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Contactless Monitoring Systems for the Offshore Production Platforms

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Abstract

The report describes a contactless system for monitoring the technical condition of the production platforms. Technological binding of the caissons of offshore platforms requires the creation of a monitoring system. A monitoring system has been proposed to reduce the risk of operating production platforms with caissons. The complex of equipment for the monitoring system of the platform is described. The monitoring system is based on the use of the method of magnetic tomography.

Introduction

Periodic maintenance of the technological binding of the caisson is necessary to maintain its reliability. Maintenance of the caisson strapping should be based on its real technical condition according to RBI (Risk Based Inspections) methodology. Usually, the control of the technological strapping is carried out in manual mode with complete emptying of the caisson. With constant discharge and loading of oil is a cyclic loading of the technological binding. Cyclic loads contribute to the accelerated development of latent defects. The defect growth can lead to failure of the caisson equipment. Monitoring systems based on magnetic tomography are designed to prevent such situations.

Reducing the risk of accidents on the technological piping is achieved by timely identification and elimination of the main causes of accidents: factory defects of metal; defects in welding and assembly work during pipeline construction; metal defects that have arisen during operation under the influence of natural factors (stress corrosion cracking, hydrogen embrittlement) (4, 6, 9, 11, 13, 15, 17). One of the promising areas of technical diagnostics of pipelines is contactless magnetometry for the analysis of the degree of mechanical stress concentration and monitoring of local concentrators in operation. One of the promising areas of technical diagnostics of pipelines is non-contact magnetometry for the analysis of the degree of mechanical stress concentration and monitoring of local concentrators in operation. From this point of view, the magnetic tomography method is very promising, which is based on the Villary effect and makes it possible to observe the development of the defect as a stress concentrator up to quantitative indicators of the risk of transition to the limit state. The monitoring system allows you to respond quickly to possible emergency situations and prevent failures at the stage of origin of risks (5, 7, 8, 10, 12, 14, 16, 18).

The oil fields of the shelf occupy a growing volume in the oil production and penetrate deeper and deeper into the open sea. Coastal fields continue on the underwater part of the mainland to the shelf zone. Its boundaries are the coast and the so-called edge - a distinct ledge, beyond which the depth increases rapidly. Along with the complex structure, these structures are operated in very aggressive conditions, including wind, wave, ice loads, cyclic rhythm of work, the impact of various aggressive agents, including corrosion-mechanical nature. Such conditions determine the high relevance of the problem of monitoring the technical condition of marine facilities.

The main types of offshore oil platforms are divided into the following:

- offshore floating drilling rigs are vessels capable of drilling and resource extraction. They, in turn, are divided into self-lifting, semi-submersible, submersible, floating drilling rigs on tension ties, drilling vessel and drilling barge;
- offshore fixed platforms are offshore oil and gas facilities consisting of an upper structure and a support base fixed on the ground. Marine fixed platforms are divided into gravity, pile and mast. As part of offshore fixed platforms there are structural islands - the caissons. Caisson – shallow platform on a solid metal base.
- offshore oil and gas facilities are structures that carry out processes for the extraction, transportation, storage and processing of oil and gas from fields (1).

The development of the largest Prudhoe Bay field (USA) on the Arctic shelf of Alaska required the development of special stationary platforms that can withstand ice loads, such as large caisson platforms. Examples of a caisson ice-resistant platforms are the platform "Prirazlomnaya" in the Pechora Sea (19, 20) and Molikpaq, or "Piltun-Astokhskoye-A", on the shelf of Sakhalin Island. These platforms contain the lower part, consisting of several sections. Each section is a caisson filled with oil. The caisson part of the platform serves as a ballast that presses the bottom of the platform to the surface of the seabed.

A general view of the platform is shown in Fig. 1, and the details of the structure are shown in Fig. 2. The platform can collect and store a large amount of oil, collecting it from wells at different depths and distances from it. The caisson represents the basis serving as a support for the intermediate deck and the top structure, and including the equipment and complexes for storage of oil.

