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# Х А Б А Р Ш Ы С Ы

# ВЕСТНИК

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

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# DIAGNOSIS OF THE CORROSION STATE OF HYDRAULIC STRUCTURES IN THE CASPIAN SEA IN ORDER TO PREVENT ENVIRONMENTAL DAMAGE

**Abstract.** In order to determine the corrosive state of offshore hydraulic structures subject to strong wave impacts, and to prevent environmental damage, the monitoring was carried out at "Oil Rocks" during 5 years.

Surveys showed that on piles of overpass structures that have been in operation for 12-20 years, the corrosion rate is on average 0.22 mm / year. At the same time, at individual facilities, it ranges from 0.15 to 0.28 mm / year. The average loss of pile wall thickness is 32%, while at individual sites they range from 17 to 51%.

The technology for the manufacture of structures of the surface complex should provide for high-quality factory deposition of corrosion-resistant coatings that provide at least 30 years of service without restoration.

If the protective coating of the supports of hydraulic structures is destroyed during operation, it is proposed to use compositions based on cheap raw materials.

**Key words:** hydraulic structures; corrosion; aggressiveness of the environment, the zone of periodic wetting.

**Introduction.** Long-term operation of oilfield equipment and hydraulic structures often leads to increased corrosion destruction of underground and ground equipment, which is fraught with the occurrence of accidents, fire hazard and uncontrolled oil spills, which cause not only direct material losses, but also disturbance of the ecological balance.

It is known that for the protection of oil and gas equipment and hydraulic facilities from corrosion equipment made from resistant steel is used, polymer coatings, galvanic anodes, bactericide-inhibitors and etc. are applied. Because of the simplicity of implementation, the most promising and widely used inhibitors for the protection of downhole equipment [1-15].

It is only possible to provide the safe corrosion protection of hydraulic facilities when applying high protective insulation scheme and electrochemical protection together.

Corrosive destruction of a hydraulic structure in marine conditions has an electrochemical nature and is caused by the flow of electric current between the anode and cathode sections of the metal [16].

Offshore oil hydraulic structures (OOHS), exposed to strong wave impacts, are operated in difficult corrosive conditions, and their operational reliability depends on the timely conduct of restoration and overhauls. The corrosion rate of steel in the marine atmosphere is determined by hydrometeorological factors, distances from the water mirror, operating conditions, and structural features of the structure [17,18].

Four specific zones of corrosion damage were established on steel hydraulic structures of oil fields in the Caspian Sea - atmospheric, periodic wetting, underwater and soil zones, which differ in the nature and rate of corrosion [19,20].

It is possible to protect environment with gathering and analyzing the diagnosis data for accidents occurred in the period of hydraulic facilities and oil and gas equipment exploitation, and conducting different measures according to their limitation.

In order to prevent corrosion damage, and, consequently, disturbance of ecological balance, on-site corrosion tests were carried out on Oil Rocks for diagnosing the corrosion state of OOHS in the atmospheric and periodic wetting zones during 5 years.

Mass measurements of the wall thickness of structural elements were carried out to assess the corrosion state of the operating OOHS with an ultrasonic thickness gauge. Moreover, more than 2000 measurements were made only on the supports of the structures, and more than 10 km of flyover structures and 15 thousand m$^2$ of flyover platforms were examined.

For various OOHS objects, the arithmetic mean value of the remaining pile wall thickness was derived in the maximum corrosion section, usually located at a level of 1-2.7 meters above sea level.

The average corrosion rate $K_{ave}$ was calculated by below shown formula:

$$K_{ave} = \frac{\delta_0 - \delta_1}{\tau} mm / year$$

where: $\delta_0$ is the initial wall thickness of the piles, accepted equal to 11.0 mm; $\delta_1$ is the remaining wall thickness of the piles, mm; $\tau$ – operation life, years;

The change in the wall thickness of the piles in percent was determined by the formula

$$C = \frac{\delta_0 - \delta_1}{\delta_0} \cdot 100\%$$

The results of measurements of the wall thickness of piles are given in table.

