Research of corrosion processes in body material of electrical dehydrator

E V Khasbutdinova, E A Naumkin, A A Elizariev, P A Kulakov and A V Rubtsov
Ufa State Petroleum Technological University, 1, Kosmonavtov street, Ufa, 450062, Russia

E-mail: ekatya25@mail.ru

Abstract. The task was set of determining the dependence of the quantitative indicator of the corrosion rate of the material of the body of the electric dehydrator on the composition of the aggressive medium, the development of measures to improve the quality of the assessment of workability and the assessment of the residual life, as well as ensuring the protection of the parts of the body of the electric dehydrator from exposure to the most aggressive working phases during operation. For research, rectangular samples were made of low-alloy steel 09G2S with dimensions of 20 × 20 mm and a thickness of 4 mm. To quantify corrosion wear, the samples were immersed for different times in three model media: ordinary water with different NaCl concentrations; the water, which has stood up from oil, with various concentration of NaCl; oil-water emulsion with an oil content in the water in the range from 7.7% to 95%. It was shown that the maximum corrosion wear is observed in a model medium, which is separated water with salt dissolved in it and characteristic of the lower bottom and lower zones of the electric dehydrator body.

1. Introduction
In the refining industry, there is a problem of corrosion wear on equipment [1-8]. The specifics of the corrosion failure of various equipment is associated with the heterogeneity of the fluid extracted from the well. The corrosive properties of the produced oil, gas and water are determined by the physicochemical properties of these three components, mainly the properties of water. However, the resulting aggressiveness of this complex mixture largely depends on a number of external and internal factors associated with specific conditions. The nature and degree of corrosive effect on the equipment for oil-water emulsion fields extracted from a well depends not only on the physicochemical properties of the oil, but also on the conditions of its occurrence in the reservoir, on the method of development and operation of the oil field, on the application of one technique or another oil production, collection and transportation in the fields, as well as from the development period in which the field is located.

The bulk of commercial water and dissolved salts, mechanical impurities are separated in the fields. The final dehydration and desalination is carried out by oil refineries in electric desalination plants (ELOU).

The main apparatuses of these plants are electric dehydrators, where, in addition to the electrical treatment of the oil emulsion, sludge (deposition) of demulsified oil is carried out, i.e. it is simultaneously a sump.

Analyzing the work on monitoring the technical condition of the electric dehydrators of oil refineries, we can conclude that they are in long operation. During operation, the predominant damage
mechanism is intense erosion-corrosion wear of the material of the electric dehydrator, which causes a decrease in strength and operational reliability.

As a rule, the main methods for assessing corrosion-erosion wear are visual and measuring control, as well as ultrasonic thickness measurement [9-11]. Using these methods, it is possible to estimate the wear with a sufficient degree of certainty and predict the further period of safe operation by changing the wall thickness.

However, due to various conditions unfavorable for the examination (the device is in operation, lack of access for internal inspection, insulation, etc.), as well as a rather long surface area of the body of the electric dehydrator, it is not always possible to achieve the required accuracy of the obtained measurement results, and accordingly and calculations.

In this regard, an important and urgent task is the development of measures to ensure a better assessment of the technical condition and resource assessment of an electric dehydrator in case of corrosion-erosion wear by identifying the most unfavorable sections of the casing and protecting them from the effects of an aggressive environment [12-15].

2. The experimental procedure and the obtained results
In the process of studying the technical documentation for the examination of ultrasonic thickness gauge in an electric dehydrator, uneven thinning of the walls was revealed due to the influence of corrosion and erosion wear. To a greater extent, the thinning of the walls was recorded in the lower zone of the body of the electric dehydrator and, accordingly, the greatest thinning of the walls was recorded on the lower bottom. The upper belts of the body and the upper bottom are not subject to significant thinning of the walls. The results of ultrasonic thickness measurement of the wall of the elements of the apparatus are shown in table 1.

| Table 1. The results of ultrasonic thickness measurement of the wall of the apparatus elements. |
|-------------------------------------------------------------|
| Element | Shell of the body | Bottom |
| | | pos.1 | pos.2 | lower | upper |
| $S_{des}$, mm | 12,0 | 12,0 | 20,0 | 20,0 |
| $S_{min}$, mm | 12,4 | 11,1 | 16,7 | 20,5 |
| $S_{reject}$, mm | 10,87 | 10,87 | 10,85 | 10,85 |

In connection with these results, it was decided to study the corrosion processes in the body of the electric dehydrator.

Since electric dehydrators are made of 16GS and 09G2S steels, steel 09G2S was chosen to conduct an experiment on studying the corrosion rate in an electric dehydrator. Next, samples were cut from a sheet of steel 09G2S with a thickness of 4 mm to conduct an experiment on studying the corrosion rate in an electric dehydrator.

