# Laboratory research on the effectiveness of the corrosion inhibitors application for the conditions of west Siberian oilfields

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**Abstract.** This article presents an assessment of the effectiveness of corrosion inhibitors. The work is aimed at studying the protective properties of inhibitors on the oil fields of Western Siberia complicated with carbonate corrosion. The method and the results of experimental studies are given to obtain a single line of the comparative effectiveness of corrosion inhibitors (ELEIS) for the tested deposit.

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**Keywords:** corrosion inhibitors, corrosion processes rate, efficiency, water mineralization, polarization impedance, current density

## Introduction

Oil and gas industry of the Russian Federation is currently represented by long term deposits at the final stage of exploitation. One of the complicating factors in exploitation of such deposits is corrosion of the oil and gas equipment [1]. According to statistics corrosion in 22 % of cases is the reason for field equipment breakdown. Therefore, the need for finding solutions on prevention and control of corrosion in order to protect the oil and gas equipment is increasing.

Corrosion is the process that leads to material damage due to the contact with the corrosive environment. The corrosion process is facilitated by influence of several factors – increased water cutting of well production, increased carryover of salts and mechanical impurities, increased rate of reservoir fluid flow, currents and voltage increase in cable connections and electrical submersible motors [2, 3]. General and local corrosion is typical for oil and gas industry. In case of general corrosion the entire material surface is damaged with different depth of penetration. Local corrosion is most common. It is accompanied with high rate of metal dissolution in some areas. Basic types of local (isolated) corrosion of the downhole equipment include [4]:

2. pitting (localized) corrosion;
3. spot corrosion;
4. trenching (grooving) corrosion;
5. corrosion in the form of a plateau;
6. mesa corrosion;
7. contact corrosion;
8. underfilm corrosion;
9. galvanic corrosion.

Each type is characterized by its own area of localization, damage geometry, causes of occurrence and spread rate. The most common corrosion protection methods for the downhole equipment such as chemical, physical and process give a certain positive result (Figure 1).

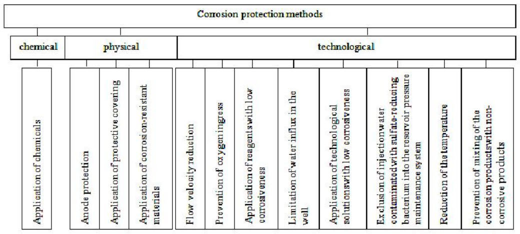

**Figure 1. Types of downhole equipment corrosion protection [4]**

Their efficiency in various geological conditions differs and each method has some restrictions and disadvantages. Today the most common protection method is a chemical method using corrosion inhibitors. When using a chemical protection method its high economic efficiency, safety and ease of implementation are important.

The mechanism of corrosion inhibitors is based on adsorptive processes. Inhibitors adsorbed onto the metal surface in the form of a film inhibit oxidation and iron dissolution [5]. The main task of inhibitors is efficient protection. Therefore, the need for active researches to detect the most efficient inhibitors for deposits under study is increasing. The chemical protection method is chosen based on the analysis of corrosion processes. Depending on corrosion localization the reagent can be transferred directly into the hole or injected into the reservoir.

This article contains research results based on which the comparative efficiency line of tested corrosion inhibitors has been developed for further proved choice of basic and alternative reagents to prevent accelerated corrosion in deposit holes of Western Siberia.

Corrosion inhibitor efficiency was tested in laboratory conditions. As a result, their basic physical and chemical properties have been determined and protection capability of reagents with various dosing rates has been assessed. For objective assessment all the inhibitors being tested were pre-encrypted.

At the first stage conformity of all physical and chemical properties of corrosion inhibitors with specified requirements was assessed. Determination of these properties is important in detecting possible use of reagents in Western Siberia. The algorithm of this stage consists in determining such parameters as viscosity, density, compatibility and solubility, freezing point, volume of solids, amine number of unrelated amines and others. Certain reagents compatible with oil and water deposit models have been determined; thus, we can conclude that it is possible to use them at this facility and it is reasonable to conduct further researches.