Characteristics of the corrosion state of the supports overpass structures of "Oil Rocks" OGEI*

| Operation life, years | Quantity of examined piles, pcs. | Wall thickness of examined piles, mm | | Average rate of corrosion, mm/year | Average loss of wall thickness of piles, % |
|---|---|---|---|---|---|
| | | average | minimum | | |
| 12 | 22 | 9,1 | 8,1 | 0,16 | 17 |
| 13 | 18 | 9,1 | 5,8 | 0,15 | 17 |
| 14 | 35 | 7,5 | 5,6 | 0,25 | 32 |
| 15 | 17 | 7,6 | 6,9 | 0,21 | 31 |
| 16 | 19 | 7,1 | 6,3 | 0,24 | 35 |
| 17 | 24 | 7.1 | 5,3 | 0,21 | 35 |
| 18 | 25 | 7,2 | 5,0 | 0,21 | 35 |
| 19 | 10 | 7,3 | 5,7 | 0,25 | 34 |
| 20 | 10 | 5.4 | 4.4 | 0,28 | 51 |
| Total: | 180 | 7,5 | – | 0,22 | 32 |
| *OGEI – Oil Gas Extracting Institution. | | | | | |

As seen from the table 1, the corrosion rate is on average 0.22 mm/year on piles of overpass structures, operating for 12-20 years. At the same time, at individual facilities, it ranges from 0.15 to 0.28 mm/year. The average loss of pile wall thickness is 32%, while at individual sites they range from 17 to 51%.

The data presented characterize the initial stage of the corrosion process. During long-term (12-20 years) operation, these values are somewhat reduced due accumulation of corrosion products on the surface by corrosion inhibition.

Inspection of piles after many years of operation without corrosion protection shows that corrosion products unevenly cover their surface. It was found that the distribution of corrosion products depends not only on the hydrometeorological conditions of the water area of the object’s location, but also on the depth of the sea, the topography, wind rose, and the location of the supports under the overlying structures, i.e. on the degree of solar exposure to the surface. For example, with a sea depth of 11 meters and solar radiation on the south and west sides, the support on the north side is covered with layered corrosion products from sea level to 4.5 m, and on the south side only 2.3 m.

Observations show that in the zone of periodic wetting, corrosion on piles proceeds at a high speed, despite the formation of thick (more than 10 mm) layered corrosion products.

So, after 18-20 years of operation of unprotected structures, through corrosion lesions on tubular elements with an initial wall thickness of 11.0 mm are detected.

Unprotected structures during operation are surface structures of stationary platforms, so it was important to determine the degree of corrosion wear in a long-term section, i.e. to study the distribution of corrosion rates in height from sea level.

For this purpose, a separate base located at the Oil Rocks field at a depth of 11 meters was carefully examined.

From the point of view of the strength of the tubular support, it is important to determine the corrosion rate along the entire perimeter and height in the area of maximum corrosion.

If we summarize the corrosion wear and derive the arithmetic mean of the corrosion rate along the entire perimeter, then you can get a conditional idea of corrosion wear in general, the cross section of the tubular support.

The change in the average corrosion rate along the height of the support is shown in figure 1.

