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Survey of reliability of offshore oil and gas infrastructure in South Baltic conditions

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ABSTRACT

The development of the hydrocarbon resources of the Kaliningrad Region shelf has been carried out systematically since the late 1980s. In the existing offshore oil and gas infrastructure of the region should be mentioned drilling platforms (C-9 and D-6), an underwater oil pipeline from the D-6 platform to the Romanovo oil collection point, the Pionersky marine regasification terminal. The experience of operating these infrastructure facilities shows that despite the low salinity of the Baltic Sea and the practical absence of ice conditions in this area, oil and gas infrastructure objects are subject to significant technical degradation. The existing offshore pipeline, which transports oil from the D-6 platform, is influenced by a complex of external factors, internal corrosion and erosion wear associated with sulphur compounds, oxygen, and the presence of abrasive particles. The study presents a factor analysis of the causes of corrosion wear of infrastructure oil and gas facilities on the shelf of the Kaliningrad region, analyses the dynamics of the processes of physical and chemical degradation of equipment surfaces. Various solutions of the reliability ensuring of these units in marine conditions are considered. The results of observations of corrosion and erosion processes in the oil and gas infrastructure of the Kaliningrad Region shelf should be taken into consideration during the development of project documentation and the selection of equipment and materials for new projects being implemented (offshore oilfield development project D-6 South and D-33).

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1 Introduction

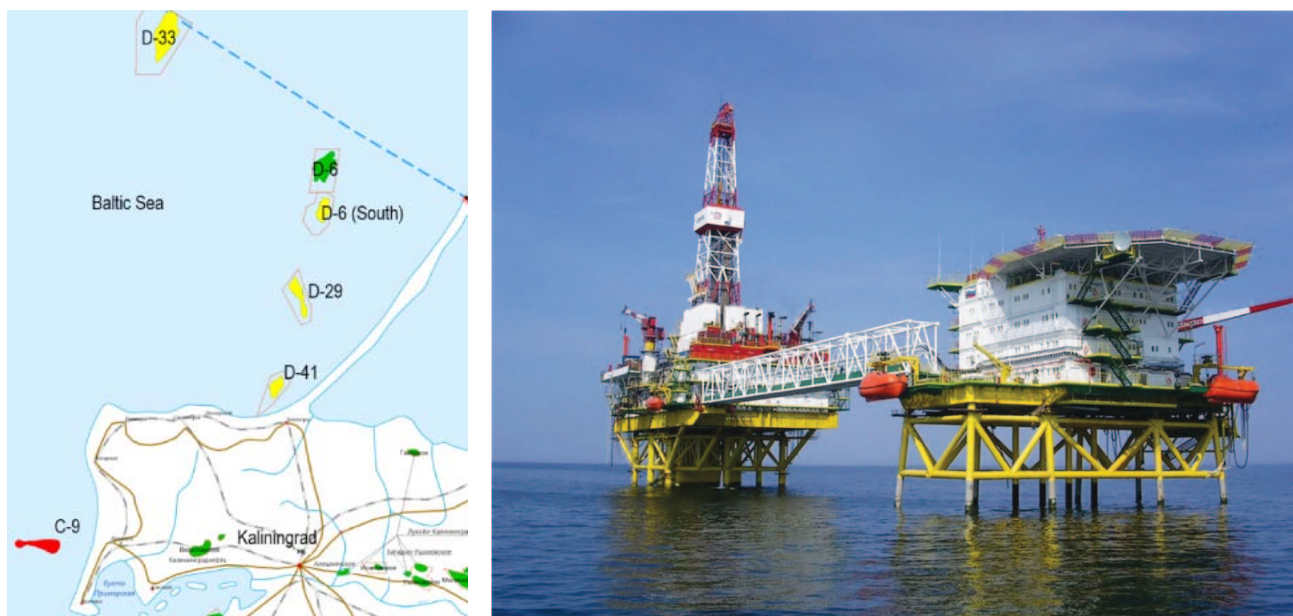
Currently, in the Kaliningrad Region there are two operating offshore oil fields D-6 and D-41. D-6 is operated from an offshore ice-resistant platform. D-41 operating unit stands on an artificial bulk island. Also, there is a C-9 field offshore unit, which was the first object of marine geological exploration in the 1980s. This structure was recognized as not profitable for further development, and that was the reason why this project was frizzed.

