CARBON DIOXIDE CORROSION AT THE OBJECTS OF THE SECOND DISTRICT OF ACHIMOVSK DEPOSITS OF URENGOY OIL AND GAS BEARING COMPLEX

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ABSTRACT

To assess the corrosion situation, it was necessary to develop the corrosion monitoring system suitable for “Gazprom Dobycha Urengoy” LLC objects, which should have contained the development of equipment, which allows to measure the speed of corrosion in the pipes with working pressure 40 MPa. As the research method we have used the gravimetric method, based on the measurement of the mass loss of the corrosion control sample exposed to the working environment. Application of the developed and implemented system allows getting necessary data for prognostication of terms of equipment service, reduction of number of failures and for increasing of accident-free operation of pipelines and equipment in general.

Keywords: Corrosion monitoring, Carbon dioxide corrosion, Achimovsk deposits, Urengoy oil and gas bearing complex.

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1. INTRODUCTION

The problem of carbon dioxide corrosion during the development of gas condensate fields became relevant again due to the beginning of the development of new deposits located in the northern regions of the Russian Federation [1–5]. A high degree of aggressiveness of CO₂ is noted in the Achimov deposits of the first and second sections of the Urengoy field, Achimov deposits within the Samburg licensed site of JSC Arktikgaz, oil and gas condensate field in Bovanenkovo. However, the development of deposits, with a CO₂ content of more than 1 % gas and reservoir temperatures above 80°C, began in Russia in 1965-1970 on the Krasnodar and Stavropol territories. It was then that Soviet specialists first encountered the catastrophic consequences of CO₂ exposure. The depth of penetration of local corrosion in the tubing...
reached 7-8 mm/year, the plumbing lines corroded on the lower generatrix to a depth of 3-5 mm/year. In 1978-1980, the first facts of intensive corrosion of pipelines in Samotlor oil collection systems and a number of other oil fields in Western Siberia were noted.

Oil companies that inject CO₂ into the reservoir to improve oil recovery are more likely to encounter problems of carbon dioxide corrosion [6–8].

Currently, 130-140 carbon dioxide injection projects are being implemented worldwide, of which 90% are sold in the USA [9]. Deposits of natural gas enriched with carbon dioxide are prevalent mainly in the US western states - Montana, Colorado, Utah and New Mexico. Some natural gas deposits in California contain up to 49% of carbon dioxide. The highest known concentrations are found in deposits in New Mexico, where the share of carbon dioxide is 99% in some cases. The extracted and produced carbon dioxide is collected in a network of pipelines, the total length of which is 7.2 thousand km and is used for pumping into oil deposits. Preparation of carbon dioxide, with the extraction of water and other components, eliminates the possibility of corrosion during the transport of CO₂ in the liquid phase through pipelines made of carbon steels [10].

Currently the largest project in the process of extracting CO₂ from natural gas is the project "Gorgon". Gas from the deposits of the group of gas fields located approximately 130 kilometers from the orth-west coast of Western Australia, contains about 14% of carbon dioxide. When gas is liquefying, it extracts 3 to 4 million tons of CO₂ annually, which is pumped into the seams to a depth of 2 km.

In 2008, JSC "Gazprom" started the development of Achimov deposits of the Urengoy oil and gas condensate field. Joint Russian-German company CJSC "Achimgaz" introduced the complex gas treatment unit No. 31 (GCDS-31) (GCDS= gas and condensate developing site) that was put into operation to develop the first licensed area. In October 2009 the gas condensate field No. 22 (GCDS-22), which is developing the second section, has been put into operation. The development and arrangement of Achimov deposits in all licensed areas is one of the main directions for the development of PJSC "Gazprom" in the coming years.

In 2014, during the scheduled works on the inspection of the Christmas tree assembly AF6D-80 / 65x700 K1 KhL of the gas condensate well No. 2114 of the GCDS-22, omission of formation mixture through the flange connection of the crosspiece EF6D-80 / 65x700 K1 KhL and emergency (control) gate valves ZMS 65 × 700 K1 KhL occurred. After that, it was decided to stop the well and depressurize the flange connection. During the inspection of the O-ring BKh154 and the flange connection, the destruction of the O-ring (Fig. 1) and the seat of the O-ring on the crosspiece and stop valve, was revealed.

![Corrosion destruction of O-ring](image)
While replacing the crosspiece, it was found that the landing pad was damaged under the O-ring sealant at the ZMSG 80 \times 700 K1 KhL-anchor valve, as well as the integrity of the cross-sectional area of the ZMSG 80 \times 700 K1 KhL-anchor valve and the ZMS 80 \times 700 K1 KhL-core valve. Later, work was carried out to replace the root stop valves with the replacement of O-rings. In the course of work on the stop valves replacement, a breach of the integrity of the flow section of the Flan pipe head adapter was found 3 1/16"-10000-BKhL154 and the seats under the O-ring seal. After that, the elements of the fountain fittings of the Achimov horizon wells were inspected, and similar damage was revealed.