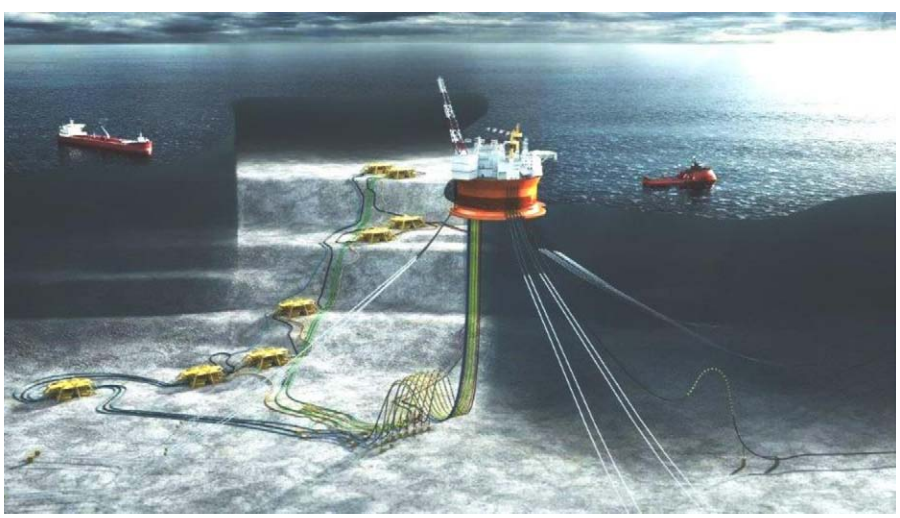

Figure 1—General view of the platform with facilities for the storage of oil - a caisson.

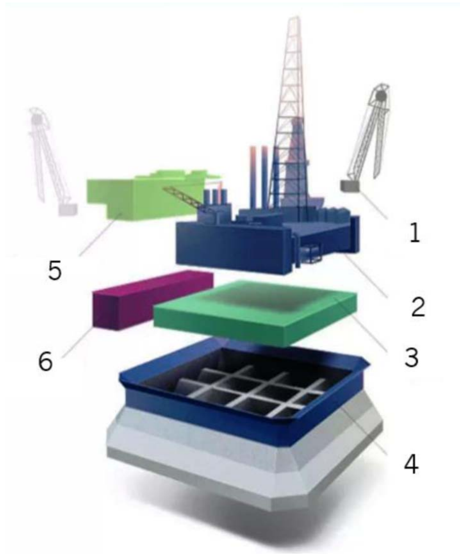

Figure 2—Schematic representation of a platform structure with a caisson, where 1 - shipment module; 2 - upper structure; 3 - intermediate deck; 4 - caisson; 5 - additional module; 6 - auxiliary module. Source: PJSC Gazprom Neft.

The oil company LLC Gazprom Neft Shelf, a subsidiary of PJSC Gazprom Neft, is currently engaged in oil production at the "Prirazlomnoye" oil field located in the Pechora Sea of the Russian Arctic shelf (19, 20). According to specialists of Gazprom Neft Shelf LLC, "the foundation of the platform (caisson) is simultaneously a buffer between the well and the open sea. Caisson is a unique development: it carries the main load, and the reliability of the entire platform depends on its reliability. It is the caisson part that allows the sea ice-resistant stationary platform «Prirazlomnaya» to successfully resist the harsh Arctic climate, protect all equipment and ensure the safe operation of personnel. The safety margin of the platform base is many times greater than the actual load. For greater resistance to corrosion and wear, the walls of the caisson are made of a layer of clad steel with a thickness of four cm, the three-meter space between which is filled with heavy-duty concrete. To protect against high humidity and aggressive marine environment, a special paint coating and cathodic and anodic protection systems are used". Figure 3 shows the detailed design of the caisson in the section.