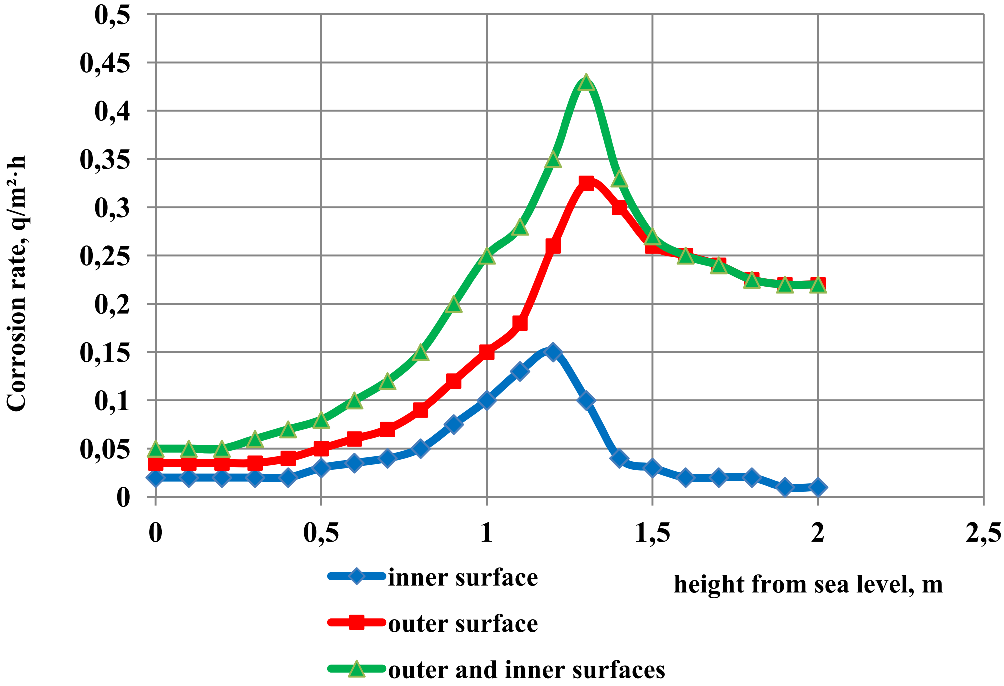


Figure 1 – Dependence of the corrosion rate along the entire perimeter of the foot of a stationary base on the height above sea level

As can be seen from the figure, the most corrosive area is located in the zone of periodic wetting with sea water.

Corrosion of steel in this zone develops under the film of electrolyte and corrosion products in the form of small frequent cavities and is activated by the depolarizing effect of hydrated oxides of ferric iron.

For the examined stationary platform, the thinning of the wall occurs at a speed of 0.23-0.43 mm/year in a section located at an altitude of 1-1.3 meters above sea level.

Dismantling the outer leg post of the stationary base, made after 20 years of operation without corrosion protection, and subsequent profiling of the surface showed that the highest average corrosion rate is 0.33 mm/year at a height of 1.3 m.

For the legs of stationary platforms, a characteristic is the fluctuation in the level of sea water in the annulus, as a result of which there is also corrosion on the inner surface of the foot of the base. Moreover, the maximum value of the average corrosion rate is 0.1 mm/year. Studies have shown that corrosion of the pipe wall from the inside and outside proceeds at a speed of more than 0.43 mm/year. Thus, taking into account local corrosion, individual through sores on pipes with a wall thickness of 11.0 mm can occur after 16-17 years of operation.

In order to assess the condition of multi-kilometer extent of OOHS erected in the Caspian, it is also necessary to determine the corrosion wear on real structures during periodic painting under operational conditions.

OOHS built in various water areas, differing in hydrometeological conditions, have different operation life, a degree of corrosion protection and options for the embodiment of elements at separate facilities. All of the above mentioned determine the uneven corrosion wear of the building elements.

According to the results of mass surveys of the corrosion state of piles of operating structures, it is possible to assess the corrosion wear and determine the interval of its maximum and minimum values.

Figure 2 presents curves showing how the thickness of the wall of piles in the zone of periodic wetting changes over time in the absence of protection and when periodic protection is applied with the paint. Curve b shows corrosive wear at facilities located in the most severe conditions, with irregular corrosion protection.