In February 2016, corrosion damage was found to the internal surface of one of the gas collectors. The gas collector is designed for transporting a hydrocarbon mixture from a bush of gas condensate wells of Achimov deposits to a gas condensate field. The total length of the gas pipeline is 4712 m. Commissioning was carried out on 31.12.2010. Material version of the pipe steel grades 09G2S. The main parameters of operation of the gas pipeline №213: pressure 13 MPa, medium temperature 25-37°C. The potential content of \( \text{C}_5^+ \) for the formation and "dry" gas was 276 and 291 g/m\(^3\), respectively, the specific water content per gas of separation of 7 g/m\(^3\) of gas. The process of corrosion started mainly along the lower generatrix of the pipe. Corrosion damage had a local in character with characteristic ulcers and pittings.

Hydrocarbons themselves are not an aggressive media. And for the corrosive process, they should contain corrosive components such as oxygen, hydrogen sulphide or carbon dioxide. In the strata gas of the Achimov deposits of Urengoy gas field, \( \text{CO}_2 \) is present in the redistribution of 0.7-1.0 % mol. or 1.0-1.4 % by weight. According to the data of gas condensate studies of wells, the content of \( \text{CO}_2 \) in produced formation gas is:

- **By wells of GCDS -31 0.69-0.86 % mol., average value – 0.8 %;**
- **The wells of GCDS -22 are 0.84-0.95 % mol., the average value is 0.9 %**.

One of the factors affecting the rate of carbon dioxide corrosion is partial pressure of \( \text{CO}_2 \) [11]. Partial pressure for typical wellhead conditions of the Achimov deposits was calculated using the example of well # 2144 with a mole content of \( \text{CO}_2 \) of 0.9% and an operating pressure of 23 MPa (1)

\[
P_{\text{part.}} = \frac{0.9 \cdot 23}{100} = 0.21 \text{ MPa};
\]

The range of partial pressures of carbon dioxide for the conditions is 0.2-0.4 MPa. In accordance with the regulatory documents of JSC "Gazprom", Achimov gas is highly aggressive [12]. The presence of mineralized water and high temperature further intensifies corrosive aggressiveness.

Due to the high partial pressures of \( \text{CO}_2 \), the water condensate produced from the wells is a solution of carbonic acid. Carbonic acid is formed by dissolving carbon dioxide in water in accordance with the following reaction (2):

\[
\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{CO}_2 \cdot \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3
\]

Carbon dioxide corrosion is caused by the effect of \( \text{CO}_2 \) contained in the formation water on the processes of anodic dissolution of iron. The carbon dioxide in the aqueous solution can be in various forms: in dissolved form, in the form of unified carbonic acid molecules, bicarbonate ions (\( \text{HCO}_3^- \)) and carbonate ions (\( \text{CO}_3^{2-} \)). Under equilibrium conditions, a balance is observed between all four forms. The relationship between the forms of \( \text{CO}_2 \), \( \text{HCO}_3^- \) and \( \text{CO}_3^{2-} \) depends on the pH of the hydrogen. As the pH increases, the content of ions \( \text{HCO}_3^- \)
increases. At pH = 8.4, only bicarbonate ions are present in water, and at pH = 12, only carbonate ions are present.

The simultaneous presence of the above ions in the produced product causes the possibility of forming various hardly soluble compounds, some of which form a film on the metal surface. Under certain conditions, these films data can act as protective, preventing the entry of an aggressive environment on the exposed metal [13, 14]. As a rule, films with good protective properties (consisting predominantly of FeCO$_3$) begin to form at temperatures from 75°C and partial pressure of CO$_2$ above 0.8 MPa [15]. The parameters of the media for the gas production of the Achimov deposits of Urengoy gas field are much lower, accordingly, the formation of valuable protective films is unlikely.

2. MATERIALS AND METHODS

Therefore, in order to obtain all the information on the corrosiveness of the environment in various parts of the GPP-22 (GPP=gas processing plants) facilities, a corrosion monitoring system was developed. That allows to determine the corrosion rates of equipment along the chain of motion of the extracted product from wells to the point of measurement of commercial gas consumption. This system includes two types of corrosion rate control units.