To determine the corrosion rate, the gravimetric method was chosen. The essence of the gravimetric method is to determine the mass loss of metal samples during their stay in the test medium. Gravimetric tests to determine the mass and depth corrosion index were carried out on steel samples in accordance with the requirements. The average relative error in measuring the corrosion rate of metal samples did not exceed 0.5%.

Samples were washed, dried, sanded, polished and weighed on an electronic balance with an accuracy of 0.0001 grams before testing. For each test, 5 samples were used. To conduct the experiment, three types of model environments were prepared. Figure 1 shows the samples before testing.

In the first simulated medium, ordinary tap water with various NaCl concentrations was used. In the second model medium, water separated from oil was used, with various concentrations of NaCl. This model medium is suitable for comparing the working fluid, which is formed as a result of the separation of the oil-water emulsion during the operation of the electric dehydrator. This is the water that falls into the lower zone of the electric dehydrator, for further removal.
The third type of model medium is a water-oil emulsion with the oil content in water in the range from 7.7% to 95%. These model media characterize the process of corrosion wear in the middle zone of the electric dehydrator where oil extracted from the fields is fed to separate the oil-water emulsion. It also affects the upper zones of the body and the upper bottom of the electric dehydrator, where the oil separated during dehydration rises.

Figure 1. Appearance of samples before testing.

After extracting the samples from corrosive media, they were cleaned of corrosion products, dried for 24 hours and were re-weighed to calculate the corrosion rate using the gravimetric method.

During gravimetric tests, the corrosion rate is characterized by a mass indicator $K_m$ (g / m²·h), which was determined by the formula (1):

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

where $m_1$ is the mass of the sample before the test, g;
$m_2$ is the mass of the sample after the test, g;
$S$ is the surface area of the sample, m²;
$\tau$ is the exposure time, h.

If the change in the mass of the sample is directly proportional to the depth of penetration of corrosion under conditions of general corrosion, then the mass index is often converted to the depth, which characterizes the thinning of the sample per unit time.

The depth indicator of the corrosion rate $P_{Fe}$ (mm / g) was determined by the formula (2):

$$P_{Fe} = \frac{K_m \cdot 8760}{7,87} \cdot 10^{-3} = 1,1131 \cdot K_m, \quad (2)$$

where $P_{Fe}$ – depth indicator of corrosion rate, mm / g;
8760 – hours per year;
7,87 – iron density, g / cm³.

The results of the calculations during the exposure of the samples in various model environments are presented in tables 2-4.

Table 2. The results of the calculations during the exposure of samples in water with salt.

| The concentration of salt (NaCl) in water, $C_s$, % | The time of immersion, $r$, h | Corrosion rate, $K_m$, g / m²·h | Depth corrosion rate, $P_{Fe}$, mm/y | Mass loss after experience, y |
|---|---|---|---|---|
| 10 | 39 | 0.31 | 0.34 | 0.0131 |
| 8  | 69 | 0.30 | 0.33 | 0.0225 |
| 6  | 70 | 0.27 | 0.30 | 0.0210 |
| 4  | 70 | 0.24 | 0.26 | 0.0190 |
| 0  | 72 | 0.22 | 0.24 | 0.0175 |
Table 3. The results of the calculations during the exposure of the samples in settled reservoir water with salt.

| The concentration of salt (NaCl) in water, \( C_s \), % | The time of immersion, \( r \), h | Corrosion rate, \( K_m \), g / m\(^2\)-h | Depth corrosion rate, \( P_{Fe} \), mm/y | Mass loss after experience, y |
|-------------------------------------------------|-------------------------------|-----------------------------------|----------------------------------|------------------------------|
| 10                                             | 69                            | 0.26                              | 0.29                             | 0.0202                       |
| 8                                              | 70                            | 0.22                              | 0.24                             | 0.0170                       |
| 6                                              | 72                            | 0.19                              | 0.21                             | 0.0152                       |
| 4                                              | 49.5                          | 0.17                              | 0.19                             | 0.0096                       |
| 0                                              | 49                            | 0.15                              | 0.17                             | 0.0081                       |

Table 4. The results of the calculations during the exposure of the samples in the oil-water emulsion.

| № sample | The time of immersion, \( r \), h | Corrosion rate, \( K_m \), g / m\(^2\)-h | Depth corrosion rate, \( P_{Fe} \), mm/y | Mass loss after experience, y | The percentage of oil in water, % |
|-----------|-----------------------------------|-----------------------------------|----------------------------------|------------------------------|---------------------------------|
| 1         | 47                               | 0.15                              | 0.17                             | 0.0078                       | 7.7                            |
| 2         | 47                               | 0.13                              | 0.14                             | 0.0068                       | 33                             |
| 3         | 73                               | 0.12                              | 0.13                             | 0.0105                       | 42                             |
| 4         | 72                               | 0.08                              | 0.09                             | 0.0070                       | 50                             |
| 5         | 47                               | 0.05                              | 0.06                             | 0.0023                       | 95                             |

Figure 2 presents a comparison of the corrosion rate of samples in various corrosive environments.