The density of the reagent sample is determined according to GOST 18995.1-73 [6] using an areometer. It was measures at a temperature of 20 ˚C. Besides, density was measured using a Mettler Toledo DE 45 densimeter. The principle of mass density measurement in the unit is based on determining the period of vibrations of a glass U-tube (vibrations are generated by an electromagnetic vibrator). Density is an important parameter of an inhibitor used for quantitative calculations both in acquisition and preparation of work solutions [7].

According to GOST 3300-2000 “Oil Products. Transparent and Nontransparent Liquids. Determining of Kinematic Viscosity and Calculation of Dynamic Viscosity” [8, 9] kinematic viscosity of corrosion inhibitors has been determined. The research was conducted at a temperature of 20 °C using a VPZh-2 viscometer. The required temperature was set using a low temperature thermostat LT 900. It is necessary to note that viscosity characterizes the capability of this liquid to resist when moving one part of liquid relative to the other one. Thus, corrosion inhibitors should be rather flexible liquids when using them in the working environment to provide effective access to the protecting surface [6].

The freezing point of samples was determined according to the requirements of GOST 20287-91 “Oil Products: Methods of Determining Fluidity and Freezing Point of Aviation Fuels” [10]. LAUDA PROLINE RP 890 cooling thermostat was used by means of which tested inhibitor samples were cooled to the temperature of minus 50°C. The freezing point is the parameter of great practical importance especially in areas with low ambient temperature which directly influence energy costs when preparing work solutions and convenience of inhibitor injection into protected production facilities [5].

Reagent capability to make a transparent solution or dispersion is assessed based on visual inspection. If after mixing the content in the test tube is still transparent the reagent is considered to be water soluble. If there is slight turbidity in transmitted light it indicates to formation of microemulsion, in this case the reagent is considered to be self-dispersed**.** For effective equipment protection the inhibitor should be uniformly spread on the entire surface. The basic supplying agent in continuous facility inhibiting is the medium (extracted product). It is necessary to note that the inhibitor should be solvable or well dispersible in the medium of the field under investigation [6].

Table 1 shows the results of the physical and chemical study of one tested inhibitor based on organic nitrogen compound.

**Table 1. Results of the physical and chemical study of one tested inhibitor**

| Reagent parameter/name | Corrosion inhibitor |
|---|---|
| Appearance | Homogeneous transparent brown liquid |
| Density, g/cm³ | 0.8662 |
| Hydrogen ion concentration in a commodity form | 6.96 |
| Kinematic viscosity, mm2/s | 3.17 |
| Freezing point at - 50 °C | unfreezed |
| Stcapability of reagents at a temperature of 90°C | stable |
| Solubility in a water sample | soluble |
| Solubility in an oil sample | soluble |
| Measured values of the volume of solids, % | 29.03 |
| Amine number of unrelated amines, mg HCl/g | 34.64 |

Based on the results of this stage the reagents that do not meet these requirements are rejected. When determining the freezing point samples 5, 13, 15 were excluded from further study. Corrosion inhibitor #5 froze at a temperature minus 38; #13 showed low stability at subzero temperatures, at a temperature of minus 15 °C the sample flaked off; #15 was completely frozen at a temperature of minus 26°. Besides, based on the results of study of the method of thermal stability determination sample #10 flaked off which also does not correspond to specified requirements.

The second stage of work involved assessment of reagent capability to speed down carbon dioxide corrosion. Carbon dioxide synthetic brines were used as corrosive environment (Table.2).

**Table 2. Simulated conditions of experimental researches**

| | Components | Value, mg/dm$^3$ |
|---|---|---|
| 1. Water salt composition | NaCl | 136.0 |
| | or ($CaCl_2 \cdot 6H_2O$) | 4,682 |
| | or ($MgCl_2 \cdot 6H_2O$) | 5,2 |
| | $NaHCO_3$ | 1.124 |
| 2. Oil sample composition | kerosene, *n*-octane, *ortho*-xylene | in proportion (1:1:1) |

Protective properties of a corrosion inhibitor are assessed using a polarization resistance method. The scheme of this laboratory setup is shown in Figure 2.