The main volume of sea oil production in the region is currently carried out on the D-6 platform (about 300 thousand tons per year). The platform complex includes an operational module made in an ice-resistant design and carrying drilling and energy blocks, as well as a separate residential module. The depth of the Baltic Sea in the area of the D-6 platform is about 27-30 meters [1]. Among the

marine infrastructures, it is also necessary to highlight the offshore pipelines laid from the D-6 and D-41 fields to the Romanovo oil collection point.

The pipeline from D-6 to the Romanovo oil collection point consists of two parts: the offshore part and the onshore part.

The total length of the pipeline is 53 km, of which 47 km is the offshore section and 6 km is the onshore section. The diameter of the offshore section of the pipe is 273.1x18.3 mm, the onshore section is 273.1x10 mm. At the starting point of the pipeline, on the platform, the corrosion inhibitor and demulsifier are injected by dosing pumps [2]. The pipeline from D-41 is similar in design. The length of its offshore section is 3.5 km. Besides, it should be mentioned that in 2020, a new regasification terminal in Pionersk was put into operation. This terminal is also



a)

b)

Figure 1 a) Location of deposits and hydrocarbon structures at the Kaliningrad region offshore; b) Offshore platform D-6. Kravtsovskoye field

Source: Authors

an important part of offshore oil and gas infrastructure. It was designed and constructed for transportation of liquefied gas from Ust-Luga to Kaliningrad and further filling of underground gas storage facilities.

2 Evaluation of the main factors affecting corrosion processes in the offshore oil and gas infrastructure of the Baltic Sea

Objects of offshore oil and gas infrastructure, most often presented in metal and reinforced concrete design. In general, offshore oil and gas facilities can be damaged for various reasons. Statistics shows that offshore in metal objects, the corrosion process is a reason of 50% of damage cases [3].

Degradation processes in these objects (reducing reliability) occur at different rates and depend on various parameters. It should be taken into consideration that the weight of each of the factors affecting the rate of corrosion processes in marine conditions may vary depending on the characteristics of the external environment, the design decisions, and the process of infrastructure operation.

Steel offshore oil and gas structures undergo a corrosion process in two stages [4]. The initial stage, when the object falls into the conditions of the sea water. The stage of long-term operation, when the object is located for a long time in specific conditions and other factors come to the fore in the weight of the impact. Figures 3a and 3b present the weight of factors affecting the steel structures of the C-9 platform in conditions typical of the Baltic Sea.