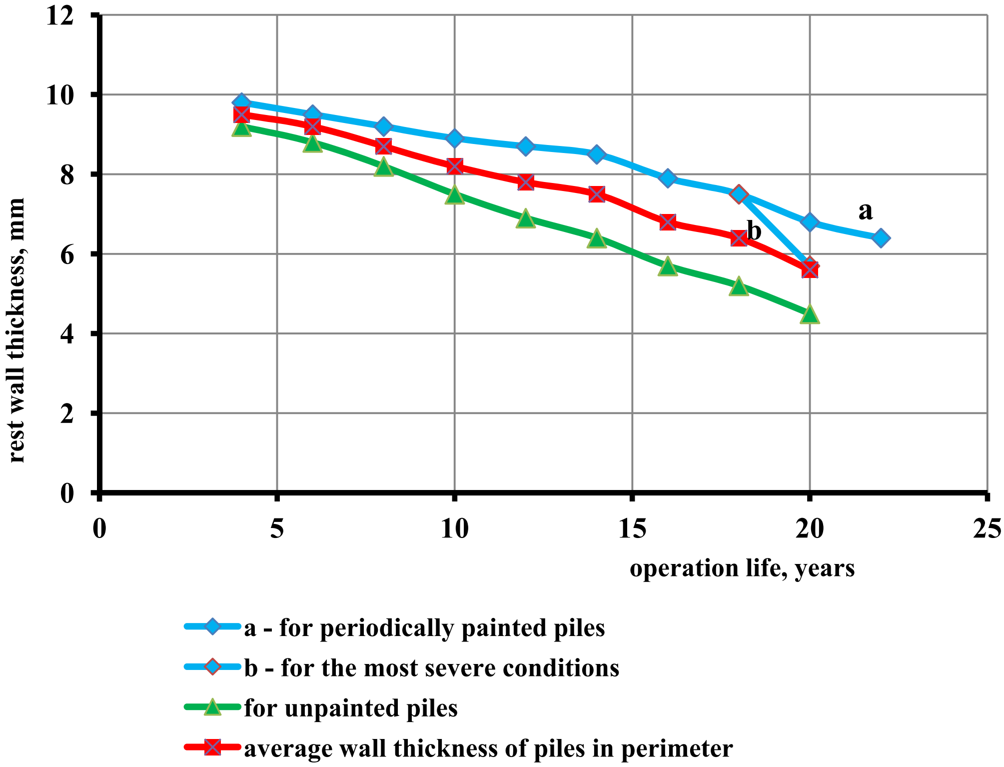


Figure 2 – Dependence of the average value of the remaining wall thickness of piles in the zone of maximum corrosion on the operating time

As can be seen from figure 2, after 16-20 years of operation of the supports, it becomes necessary to restore them in the zone of periodic wetting, while focusing on the increase in overhaul volumes.

The data obtained show that when staining piles operating in difficult conditions, natural corrosion wear is reduced by 40-50%, however, the necessary protection is not provided. It should be noted that the service life of the applied coatings on piles is relatively short and amounts to 2-2.5 years, and the possibility of coating due to frequent sea disturbances is limited to only 92 days a year.

A significant reduction in metal losses due to corrosion in the periodic wetting zone and an increase in the life of fixed assets can be achieved by protecting the support complex of structures with metal and thick polymer coatings applied in the factory.

If the coating is applied after the platform is installed at sea, the cost of the work may be 50-60% higher than carrying out these operations in the factory, and the quality is much lower.

In marine conditions, any damage to the paintwork or other coating is fraught with serious consequences. Therefore, it must be eliminated immediately. After the platform is installed at the point and the well drilling is completed, all anticorrosion coatings are updated in preparation for the next phase of operation. Subsequently, paint coatings are applied every 5-8 years.

In the practice of designing and building new OOHS, it is important to take into account the accumulated material by the nature of the corrosion and mechanical damage observed during operation.

Already, individual solutions should be reviewed both in the design and in the technology of manufacturing structures, work towards increasing operational reliability, significantly increasing the service life of structural elements located in the periodic wetting zone.

So, for example, significant loss of operability of underwater communications in water areas with a hard wave effect indicates that in such conditions it is necessary to use supports from separate blocks manufactured on the shore.

When designing, it is necessary to exclude, if possible, getting into the zone of periodic wetting of connecting parts and welds. The technology for the manufacture of structures of the surface complex of structures should provide for high-quality factory deposition of corrosion-resistant coatings that provide at least 30 years of service without restoration of the structure.