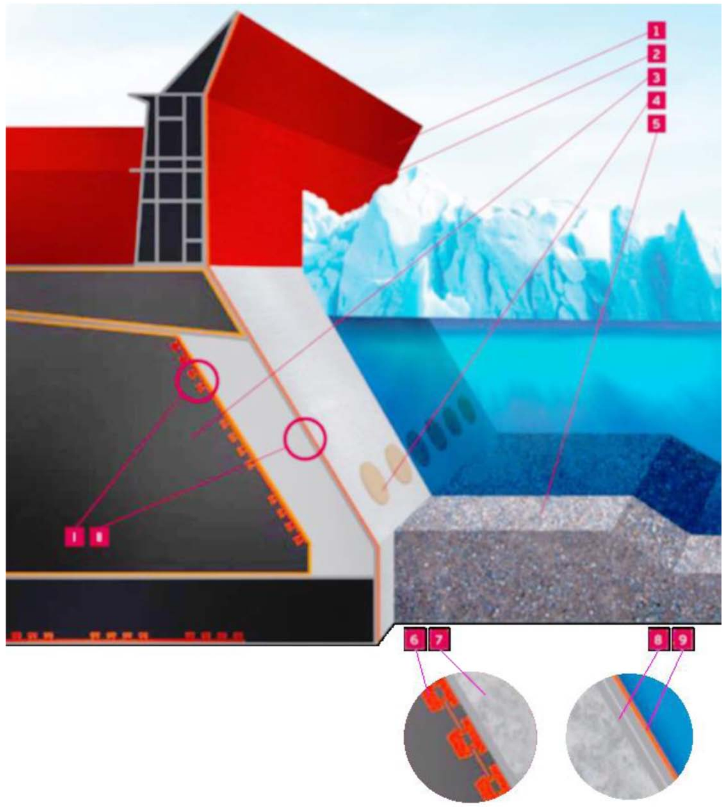

Figure 3—Design of the caisson in the section: 1 - wave deflector, 2 - ice deflector, 3 - resistant paint coating of oil storage tanks, 4 - electrical corrosion protection, 5 - bulk soil layer, 6 - protection against corrosion, 7 - concrete 3 m thick, 8 - double-layer steel sheet, 9 - cladding with stainless steel. Рис. 4. 3D схема кессона. Source: PJSC Gazprom Neft.

In fig. 4 the structure of extensive internal piping and its technological devices is presented. These technological elements are very important in the operation of the entire platform, since failure of any of them can lead to failure in the production/loading of the whole complex. Periodic maintenance of the platform infrastructure with an oil collection and storage point (caisson) and technological caisson binding is necessary to preserve its reliability and should be based on the actual technical condition according to the methodology of RBI (Risk Based Inspections) (14). The Risk Based Inspections methodology is a system of technical condition control, in which the frequency of monitoring is set according to the results of a platform operation risk analysis. Monitoring of the technological strapping condition can currently be performed only in manual mode with full emptying of the caisson.

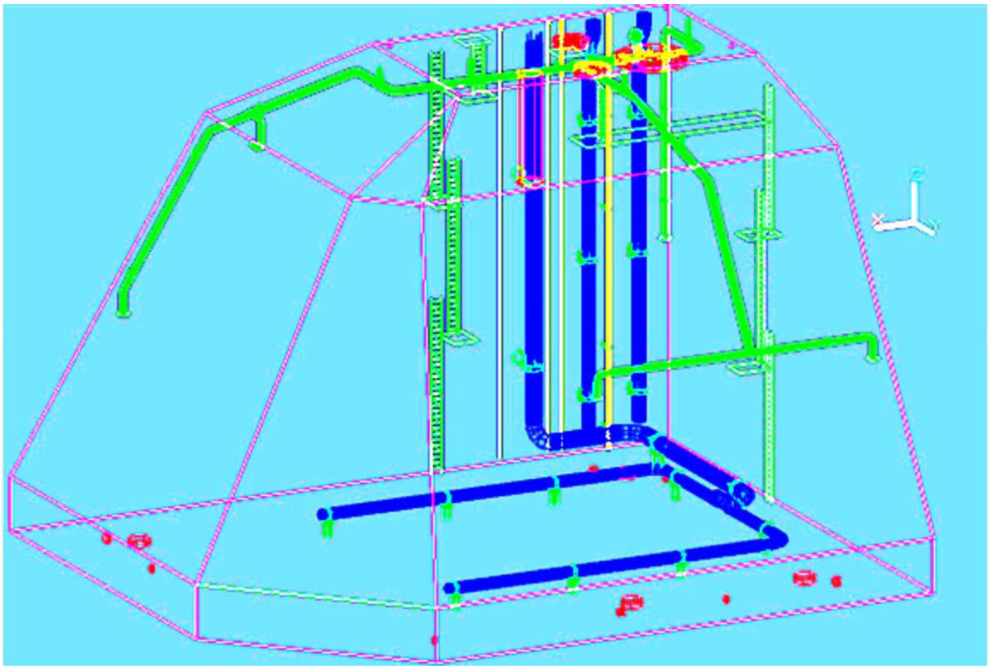

Figure 4—scheme of the caisson. Source: PJSC Gazprom Neft.

To carry out these procedures, operating organizations have established maintenance procedures. The regulations of the technical inspection during the working cycle of the caisson exclude the admission of non-destructive testing specialists to the site, which raises suspicions of reliability. The situation with the constant discharge and loading of oil can change significantly. Due to cyclic loading — this helps to accelerate the development of defects, which in turn can lead to failure of technological strapping equipment caisson and exit it in emergency mode or to a complete stop. In the event of an emergency, this can lead to serious economic and environmental consequences due to equipment downtime and fines, and even to fatal accidents. Monitoring systems of technical condition are designed to prevent such situations.

