Corrosion of tubing of oil fields

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Abstract. Tubing are intended for a wide range of works from pumping out of oil and gas from a well cavity before production of various repair work. With their help on oil fields carry out raising of oil from a productive zone of layer to well head and also force water for maintenance of reservoir pressure. The main problem at operation of these pipes are refusals because of corrosion defeat. The main types of corrosion destructions of tubing connected with presence at the obtained environment of carbon dioxide and hydrogen sulfide are given in the paper. One of the ways of protection of an internal surface of tubing is the use of corrosion inhibitors – chemical reagents which introduction in small dosages on corrosion Wednesday significantly reduces metal corrosion rate. Results of experiments on corrosion inhibitor selection for protection of the oil-field equipment of one of fields of the Russian Federation are given in the paper.

1. Introduction
The tubing are intended for extraction of liquid and gas from wells, water injection, compressed air (gas) and production of different types of works on routine maintenance and overhaul repairs of wells. Their cost can be 75 % of the cost of fixed assets of mining company. In this regard protection them from premature destruction is very relevant task.

On a way of production according to [1] distinguish pipes seamless and electrowelded straight-line-seam. Seamless pipes have to be produced groups of durability of D, K, E, L, M and R, and electrowelded — groups of durability of Ds, Ks, Es, Ls, Ms and Rs. Mechanical properties of base metal of pipes and couplings to them are given in table 1.

The first and second stages of development of oil fields which are characterized by growth and stabilization of production level and also increase in water content of oil are followed by low corrosion rates of tubing, if the liquid extracted from wells does not contain carbon dioxide and hydrogen sulfide in that case. use as working reagent of compressed air at compressor operation of oil wells leads to growth of speed of corrosion destructions of tubing, as oxygen of air is the main depolarizator in the presence of which corrosion processes are possible [2-6].

The durability of work of tubing considerably decreases on fields which products contain carbon dioxide. Especially intensively these processes of carbon dioxide corrosion proceed in wells of gas-condensate fields. Increase in danger of corrosion defeats is connected with the emergence moment in a condensate pipe (dew point). In this case carbon dioxide is dissolved in condensation water with formation of coal acid. Carbonic acid lowers pH environment, strengthening corrosion destruction of carbon steel (figure 1) as products of corrosion form a friable film through which electrolyte easily
gets to metal. According to trade and laboratory data the maximum speed of carbon dioxide corrosion is observed in the range of temperatures 60 … 90 °C.

Table 1. Mechanical properties of base metal of pipes and couplings to them at a temperature (20±3)°C.

| Name of an indicator | Group of pipes durability |
|----------------------|---------------------------|
|                      | Ds            | D            | Ks          | K            | E, Eₜ    | L, Lₜ    | M, Mₜ    | R, Rₜ    |
| Temporary resistance | σₚ, MPa (kgf/mm²), not less | 517          | 655         | 595         | 687       | 689       | 758       | 823       | 1000     |
| Fluidity limit       | σₜ, MPa (kgf/mm²): not less | 379 (38.7)   | 491 (50.0)  | 552         | 654       | 724       | 930       |
|                      | no more       | 552 (56.2)   | 600         | 600         | 758       | 862       | 921       | 1137      |
| Relative lengthening | δ, %, not less | 18           | 14.3        | 15.0        | 14.0      | 13.0      | 12.3      | 11.3      | 9.5      |
| Hardness number      | according to  | don't define  | 235         | 255         | 277       | 320       |
| Vikkers HV, no more  |                          |              |              |              |           |           |           |           |

Figure 1. Corrosion of steel 1020 in solution of organic acids and CO₂ in a water phase at temperatures, °C: 1 – 100; 2 – 70; in a steam phase at temperatures, °C: 3 – 100, 4 – 90.

Pipes on gas-condensate fields which products contain about 3% of carbon dioxide are exposed to considerable destruction. Depth of ulcers on an internal surface of pipes in the fittings can be 3.5 mm through 1 … 1.5 years of operation.

