a potentiostatic method of obtaining polarization curves of 1020 steel was also used. The research results are shown in figure 2.

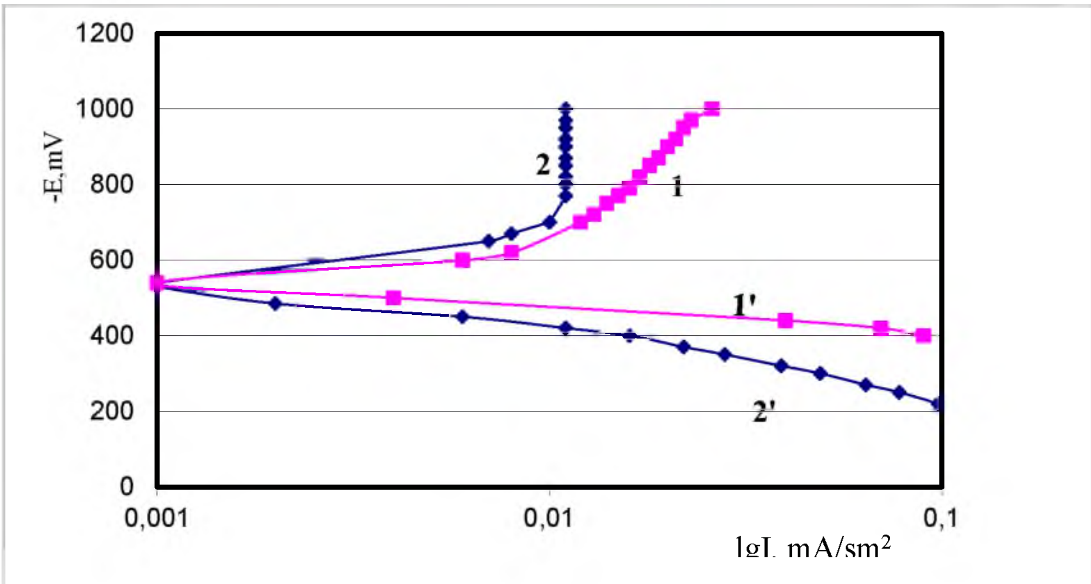

Figure 2 – Cathode (1-2) and anodic (1^1-2^1) potentiostatic polarization curves
1,1^1- cathode and anode curves without reagent
2, 2^1 - cathode and anode curves with a reagent (200 mg/l)

As can be seen from figure 2, a mixed-type reagent is capable of equally effectively inhibiting both electrochemical reactions on an electrode at a concentration of 200 mg/l, which is consistent with gravimetric tests.

In recent years, the use of physical fields encompassing fixed and variable magnetic fields has been widely used in various industrial sectors. Magnetic, like any other effect, has negative and positive sides [13-20].

Therefore, in order to examine the joint influence of the different voltage stable magnetic inductors and the developed new composite, the investigations were performed in laboratory circumstances.

To inspect the effectiveness of stable magnetic field in preservation from salt deposition and corrosion, the laboratory experiments were performed in magnetized and non-magnetized ground water throughout the period of six hours. 30x50x3 mm samples prepared from 1020 brand steel and 40, 120, 200, 280, 360, and 400 kA/m voltage stable magnetic inductors were utilized in the tests. A laboratory setup for studying the effect of a constant magnetic field on the corrosion rate in formation waters is shown in Figure 3.

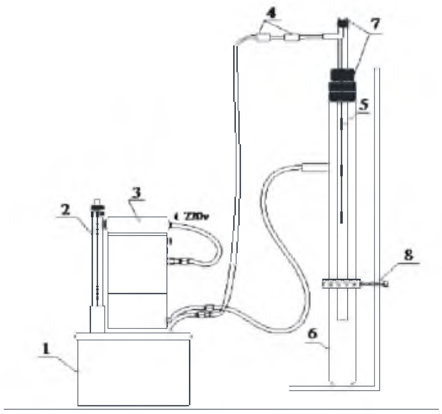

Figure 3 - Laboratory installation for studying the effect of magnetic fields on the corrosion rate in formation waters
1-thermostat u1, MLW, 2-contoct thermometer, MLW PGW, 3- Medingen/silz freital,4- magnetic inductors,5-tests coupon (samples),6- well model,7- laboratory cork, 8-laboratory tripod

The effect of stable magnetic field can vary depending upon the static regime of the exploited environment, the duration of the effect of magnetic field on the environment, the intensity of the field. Considering these, to determine the optimum effect conditions of magnetic field, the velocity of the water used in the investigations and the outcomes of the water magnetized by different voltage magnetic fields are demonstrated in figure 4 and 5.