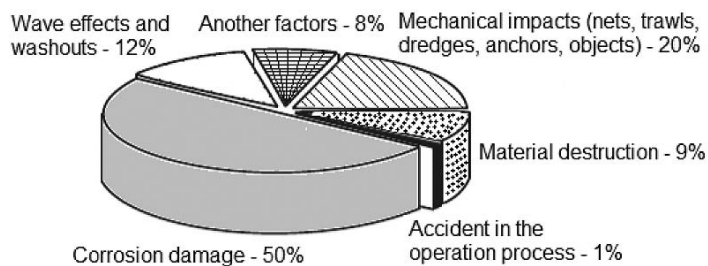


Figure 2 Causes of damage to the offshore oil and gas infrastructure

Source: Authors

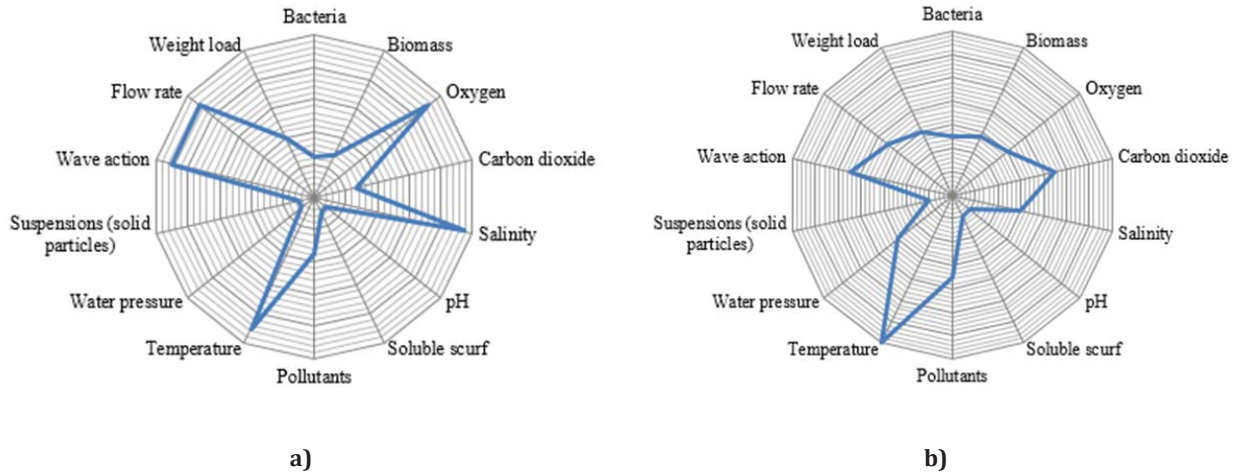


Figure 3 The weight of the factors affecting the initial corrosion rate (a) and long-term corrosion rate (b) of carbon steel supports of the C-9 platform (South-Eastern Baltic).

Source: Authors

At the initial stage, the main impact is on the protective coatings of offshore oil and gas structures. With the degradation of this passive protection, as well as with the deactivation of the active protection (or its non-rational functioning), the process of corrosion destruction develops and passes into a long-term stage.

The metal is oxidized and crumble under shock-abrasive and temperature influence. In addition to corrosion of the external parts of oil and gas structures in marine conditions, internal corrosion occurs in equipment transporting hydrocarbons. Such corrosion is often associated with exposure to oxygen, sulfur compounds, and transported abrasive particles. In general, internal corrosion of offshore pipeline systems is similar to the same processes onshore [5].

3 Investigation of the corrosion process of oil and gas infrastructure on the shelf of the Kaliningrad region

Among long-operated offshore oil and gas facilities in the region, the decommissioned stationary platform C-9 stands out. Geological exploration at this field was carried out in the mid-1980s, as a result of its development was considered economically impractical. Drilling and specialized equipment of the platform were removed.

Over the past 30 years, the C-9 platform has been gradually exposed to the increasing impact of the marine environment and is a convenient object for analyzing the specifics of changing the parameters of the technical condition of equipment in the Baltic Sea. During the 1990s,



Figure 4 a) C-9 Baltic sea offshore platform, b) Damages of the supports of the C-9 Baltic Sea offshore platform