The practice of operating OOHS has shown that the anticorrosive protection of the supports carried out during operation is ineffective, therefore only a positive solution to the tasks posed will reduce the amount of expensive repair work carried out on the support of towers, significantly increase the overhaul period, and thereby increase the economic efficiency of the operation of structures in general.

If it is necessary to conduct anti-corrosion measures in the conditions of operating supports of hydraulic structures in the zone of periodic wetting, it is very advisable to use lubricating compositions. For this purpose, a lubricant composition based on locally produced products was developed. BNB 70/30 grade bitumen, technical salomas, heavy high-temperature resin, “KAB” brand bactericidal inhibitor were used in developing this grease, and natural bitumen containing sand and clay were used as a filler [21].

Field tests of lubricant were carried out at 34 overpass platform of OGEI named after N.Narimanov. Field tests have shown that the lubricant has anticorrosive and sealing properties, good hiding power, high adhesion to the metal surface, stability, and provides effective protection of hydraulic structures supports against corrosion in the periodic wetting zone.

To protect hydraulic structures in the atmospheric zone, a primer - rust converter and bitumen-polymer mastic (BPM) based on non-deficient local raw materials was developed and tested.

The new rust converter is based on phosphoric acid, bottoms of polypropylene glycol, isopropyl alcohol and surfactants. Upon receipt of the new BPM, organic solvents, BNV-70/30 bitumen, SKS rubber, water glass, polymer-propylene resin and natural bitumen containing sand and clay were used as filler. To enhance the anti-corrosion properties, corrosion inhibitors based on fatty acids, asidole, and light gas oil were introduced into the mastic, which also positively affect the hiding power and mechanical strength of the mastic.

Thus, the use of the developed compositions based on inexpensive products to protect the supports of hydraulic structures from corrosion damage during their operation allows preempting environmental damage and is economically feasible.

**Conclusions.** 1. Surveys have shown that on piles of overpass structures that have been in operation for 12-20 years, the corrosion rate is on average 0.22 mm/year.

2. The thinning of the wall of the stationary platform in the zone of periodic wetting at an altitude of 1.3 meters above sea level occurs at a speed of 0.33 mm/year. The average loss of pile wall thickness is 32%.

3. To protect the supports of hydraulic structures from corrosion in the atmospheric zone and in the period of periodic wetting during the destruction of the factory protective coating, it is proposed to use compositions based on cheap local raw materials.

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## ЭКОЛОГИЯЛЫҚ ЗАЛАЛДЫҢ АЛДЫН АЛУ ҮШІН КАСПИЙ ТЕҢІЗІНДЕГІ ГИДРОТЕХНИКАЛЫҚ ҚҰРЫЛЫСТЫҢ КОРРОЗИЯЛЫҚ ЖАҒДАЙЫН ДИАГНОСТИКАЛАУ

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# ДИАГНОСТИКА КОРРОЗИОННОГО СОСТОЯНИЯ ГИДРОТЕХНИЧЕСКИХ СООРУЖЕНИЙ НА КАСПИЙСКОМ МОРЕ ДЛЯ ПРЕДОТВРАЩЕНИЯ ЭКОЛОГИЧЕСКОГО УРОНА

Длительная эксплуатация нефтепромыслового оборудования и гидротехнических сооружений часто приводит к усилению коррозионного разрушения подземного и наземного оборудования. Это чревато возникновением аварий, пожароопасных ситуаций и неконтролируемым разливом нефти, что становятся причиной не только прямых материальных потерь, но и нарушения экологического равновесия.

Для оценки коррозионного состояния эксплуатируемых морских нефтепромысловых гидротехнических сооружений (МНГС) проводились массовые измерения толщины стенки элементов конструкций ультразвуковым толщиномером. Обследования показали, что на сваях эстакадных сооружений, эксплуатирующихся в течение 12-20 лет, скорость коррозии в среднем составляет 0,22 мм/год. При этом на отдельных объектах она колеблется от 0,15 до 0,28 мм/год. Средние потери толщины стенки свай составляют 32 %, а на отдельных объектах - от 17 до 51%.