As depicted in figure 4 and 5, in the magnetized underground water flowing at the velocity of 0.5 m/sec during the period of six hours corrosion rate and intensity of salt deposition of 1020 brand steel were 0.73 $g/m^2 \cdot hour$ and 0.0127 $mg/sm^2 \cdot hour$ accordingly. Once the environment was affected by stable magnetic field having different voltage, it was revealed that there was reduction in corrosion and salt deposition to certain extent. The maximum effect against corrosion and salt deposition was acquired in 280 kA/m voltage stable magnetic field. Therefore, when the undeground water flowed at the speed of 0.5 m/sec through 280 kA/m voltage stable magnetic field, corrosion rate and protection effectiveness against corrosion decreased up to 0.59 $g/m^2 \cdot hour$ and 19% respectively. In the meantime, intensity of salt deposition and protection effectiveness against salt deposition comprised 0.0097 $mg/sm^2 \cdot hour$ and 24% accordingly.

The influence of the magnetic field on the concentration of cations of magnesium, calcium, and iron was studied in well formation water № 117 deposits of Gunashli. The results of the study are shown in figure 6.

As can be seen from the figure, after 200-300 hours of exposure to formation water with a magnetic field of 280 kA/m, the concentration of Ca^{2+} and Mg^{2+} ions decreases, a particularly active decrease is observed in Ca^{2+}. Subsequently, with increasing time of exposure to a magnetic field, the concentration of these ions does not change. In contrast to calcium and magnesium ions, the concentration of iron ions in the first 120 hours of exposure to a magnetic field increases as a result of corrosion processes. In the range of 120-200 hours, the amount of dissolved iron stabilizes, and after 200 hours of exposure is reduced. A decrease in the concentration of iron ions in the formation water is a sign that under the influence of a constant magnetic field, the corrosion of the metal is inhibited. This assumption is confirmed by measurements of the corrosion rate made by the gravimetric method in laboratory conditions.