Source: Authors

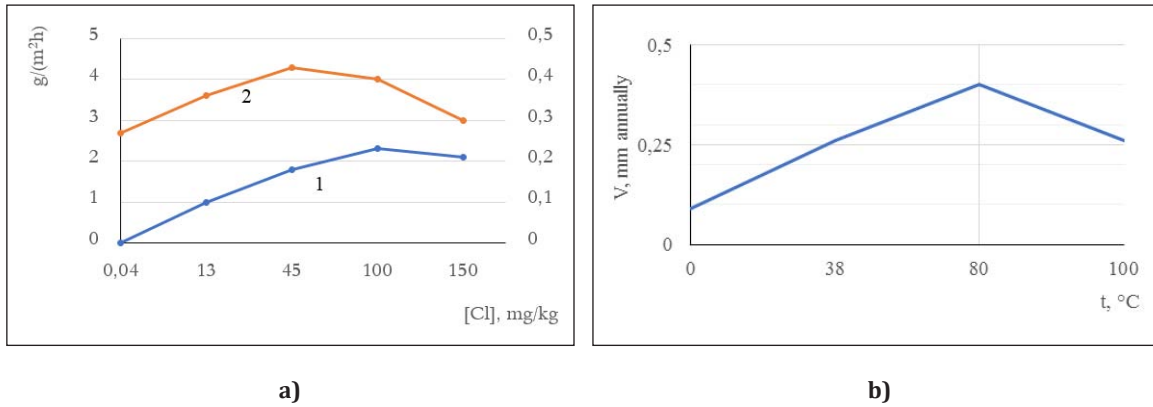


Figure 5 a) The dependence of the corrosion rate of constructional steel of offshore objects on the concentration of salts in seawater (1 – general corrosion, 2 – pitting corrosion), b) The dependence of the corrosion rate of constructional steel of offshore objects on the temperature of sea water

Source: Authors

the platform supports were gradually stripped of their insulation coating due to the impact of the marine environment. By 2002 the separation of the insulation coating of the supports was fixed at the C-9 platform. The process of corrosion-abrasive wear of the main metal of the structure began. Laboratory complexes of the Baltic Federal University and the Atlantic Research Institute of Oceanography investigated the dynamics of changes in the corrosion rate of constructional steel used in the C-9 platform, depending on salinity, temperature, and current velocity [6].

However, all considering parameters, coupled with the wave effect, the effect of sand suspension as an abrasive, are multiplied and have a significantly greater impact jointly. Modeling of the process of general and pitting corrosion over time (excluding the wave action) also shows

significant rates of increase in the depth of steel destruction [6]. Calculations on the dynamics of corrosion wear were carried out using the following formula:

$$V_k = (\delta_0 - \delta_f) / T \tag{1}$$

Where: V_k – average corrosion rate in mm. annually; δ_0 – initial zone thickness in mm; δ_f – actual zone thickness in mm; T – operating time in years.

At the same time, it is necessary to point out the fact that the vertical dynamics of the corrosion process on the offshore platform vary. The above data is averaged. In the case of constructing a complete model including the wave action, it is necessary to consider not only the sea water flow velocity near the steel support, but also the dynamics of changes in the flows over time and force [7].

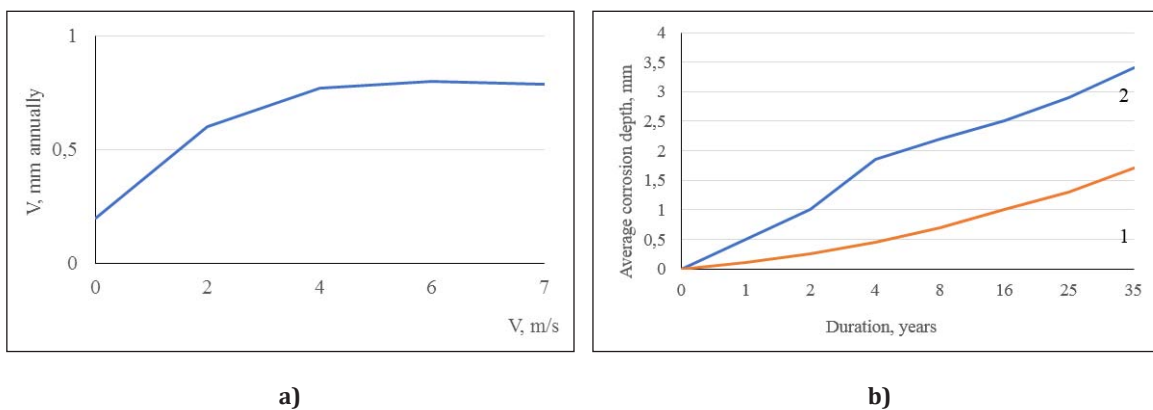


Figure 6 a) The corrosion rate of constructional steel of offshore objects as a function of water flow rate, b) Changes of general (1) and pitting (2) corrosion depth of constructional steel of offshore objects in time