Destructions of tubing are usually localized on quite certain sites: or in fittings or in a zone of transition of the landed part of a body of a pipe to cylindrical. Destruction occurs, as a rule, in places of a sharp change in the direction and nature of the gas-liquid flow, in places of structural changes in the metal and stress concentrations caused by the process of pipe disembarkation. Corrosion and an erosion of other surface of pipes usually does not exceed 0.1 - 0.2 mm/year that does not constitute serious danger [7-12].

Secondary methods of production which use for increase in oil recovery of the exhausted layers at the third and fourth stages of development of oil fields have significant effect on corrosion activity of the extracted water oil mixture.
Corrosion defeats of tubing gain dangerous character at contents in products of wells of hydrogen sulfide. On oil fields the internal surface of tubing is in contact with a water oil emulsion in the presence of hydrogen sulfide, and an outer surface and an internal surface of an upsetting column – with the oil gas containing moisture and hydrogen sulfide. The wells of hydrogen sulfide-containing gas condensate fields are characterized by the contact of wet hydrogen sulfide gas with the inner and outer surface of the tubing, as well as with the inner surface of the casing pipes. In both cases defeat of metal happens on the mechanism of the general corrosion and sulphide cracking.

The character and speed of the specified defeats of tubing depend, first of all, on concentration of hydrogen sulfide in the taken product and sizes of the external stretching loading.

Design, in which the voltage is small, susceptible to general corrosion is much stronger than the sulfide stress cracking and high tensile loads they lose their efficiency as the result of sulfide cracking, the danger of which for the carbon steel occurs even when the content is 0.05 kg/m$^3$ of hydrogen sulfide in the environment.

The pressure exerts a great influence on the nature of the corrosive effect of hydrogen sulfide-containing gas environment. Destruction of tubing from the outer side often several times exceeds destruction on an internal surface. This phenomenon is explained by condensation an outer surface of tubing of water and light hydrocarbons which are sated from gas H$_2$S and CO$_2$ environment. As a result on the surface of carbon steel the friable film of sulfide of iron is formed. Iron in contact with sulfide forms galvanic couple in which metal works with the anode and is quickly dissolved. The layer of products of corrosion periodically collapses, but on its place new appears. As a result on tubing walls mainly about connecting couplings where iron sulfide collects more intensively, through 4 … 5 years appear through openings. On an internal surface of tubing these processes do not happen as iron sulfides are taken out by a stream of the environment in the collecting system [13-16].

The tendency of steels to sulfide cracking increases with grain size. Steels whose structure consists of fine-grained spherical carbides evenly distributed in ferrite are less prone to cracking than steels containing coarse globular carbides or carbide lamellae. In this regard, normalization, which is mainly carried out in the manufacture of tubing, is not optimal heat treatment. The most effective way of ensuring reliability of tubing is their production from stainless steels [17, 18]. Besides high corrosion and erosive resistance in this case receiving pipes with higher strength properties is possible. One of perspective the directions of increase in durability of tubing in wells which products contain carbon dioxide and hydrogen sulfide is application as structural material of aluminum alloys.

One of widespread ways of protection of tubing is use of inhibitors of corrosion [19, 20]. The defining indicator of each inhibitor of corrosion is its protective action.

Inhibitors with protective action more than 90 % are applied to oil and gas production. Degree of protection is in actual practice reached by selection of dosages of inhibitor. The expediency of application of inhibitory protection is estimated taking into account its price and system performance.

Inhibitors should not cause local corrosion of metals and affect mechanical properties of metal products. Also important that the viscosity and temperature of hardening of inhibitor allowed to apply it in all climatic conditions.

Protective properties of inhibitors have to remain at least a year at their storage on the open areas or in not heated rooms. Besides, inhibitors should not have an adverse or toxicological effect on the person.