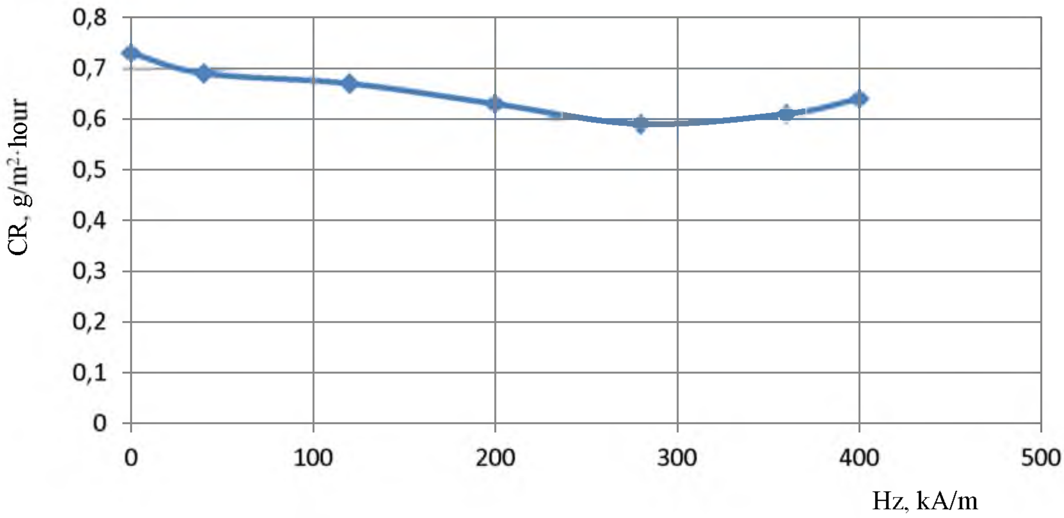

Figure 4 – Effect of stable magnetic field on corrosion rate of layer water

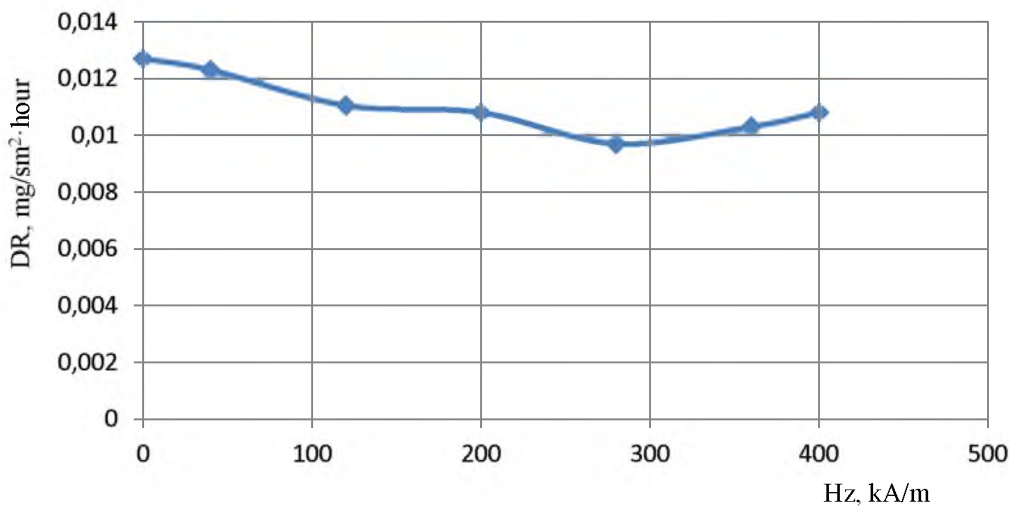

Figure 5 – Effect of stable magnetic field on intensity of salt depostion of underground water

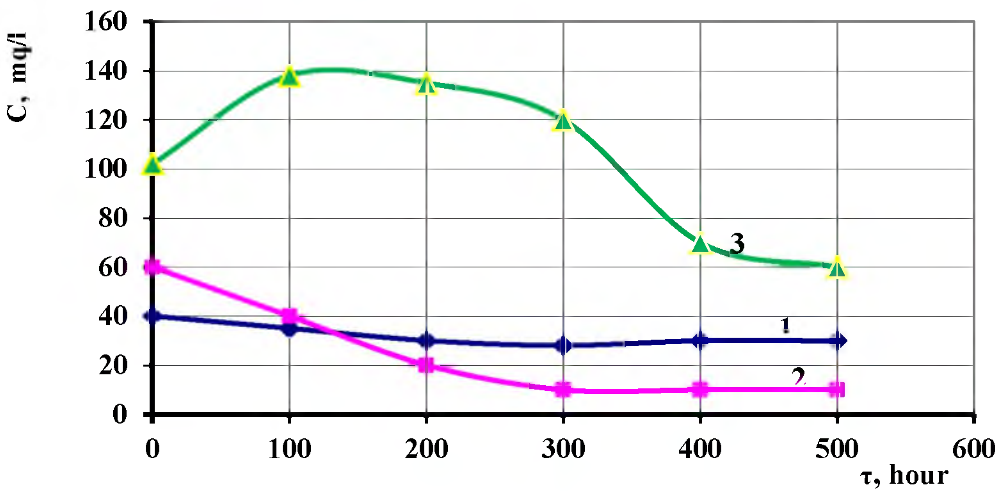

Figure 6 – Dependence of the concentration of cations of magnesium, calcium and iron in produced water of wells №117 of the Guneshli fields from the time of exposure to a magnetic field of 280 kA / m (1 - Mg^{2+}, 2 - Ca^{2+}, 3 - $Fe^{2+} + Fe^{3+}$)

A constant magnetic field affects not only the chemical composition of the produced water, but also the number of microorganisms contained in the well's production. In laboratory conditions, the effect of a constant magnetic field of 280 kA / m on the number of SRB was studied. After 200 hours of exposure to a magnetic field, the amount of SRB decreased from 10^7bacteria/ml to 10^3bacteria/ml , indicating a biostatic effect. Thus, laboratory studies have shown that when a magnetic field of 280 kA/m is exposed to formation water, its corrosiveness decreases.

Inside aggressive environment, for researching the joint influence of 280 kA/m voltage fixed magnetic field with the prepared new composite the conducted investigation results are represented in figure 7.