Source: Authors

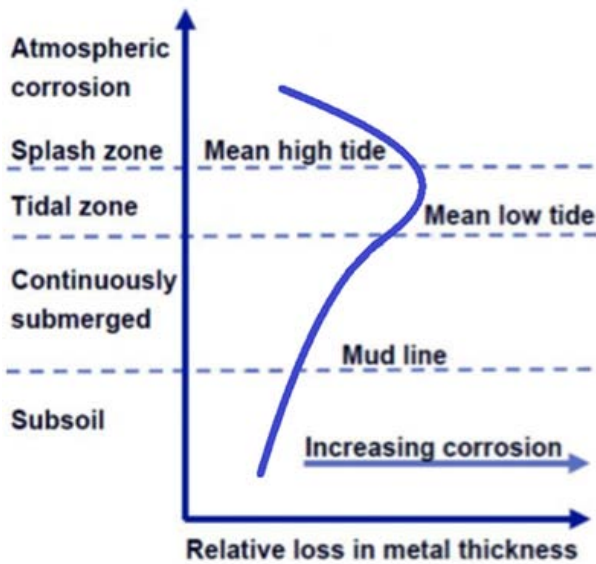


Figure 7 Dynamics of metal loss in steel structures from complex impact of a number of factors [8]

It should be noted that according to the results of statistical observations, the greatest metal losses were recorded in the tidal zone. Alternating wetting and drying as a result of waves, mechanical impact of the mass of water, leads to accelerated corrosion of exposed metal surfaces. In the conditions of the actual absence of the ice factor, low salinity (about 10 ppm), insignificant fluctuations in water temperature – the mechanical effect of waves, as well as the temperature drop from heating during drying and cooling during immersion of metal structures, play the greatest role in initiating and maintaining the dynamics of the corrosion process of marine structures in the southeastern Baltic [8].

4 Corrosion prevention features of new offshore oil and gas projects construction in the conditions of south-eastern Baltic

In 2018-2019, geological exploration of offshore hydrocarbon deposits in the area of the D-6 Kravtsovskoye field was completed. According to the results of these studies, it was found that the structures D-2, D-8, D-18, and D-19 are unproductive. The D-33 and D-41 fields are promising for further development. The D-6 South and D-29 fields are currently not profitable for development.

The D-41 field started to develop from an artificial island in 2019-2020. The D33 field will be developed in the period 2023-2025 from a stationary platform. Infrastructurally, there are several options for the location of new offshore oil production facilities in this area [9].

Firstly, the D-33 platform can be connected by a new offshore oil pipeline to the existing transport system of the D-6 platform. However, based on the service life of this oil pipeline, the degree of its internal and external wear, as well as the planned production volumes for the D-33 structure, this decision is not rational (Figure 8, Diagram A).

Secondly, it is possible to construct a new offshore oil pipeline directly from the D-33 field to the Romanovo oil collection point. In this way, it will allow more freedom to carry out the process of production and transportation, without being linked to the existing infrastructure and its technical condition. However, this technical solution is not optimal from an economic point of view.

The most rational approach is to build an intermediate technological platform, with the installation of an underwater oil pipeline from the D-33 field to the Romanovo oil collection point, so that in the future the D-29 and D-6 South deposits can be connected to this new oil pipeline and technological platform (Figure 8, Diagram B). The