The following requirements are imposed to the inhibitors applied at oil production:
- must maintain high protective properties when changing the water content of products;
- should not contribute to the stability of oil-water emulsions and their foaming;
- can be oil or water soluble;
- should not contribute to the development of sulfate-reducing bacteria;
- should not disturb the balance of the aqueous phase, do not poison the catalysts degrade the quality of petroleum products;
- should not impair well acceptance.
One of conditions of successful use of inhibitors are conditions of formation of a protective film. As formation of a protective film depends on time, the shock dosage is in a short space of time applied to its formation, at the same time metal is isolated from hostile environment at once.

The most widespread ways of input of inhibitors:

- continuous input of inhibitor on Wednesday;
- periodic processing of the equipment inhibitor solution;
- pumping inhibitor in layer.

At continuous processing corrosion inhibitor constantly is pumped in a system. For reduction of time of formation of a protective film usually there is a processing to the increased concentration of inhibitor. Stability of a film is maintained further by constant dispensing of undiluted inhibitor, or its solution.

Concentration of inhibitor in the environment at the same time fluctuates within 25-100 mg/l. At such low concentration it is easy to achieve good solubility or dispersion of inhibitor in the corrosion environment.

At periodic processing the steady protective film is formed at a shock dosage in the system of large amounts of inhibitor without dilution. For full contact of inhibitor with all protected surface it is recommended to clean it with scrapers. For fast formation of a protective film it is necessary to use rather concentrated solutions of inhibitors. Processing is carried out with certain intervals for prevention of increase in corrosion rate.

Intervals between repeated processings fluctuate from weekly to several months. Concentration of inhibitors has to make not less than 0.2 %, on average 10 %.

Pumping inhibitors in layer is applied to protection of the underground equipment, using a bottomhole zone of wells as natural and it is long the functioning batcher. Usual frequency makes 3-18 months.

Flowlines of wells process the inhibited liquid arriving from a production well. For increase in degree of protection of flowlines sometimes in addition they are protected periodic or continuous processing.

### 2. Experimental

Researches of corrosion rate of water environments of various mineralization with use of inhibitor of corrosion "Akvakor 7202" were conducted. The dosage of inhibitor made 20 ppm. Researches were conducted by means of a corrosion meter "Monikor – 2M".

Solutions characteristic is given in table 2.

#### Table 2. Characteristic of model solutions.

| Solutions | Na⁺, mg/l | Ca²⁺, mg/l | Cl⁻, mg/l | CO₂, mg/l | pH | t, °C | Total salt content, mg/l |
|-----------|-----------|-----------|-----------|-----------|----|-------|------------------------|
| I         | 8815      | 164       | 17326     | 630       | 7.998 | 12    | 26258.5                |
| II        | 17630     | 328       | 34652     | 1260      | 8.176 | 15.9  | 52626.1                |
| III       | 26445     | 492       | 51978     | 1890      | 8.044 | 7.9   | 78827.9                |
| IV        | 35260     | 656       | 69304     | 2520      | 7.712 | 18.2  | 105023.1               |
| V         | 4407.5    | 82        | 8663      | 315       | 8.066 | 14.2  | 13125                  |

### 3. Results and discussion

In figures 2, a - d results of researches are presented.
Thus, use of inhibitors of corrosion for protection of tubing can provide the low corrosion rate of the equipment, and, therefore, will allow to increase a resource of trouble-free operation of the equipment. For this purpose it is necessary to consider the external and internal factors influencing operation of the equipment, it is correct to choose a dosage of inhibitors and a way of their input.

4. Conclusions
Speed of distribution of corrosion damages of pump and compressor and casing pipes is defined by the mode of the movement of the environment taken from the well, structure and properties got oil, gas, reservoir water. Corrosion destruction of tubing is enhanced if the extracted products contain hydrogen
sulfide and carbon dioxide. Accounting of the corrosion situation which developed in the oil-field equipment during performing its technical diagnostics, will allow to reduce considerably the probability of emergence of emergencies in use and also it is essential to reduce the expenses connected with repair and recovery from the accident.