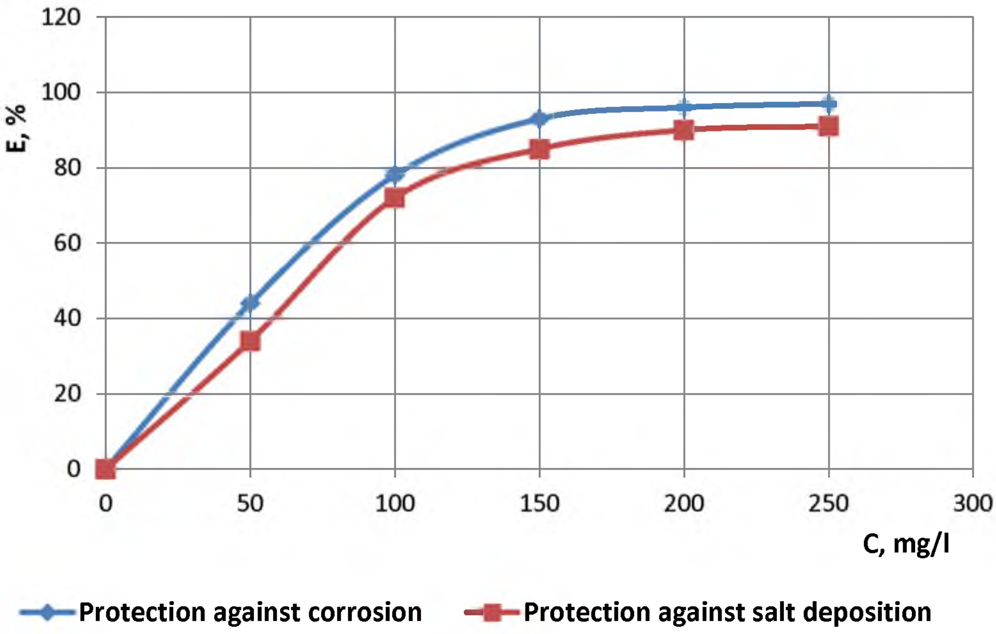

Figure 7 – Joint effect of fixed magnetic field with prepared composite on intensity of salt deposition and corrosion rate in layer water

It can apparently seem from figure 7 that the existence of protective effect is noticed as a consequence of the joint effect of 280 kA/m voltage fixed magnetic field with the prepared reagent. Thereby, it is concluded from the obtained outcomes during carrying out the laboratory experiments the optimum consumption of the composite with the fixed magnetic field is equal to 150 mg/l. In this condition, protection effectiveness against salt deposition and corrosion constitute 85% and 93% respectively. As seen from the comparative analysis of the results obtained that co-application of composition with fixed magnetic field is efficient with respect to economy. In this case, 25% of the reagent is saved.

Conducted researches have shown that the new composite can be utilized in oil wells, petrochemical plants, internal transportation systems of mines and also against corrosion and salt deposition in preservation system of layer pressure.

Production tests

Commercial tests of the combined action of the reagent and the permanent magnetic field were carried out on the cooling system of compressors"Bibiheybatneft" OGED (Oil and Gas Extraction Department).

To determine the corrosion rate by gravimetric method and assess the braking effect of the inhibitor, control specimens were installed for 30 days before and after injection of the reagent. The samples were made from steel grade 1020.

Fishing tests showed that with the use of the reagent, the corrosion rate decreased on average from 0.0815 $g/m^2 \cdot$hour to 0.0082 $g/m^2 \cdot$hour, with a protective effect of 90%. Tests have shown that treating water with a permanent magnetic field inhibitor significantly (up to 10 times) reduces the rate of corrosion.

The rate of scale deposition decreased on average from 0.0097 to 0.0026 mg/sm$^{2}\cdot$hour and the protective effect of scaling was 73%.

Using the composite has not only expanded lifetime of pipelines and equipment and time needed for corrosion and salt deposition to be occurred, but also provided ecological safety in by decreasing the number of accidents.

Conclusions

1. A new composite has been generated from the mixture of technical phosphatide, cubic thickness of polypropylene glycol, and sodium hexametaphosphates a result of laboratory researches.
2. Optimal consumption of the composite has been determined as 200 mg/l in an aggressive environment. In this case, protection effectiveness values against corrosion and salt deposition are accounted for 94% and 87%, respectively.
3. Has been determined by means of the joint protective effect of 280 kA/m voltage fixed magnetic field with the prepared new composite. Hence, the optimal consumption has been diminished by 200 mg/l, constituting 150 mg/l. In this case, protection effectiveness against corrosion and salt deposition has been accounted for 93% and 85% accordingly.
4. The results obtained showed that the combined use of the composition with a fixed magnetic field is effective from the point of view of economy. In this case, the reagent consumption is reduced by 25%.
5. In the field with the combined use of a magnetic field and inhibitors the protective effect is 90%, and the protective effect of salt deposition is 73%.

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