Traditional methods of defectoscopy practically do not provide reliable detection of fatigue phenomena of the metal structure due to the negligible geometrical dimensions of the emerging defects. The dimensions of the loading concentration zones are large and significantly exceed the dimensions of a single defect (4). For example, the magnetic coercimetric method is traditionally used to detect the load concentrations only in areas with certain structural features of a construction. A number of authors believe that this cannot be any accident, because all designs are built according to the same laws and principles of theoretical mechanics and resistance of materials.

In the assessment of metal defects (that is, in the main field of application of non-destructive testing methods), the methods of flaw detection guarantee high reliability and reproducibility of control only under the conditions of stationary automatic flaw detection installations of the manufacturer of the metal structure. Operational control of the equipment in the common examination is performed by manual flaw detectors, which do not provide high performance and reliability, as well as reproducibility, not to mention the possibility of automatic generation of reports and filling in the database.

The complexity of the preparation of the metal surface for control using traditional methods of ultrasonic flaw detection at existing facilities of the oil and gas industry dictated the significant interest of developers to the magnetic control methods. The proposed monitoring system using contactless magnetometry is designed to provide status monitoring of the equipment of the caisson without stopping it, notify about the emergence of a critical situation in the process equipment and automatically prevent the occurrence of accidents. The special relevance of these methods is associated with their accuracy, high information content, high performance, and, mainly, with the possibility of contactless control and monitoring (5). Their advantage in detecting fatigue damages of metal is very significant.

Reducing the risk of pipeline accidents is achieved by timely identification and elimination of the main causes of accidents:

- factory metal defects;
- defects of welding-installation works during construction of the pipeline;
- metal defects that have arisen during operation under the influence of natural factors (stress corrosion cracking, hydrogen embrittlement, soil movements, etc.).

One of the promising areas of technical diagnostics of pipelines is the contactless magnetometry for the analysis of the degree of mechanical stress concentration and monitoring local concentrators under operating conditions. From this point of view, the method of magnetic tomography is very promising, which is based on the Willary effect and makes it possible to observe the development of a defect from stress concentration until a risk of transition to the risk of transition to the limit state [HL 102-008-2002]. This allows you to quickly respond to possible emergency situations and prevent failures at the stage of origin of accident risks.

The schematic diagram of the monitoring system by contactless magnetometry includes the following steps:

- decision making;
- output information about the technical condition;
- analysis of input data;
- collection and transmission of signals;
- signal acquisition and transmission;
- measurement with the use of a set of sensors from 10 to 100 pcs. per single signal processing unit.

If necessary, the sensors are installed in the areas of anomalies to conduct continuous monitoring of the state of the caisson pipelines. The sensor blocks are set up at some distance from the defect using specialized fasteners that are inert to hydrocarbons and wet environments, see fig. 5. At the control room, an alarm system and information about the adoption of standard decisions is installed. The training of a team of dispatchers is carried out. Data collection is carried out according to the regulations. In the process of machine learning of the monitoring system, a phased loading of the caisson tank takes place, during which typical magnetic response levels are recorded, which are taken as benchmarks. The monitoring system accumulates a "knowledge base" and, in case of exceeding the established threshold values, issues a warning at the control station. Exceeding the threshold value will indicate a critical growth of the identified defect.

Figure 5—Scheme of continuous monitoring of the state of caisson pipelines on the basis of magnetic tomography technology.

Data transmission to the control room is carried out via a wired RS-232/485 interface. The monitoring system is designed to prevent abnormal situations in the operation of technological equipment of the caisson. Based on big data processing, the system can predict potential malfunctions of the process equipment. The established monitoring system increases the reliability of the entire caisson complex as a whole, improves economic performance and reduces the likelihood of adverse events (abnormal situations, accidents, emissions, shutdowns of the production platform).

Conclusion

A system for monitoring the technical condition of the caisson strapping has been created. During the maintenance of the caisson, specialists of contactless testing determine the state of the process equipment. Critical, dangerous and nascent defects are identified. Required scheduled or emergency repairs are carried out. In the identified zones of stress concentrators, sensors are installed to collect magnetic data, and a monitoring system for the growth of defects from loading cycles is installed.

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