References
[1] GOST 53365 2009 Pipe upsetting and pump and compressor and couplings to them. Key parameters and control of threaded connections. General technical requirements (Moscow Standardinform) p 12

[2] Kravcov V V, Kiseleva T V and Malinin A V 2007 Corrosion resistance of structural materials in working environments of the enterprises of the oil and gas industry (Ufa: USPTU) p 272

[3] Saakiyan L S and Efremov A P 1982 Protection of the oil and gas equipment against corrosion (Moscow: Nedra) p 227

[4] Saakiyan L S, Efremov A P and Soboleva I A 1988 Increase in corrosion resistance of the oil and gas equipment (Moscow: Nedra) p 211

[5] Markin A N and Nizamov R E 2003 CO2 corrosion of the oil-field equipment (Moscow: OJSC "VNIIOENG") p 188

[6] Laptev A B and Bugay D E 2010 Fighting against corrosion in oil and gas complex of Russia: problems and the ways of their solving European Corrosion Congress (EUROCORR-2010) (Moscow: Curran Associates, Inc.) p 191

[7] Rizvanov R G, Mulikov D Sh, Karetinkov D V, Cherepashkin S E and Shigazina R F 2017 Corrosion resistance of "tube – tubesheet" weld joint obtained by friction welding Nanotechnologii v stroitel'stve = Nanotechnologies in Construction 9(4) 97–115

[8] Nasibullina O A, Gareev A G and Rizvanov R G 2018 Investigation of the hydrogen stratification of the metal of the active gas Solid State Phenomena 284 1302–06

[9] Gareev A G 2011 Basics of metal corrosion: a training manual (Ufa: UGNTU) p 256

[10] Gareev A G, Khudyakov M A and Kravtsov V V 2010 Destruction of oil and gas equipment: a training manual (Ufa: USPTU Inst. prof. Education) p 143

[11] Tyusenkov A S 2017 Chemical resistance of steel 13CrV (rus 13ХФА) J. of Chem. Technol. and Metallurgy 52(4) pp 766–72

[12] Archakov Yu I 1985 The Hydrogen Corrosion of Steel (Moscow: Metallurgy Publ.) p 112

[13] Gerasimenko A A (ed) 1987 The Protection against Corrosion, Aging and Biodeterioration of Machines, Equipment and Structures: a handbook in 2 vol 1 (Moscow: Mechanical Engineering Publ.) p 688

[14] Steklov O I 1990 The Resistance of Materials and Structures to Stress Corrosion (Moscow: Mechanical Engineering Publ.) p 384

[15] Ovchinnikov I H, Kudaiberhenov N B and Shein A A 1999 The Operational Reliability and State Assessment of Tank Structures (Saratov: STUS) p 316

[16] Petrov V V, Ovchinnikov I H and Shikhov Yu M 1987 The Calculation of Structural Elements Interacting with an Aggressive Media (Saratov: STUS) p 288

[17] Mirkhaydarova K A, Tyusenkov A S and Rizvanov R G 2018 Gas Corrosion of Pyrolysis Furnace Coils Solid State Phenomena 284 1297–301

[18] Tyusenkov A S, Rubtsov A V and Tlya sheva R R 2017 Heat Resistance of Certain Structural Steels Solid State Phenomena 265 868–72

[19] Khaidarova G R, Tyusenkov A S, Bugay D E, Raskildina G Z, Islamutdinova A A and Sidorov G M 2018 Development and testing of corrosion inhibitor properties based on quaternary ammonium compounds Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Khimiya i Khimicheskaya Tekhnologiya 61(7) 130–6

[20] Tyusenkov A S and Cherepashkin S E 2014 Scale Inhibitor for Boiler Water Systems Russ. J. Appl. Chem. 87(9) 1240–45