The gravimetric control of the corrosion speed rate was taken as a basis for the measurements. The gravimetric method is based on the principle of measuring the mass loss of corrosion specimens exposed in a working product environment. As samples-witnesses of corrosion, as a rule, samples are made from metal of a similar metal of the equipment under investigation are used. Within the framework of the described studies, the witness samples made of steel 09G2S were used.

Before the development of these devices, a large number of standard options for installing witness specimens in the medium flow were considered, but each of the methods involved a change in the design of pipelines that required the coordination of design institutes. Therefore, inter-flange corrosion rate control units have been developed for high-pressure pipelines with no pipe socket for protective sleeves (Fig. 2), and gravimetric cassettes were developed for pipelines with sites for mounting thermowells (Figure 3).

![Figure 2 Mounting of an inter-flange corrosion rate control unit](image-url)
3. RESULTS
Currently, corrosion monitoring is carried out in the pipelines of Achimov deposits, the pipelines of the gas gathering system, technological pipelines of the complex gas treatment unit No. 22 (GPP-22) using inter-flange corrosion control units and gravimetric cassettes. Fig. 4 shows the corrosion rates on the well’s pipelines located up to the pressure regulator (working pressure up to 40 MPa, temperature 40-60°C); Fig. 5 shows corrosion rates after the pressure regulator (operating pressure up to 12.5 MPa, temperature up to 30°C).

![Figure 4 Corrosion rates on wells pipelines, located up to the pressure regulator](image-url)
4. DISCUSSION
Practically in all wells, the corrosion rate on pipeline sections to the pressure regulator exceeds the value 0.1 mm/year, stated by the project as the maximum allowable. It is worth noting that at this section the working pressure reaches 40 MPa, and the temperature of the product produced ranges from 40 to 60°C, which in its turn creates favorable conditions for carbon dioxide corrosion. It is therefore natural that some wells have a significant excess of the design corrosion rate. According to these measurements, the maximum speed was fixed at the well 2A151. The speed of the upper sample was 0.23 mm/year, the average speed was 1.41 mm/year, and the lower one was 4.63 mm/year.

It is necessary to note that on the overwhelming majority of stations controlling the rate of corrosion, the corrosion rate on the lower witness samples is higher than at the middle and upper ones. Such gradation of the corrosion rate from the position of the sample at the station is explained by the precipitation of water in the dispersion state in the lower part of the flow, under the influence of gravitational forces, since water has the greatest density of all components of the fluid mixture. Dissolved in the formation and condensation water, carbon dioxide creates ideal conditions for intense corrosion to occur. The upper samples, while in a gas stream with a lower liquid content, corrode at a lower rate because of the presence of fewer aggressive components.

On the wells pipelines after the pressure regulator, the corrosion rate decreases. This is due to reduction of working pressure to 12.5 MPa and the temperature of up to 30°C. In general, the aggressiveness of the product is reduced in this area, but despite this fact, there are wells with excessive corrosion rates.

In addition, the corrosion rate was measured at the end of the gas collection collectors in the building of the switching armature, in the gas preparation shops and in the gas flow measurement station. The obtained values are within the permissible limits (two orders of magnitude lower than the projected maximum value). This is also explained by the natural decrease in corrosive aggressiveness along the way of the extracted product.

5. CONCLUSION
Thus, the problem of carbon dioxide corrosion that arose in LLC "Gazprom production Urengoy", simultaneously with the development of Achimov deposits, led to a study of the
aggressiveness of the extracted product and the development of a corrosion monitoring system whose initial purpose was to obtain information on the current corrosion state of the objects and the corrosiveness of the produced product.

Based on the results of the research, it was determined that the Achimov deposits gas of Urengoy gas field is highly corrosive. Formation of dense protective films from corrosion products on the metal surface in the conditions of gas production of Achimov deposits of Urengoy gas field is unlikely.

To monitor the aggressiveness of the fluid at various sites, a corrosion monitoring system was developed. This system allows to measure corrosion rates on pipelines with high operating pressure. To obtain the possibility of carrying out corrosion monitoring in areas with high pressures, the specialists of the Company developed an inter-flange corrosion control unit operating at pressures up to 40 MPa. Another advantage of this device is the ability to measure the rate of corrosion without making changes to the construction of pipelines. To install inter-flange units and gravimetric cassettes, welding operations are not required, there is no need for capital installation of additional equipment. Installation of inter-flange units is carried out in existing flanged pairs on pipelines; gravimetric cassettes are installed in reserve lugs designed for mounting thermowells. Thus, after measurements of corrosion rates and dismantling of equipment, the technological diagram of the pipelines remains in the initial state.

The use of the developed and implemented system allows obtaining the necessary data for forecasting the service life of the equipment, reducing the number of failures and, in general, increasing the accident-free operation of pipelines and equipment.

REFERENCES