Figure 2 shows the results from three simulated media. According to the graph, the highest corrosion rate was detected in water with salt, but it does not reflect the actual conditions of the corrosion rate in the installation case, since it does not fit the operating conditions of the electric dehydrator. But it reflects the general tendency of the tests for the corrosion rate and consists in the fact that with a decrease in the salt content in water, the corrosion rate of the samples decreases.

In Figure 2, a curve that displays the results of a study of corrosion processes in oil and water separated from oil shows average values. If we evaluate the corrosion processes in the body of the
electric dehydrator, samples 1 and 2 show the corrosion rate of the lower bottom of the electric dehydrator, and samples 3 to 5 show the corrosion rate in the lower zone of the body. These model media were prepared on the basis of the operating principle of a dewatering and desalting plant, where as a result of the separation of a water-oil emulsion, water and salts dissolved in it accumulate at the bottom of the electric dehydrator.

The curve, which displays the corrosion rate in the oil-water emulsion in figure 2, shows the data of the corrosion processes in the body of the electric dehydrator that occur in the middle and upper zones of the dewatering plant. Samples 1 to 3 show the corrosion rate in the middle belts, where a water-oil emulsion is supplied during the operation of the electric dehydrator for further dehydration. Samples 4 and 5 evaluate the rate of corrosion wear in the upper zone of the body and in the upper bottom, where oil purified from water and salt rises during dehydration.

If we evaluate the corrosion rate in the body of the electric dehydrator, according to table 5 of the corrosion resistance of metals, then the lower and middle belts of the body of the electric dehydrator, and the lower bottom are evaluated by 4 groups, as they are resistant to corrosion rate and rated at 6 points. But the upper belt and the upper bottom of the electric dehydrator are evaluated in group 3, as resistant to corrosion processes and are rated at 5 and 4 points, respectively.

Figure 3 shows how the corrosion rate proceeds depending on the working areas of the electric dehydrator.

As a result of the studies, three zones were identified that are subject to varying degrees of corrosion damage:

- lower bottom and lower belts of the shell;
- middle shell belts;
- the upper bottom and upper belts of the shell.

This is due to the different working areas of the electrical dehydrator, which occur during the separation of the oil-water emulsion in the electrical dehydrator.

Based on the results obtained, recommendations were developed to increase the reliability of assessing the workability and service life of the electric dehydrator according to the criterion of
corrosion wear and protection from the corrosive effects of the aggressive phases of the working medium on its various sections, which include the following items:

1. For further more accurate determination of the residual life of the apparatus, expert diagnosticians are recommended to increase the number of points for measuring ultrasonic thickness gauge on the bottom of the apparatus, for a better assessment of performance and determination of the residual life of the electric dehydrator.

2. The use of corrosion inhibitors and neutralizers of crude oil, and process streams, in order to suppress corrosion of equipment. These methods of preventing corrosion processes are recommended to be used from the first days of equipment operation in order to increase the design service life.

3. The aqueous phase, which accumulates in the lower part of the electric dehydrator, is particularly aggressive. Therefore, the lower part of the apparatus to a height of 1.5 - 1.7 m from the lower generatrix of the housing is recommended to be protected from the influence of this environment by a lining of shotcrete. The upper part is quite successfully inhibited by the oil itself.

3. Conclusion
The developed recommendations for improving the reliability of assessing the workability and service life of the electric dehydrator according to the criterion of corrosion wear and protection from the corrosive effects of the aggressive phases of the working medium on its various sections should be applied both during operation and during periodic technical examination and diagnosis. The advantage of the research is the identification of three working areas in the electric dehydrator from the point of view of the rate of corrosion wear of the material of the electric dehydrator, three zones are distinguished: dehydrated oil; oil emulsion; separated water. In the first zone, the rate of corrosion wear is minimal and does not exceed 0.06 mm / g. In the second zone, with a decrease in the oil content in water from 95 to 7%, the rate of corrosion wear increases from 0.06 to 0.17 mm / g. In the third zone, with an increase in the salt content in the separated water, the rate of corrosion wear increases from 0.17 to 0.29 mm / g.

When diagnosing the apparatus, special attention should be paid to the bottom of the electric dehydrator and the lower zones of the shell. In addition, it is recommended to increase the number of points when measuring the wall thickness of the lower bottom for a better assessment of performance and determine the residual life of the electric dehydrator. For newly manufactured equipment of this type, we can recommend the use of innovative methods of processing the inner surface of the material in order to extend the life of safe operation.

This method allows you to determine the most unfavorable sections of the body of the electric dehydrator from the point of view of the rate of corrosion wear, taking into account both the structural and operational features of the apparatus. This helps to increase reliability during operation by increasing the amount of control by non-destructive methods in such areas and by providing a protective coating in the form of a shotcrete concrete lining of the lower part of the apparatus, which is most subjected to corrosion wear.

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