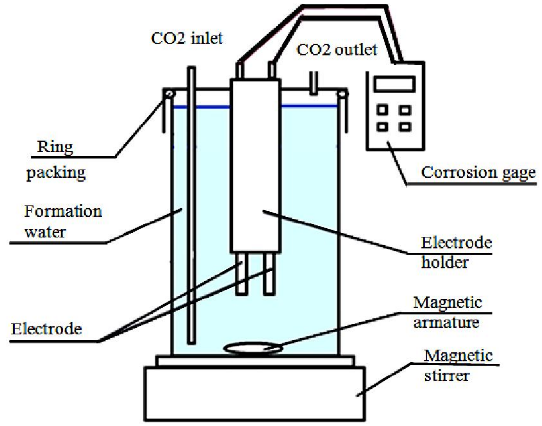

**Figure 2. Scheme of electrochemical setup**

The system includes electrochemical corrosion cells, 3-electrode probe with electrodes of a cylindrical form made of tube steel (steel 20), magnetic stirrer with temperature control, stirring bar, compressed $CO_2$ cylinders, $CO_2$ flow regulators. Corrosion rate is measured using a potentiostat. To identify the best reagents they have been ranked according to total points (Table 3). Each reagent dosage depending on the protective action level (Z, %) has the following points:

- Z more than 90 % - 5 points;
- Z from 80 to 90 % - 4 points;
- Z from 70 to 80 % - 3 points;
- Z from 60 to 70 % - 2 points;
- Z from 30 to 60 % - 1 point;
- Z less than 30 % - 0 points.

**Table 3. Corrosion inhibitors ranking**

| Reagent encryption | Number of points at inhibitor dosage, mg/l | | | Total points (rating) |
|---|---|---|---|---|
| | 25 | 15 | 5 | |
| 1 | 5 | 4 | 1 | 10 |
| 2 | 5 | 5 | 4 | 14 |
| 3 | 5 | 5 | 4 | 14 |
| 4 | 5 | 4 | 1 | 10 |
| 6 | 5 | 1 | 0 | 6 |
| 7 | 5 | 5 | 3 | 13 |
| 8 | 0 | 0 | 0 | 0 |
| 9 | 1 | 0 | 0 | 1 |
| 11 | 1 | 0 | 0 | 1 |
| 12 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 |
| 16 | 5 | 5 | 4 | 14 |
| 17 | 5 | 2 | 2 | 9 |
| 18 | 3 | 2 | 1 | 6 |
| 19 | 4 | 0 | 0 | 4 |
| 20 | 2 | 1 | 0 | 3 |

Diagrams (Figure 3) were obtained in the course of the experiment by means of which protective effect of reagents (*Z*, %) has been calculated by formula:

$$Z = \frac{Пк - Пи}{Пк} \times 100,\% \qquad (1)$$

where: *Z* – corrosion inhibitor protection level, %;

*Пк* – control corrosion rate, mm/year;

*Пи* – corrosion rate after corrosion inhibitor dozing, mm/year.

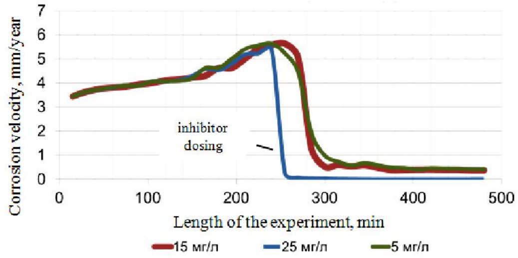

**Figure 3. Dynamics of the corrosion velocity rate**

According to the developed method 20 different corrosion inhibitor samples have been tested. As a result of testing the single line of the comparative effectiveness of corrosion inhibitors (ELEIS) for tested conditions of fields in Western Siberia has been developed and obtained.

Summarizing the research results we can conclude that it is necessary to further study the influence of inhibitors on the intensity of the corrosion process for the oil and gas equipment.

Research of dependencies of inhibitor action efficiency on water mineralization, flow and circulation fluid is of considerable interest for further recommendation for use of this method in the fields complicated by corrosion processes.

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