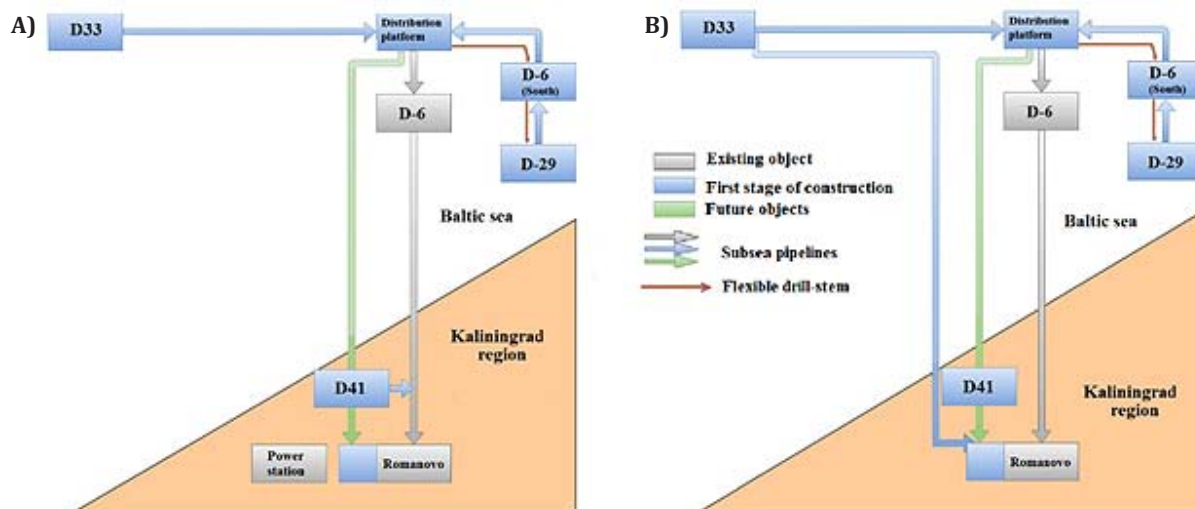


Figure 8 Preliminary options for the layout of the existing and projected offshore oil production infrastructure of the Kaliningrad region

specifics of impacts on offshore objects in this water area form the necessity of increasing protection of the tidal zone of the platforms. The area of the oil pipeline leaving the platform into the sea, as well as the exit of the oil pipeline from the offshore part to the onshore also should have additional protection [10, 11].

5 Conclusion

Thus, ensuring corrosion resistance and overall reliability of oil and gas facilities in the Baltic Sea area, it is required that: the projects of the stationary drilling platform D-33, the technological platform (if this scheme would be chosen), as well as the new projected underwater oil pipeline take into account the experience of operating platforms C-9 and D-6, as well as pipeline systems in this water area. Designers and users of offshore fields need to pay special attention to the choice of modern protective coatings. These coatings should be checked for the level of protective properties losses under existing conditions from the mechanical effects of water, as well as from temperature changes (which is the most critical for the tidal zone).

The passive protection must withstand these stresses, have strong adhesion and not peel off from the metal surface for a long time (in order to prevent the offshore structures metal from coming into contact with water and reduce the rate of corrosion damage). The effectiveness of the active protection systems requires additional study for the coverage of the surface area of metal structures and the completeness of protection in the considered marine conditions.

Prior to the tender procedures and the construction of new oil and gas facilities on the shelf of the southern Baltic, the customer must develop its own criteria for the quality and reliability of these technical systems. This work should be guided by the best European experience and practices, as well as the results of this experimental and analytical study.

As a basic regulatory documentation, it is rational to use: NORSOK STANDARD M-001. Materials selection; NORSOK STANDARD N-001 . Integrity of offshore structures. Russian regulatory documents developed on the basis of the international standardization system should also be used: GOST ISO 17776 "Oil and gas industry. Offshore mining installations. Methods and methods of hazard identification and risk assessment. Basic provisions" and GOST 57148— 2016 (ISO 19901-1:2015) "Oil and gas industry. Offshore oil and gas facilities. Design and operation taking into account hydrometeorological conditions". These standards have been adopted in recent years. The D-33, D-29 and D-41 fields development projects will be-

come the base on which the implementation of these new standards requirements will be monitored in real practical conditions. Presented regulatory approaches are of particular importance in the context of ensuring corrosion resistance of marine metal structures, improving the reliability and safety of operation of these technical devices.

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