Обследование свай после многолетней эксплуатации без антикоррозионной защиты показывает, что продукты коррозии неравномерно покрывают их поверхность. При этом обнаружено, что распределение продуктов коррозии зависит не только от гидрометереологичесих условий акватории расположения объекта, но и от глубины моря, рельефа дна, розы ветров, расположения опор под перекрывающими конструкциями, т.е. от степени солнечного облучения поверхности. Например, при глубине моря 11 метров и солнечном облучении с южной и западной стороны опора с северной стороны покрыта слоистыми продуктами коррозии от уровня моря до 4,5 м, а с южной стороны – только до 2,3 м.

Так, на незащищаемых сооружениях уже через 18-20 лет эксплуатации обнаруживаются сквозные коррозионные поражения на трубчатых элементах с первоначальной толщиной стенки, равной 11,0 мм.

Для обследованной стационарной платформы утончение стенки происходит со скоростью 0,23-0,43 мм/год в сечении, расположенном на высоте 1 -1,3 метра над уровнем моря.

Демонтаж наружной стойки ноги стационарного основания, произведенный после 20 лет эксплуатации его без антикоррозионной защиты, и последующее профилирование поверхности показало, что наибольшее значение средней скорости коррозии составляет 0,33 мм/год на высоте 1,3 м.

Для ног стационарных платформ характерным является колебание уровня морской воды в межтрубном пространстве, вследствие чего отмечается также коррозия на внутренней поверхности ноги основания. При этом максимальное значение средней скорости коррозии составляет 0,1 мм/год. Исследования показали, что коррозия стенки трубы с внутренней и внешней стороны протекает со скоростью более 0,43 мм/год. Таким образом, с учетом местной коррозии отдельные сквозные язвы на трубах с толщиной стенки 11,0 мм могут возникать уже через 16-17 лет эксплуатации.

Значительного сокращения потерь металла на коррозию в зоне периодического смачивания и увеличения срока службы основных фондов можно достичь, защитив опорный комплекс сооружений металлическими и толстослойными полимерными покрытиями, наносимыми в заводских условиях.

При необходимости проведения антикоррозионных мероприятий, осуществляемых в условиях эксплуатации опор гидротехнических сооружений в зоне периодического смачивания, весьма целесообразным является использование смазочных композиций. С этой целью была разработана смазочная композиция на основе продуктов местного производства. При разработке данной смазки использовались битум марки БНБ 70/30, саломас технический, тяжёлая пиролизная смола, бактерицид-ингибитор марки «КАБ» и в качестве наполнителя – природные битумы, содержащие песок и глину.

Промысловые испытания смазочного материала были проведены на эстакадной площадке № 34 НГДУ им. Н.Нариманова. Промысловые испытания показали, что смазочный материал обладает антикоррозионными и уплотняющими свойствами, хорошей укрывистостью, высокой адгезией к поверхности металла, стабильностью, обеспечивает эффективную защиту опор гидротехнических сооружений от коррозии в зоне периодического смачивания.

Для защиты гидротехнических сооружений в атмосферной зоне было были разработаны и испытаны грунтовка – преобразователь ржавчины и битумно-полимерная мастика (БПМ) на базе недефицитного местного сырья.

Новый преобразователь ржавчины разработан на основе ортофосфорной кислоты, кубового остатка ПОЛИпропиленгликоля, изопропилового спирта и ПАВ. При получении новой БПМ были использованы органические растворители, битум БНВ-70/30, каучук СКС, жидкое стекло, смола полимерная-пропиленовая и в качестве наполнителя природные битумы, содержащие песок и глину. Для усиления антикоррозионных свойств в состав мастики были введены ингибиторы коррозии на основе жирных кислот, асидола и легкого газойля, которые положительно влияют также и на укрывистость и механическую прочность мастики.

**Ключевые слова:** гидротехнические сооружения; коррозия; агрессивность среды, зона периодического смачивания.

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