Oil tank operation efficiency

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Abstract. Oil tank operation efficiency highly depends on the bottom sediments clean out technologies. In order to monitor oil tank efficiency and provide design improvements certain electro-physical studies were performed. These studies allowed to find the homogeneity conditions; oil-water phase boundary; monitor and identify the state of matter and lead to significant design improvements. It was proposed to update design and arrangement of the inlet and outlet nozzles of oil tank and place them in opposite sides of tank. Along with continuous electro-physical monitoring of the phase boundaries new design allows to increase overall efficiency of oil tank.

1. Introduction

Currently oil tank operation efficiency is an utmost important topic for the petroleum industry. Operation of oil tanks represents high industrial risks [1-6]. Therefore, over the last decade, petroleum industry developed and implemented remote monitoring systems to prevent catastrophes and serious incidents, that used to happen before and affect industrial safety. However, it was found out, that personnel on site has lack of understanding of the physical and chemical processes happening in the oil tank and consequently it leads to major human based errors during operation and maintenance of the reservoir.

- Remote monitoring systems can be divided into two groups: operational methods with real-time intervention and monitoring methods that lead to planned maintenance. In addition to that, monitoring methods can be divided by processes used: physical, chemical, biological, microbiological etc.
- Physical methods allow to instantly determine current state of oil samples in comparison to chemical or biological methods that require more time and can change sample properties. However, only combination of methods can help to achieve best results: passive methods provide high accuracy and lead to planned improvements, while active methods allow quick interventions on the oil storage environment.
- Electro-physical methods are an exceptional part of physical and technological methods overall. The major advantages are: 1) real-time monitoring; 2) contactless investigation; 3) minimal effect on the object properties; 4) ease of data transfer; 5) ease of intervention using same data-transfer infrastructure.
2. Materials and methods

In order to determine homogeneity conditions and oil-water phase boundary using electro-physical methods a new device was developed. This device allows to determine electrical conductivity measuring electrical current passing through test medium [7]. The new device allows to quickly monitor and signal the appearance of liquid heterogeneity in the tank, which leads to increased efficiency in the operation of oil tanks by means of remote parameter control and modern methods of information visualization (Figure 1).

Improvement of the operation efficiency of oil tanks is directly related to monitoring and identification of the state of oil and its components stored in oil tanks [8]. For this research, bottom sediments from Vertical Stock Tank with Pontoon 5000 m$^3$ Pipeline Remote Pumping Station Subkhankulovo were used and oil from the field Ashchisay, which both are characterized by high paraffin content.

![Figure 1. Device for contactless monitoring of phase state boundaries. 1 – device to monitor phase state boundaries; 2- dielectric stem.](image)

In order to determine required parameters, frequency range and research methods to be used, set of experimental studies was conducted in a wide range of electrical frequency 0.3 Hz – 10 MHz and temperatures 20 deg.C – 70 deg.C. Digital impedance spectroscopy method was improved by digital signal processing [9], which allowed to calculate energy characteristics of samples, i.e. activation energy. According to the results of studies, it was found that in the temperature range below and above 40 deg.C, the activation energy of bottom sediments has values that differ from each other by an average of 2 times, based on difference in the electrophysical properties of the samples and, as a consequence, their phase state. The results obtained make it possible to establish the temperature limits for the transition of oil components from solid to liquid and vice versa (at which the formation and accumulation of bottom sediments do not occur) to either prevent sedimentation or choose effective clean out procedure.

3. Results

According to the results of experimental studies on medium at its stable state, there were determined a number of dependences of bridge unbalance current on the position of the interface between different media (under given positions of the interface). Graphs are plotted for a resulted value of the output voltage of a high-frequency generator. The graphs constructed in Figure 2 are taken for five preset frequencies of the high-frequency generator (harmonic signal), however changing the frequency does not affect the nature of the curve itself. After analyzing these graphs, three sections can be noted on...
them - the first from 0 to 87, the second from 87 to 140 and the third from 140 to 174. The first section is characterized by a constant current value, which indicates the presence of one liquid - water, the second section is characterized by the greatest steepness, which indicates the ingress of both media into the zone of half-cut metal electrodes, and the third section with a constant value of current strength again indicates the homogeneity of the medium, in this case air. Thus, according to the plotted graph, we determine the interface between the media.

![Graph](image)

**Figure 2.** Graph to determine homogeneity of phases and interface water-air.

In Figure 3, graphs similar in nature to those in Figure 2 are observed. Similar studies are carried out at five fixed frequencies of the generator at a known value of the interface and it is also possible to determine a ‘jump’ at the point of the oil-water interface.

![Graph](image)

**Figure 3.** Graph to determine homogeneity of phases and interface oil-water.

If during operation of the tank the temperature is maintained above the experimentally determined temperature limit for the oil, then the formation of bottom sediments is not expected and, accordingly, clean out of deposits is not required, but if it is below the experimentally determined temperature
boundary, gradual formation of bottom sediments will accordingly occur and it is necessary to wash out sediment in the tank (Figure 4-5).

In the absence of a ‘jump’ in the values of electrical conductivity of the active component or the dielectric loss tangent for the test sample in the temperature range from 20 to 70 deg.C and the frequency range from 4 Hz to 1000 Hz during the operation of oil reservoirs, sediment formation will not occur and the bottom sediments clean out is not required. The results of the study should be taken into consideration for the relatively low temperatures due to the possible occurrence of electrostatic discharges under low conductivity of bottom sediments.

Based on the results of identification of the phase of oil and its components, a decision is made on the necessity of clean out of sediments in the tank, i.e. putting tank fluids into motion. For effective clean out of bottom sediments, using electrophysical research methods reconstruction of the inlet and outlet nozzle assembly is also proposed: the nozzles are installed on the diametrically opposite side of the tank body wall [10-11]. In this case, stagnation of the product does not occur in areas remote from the reception and distribution pipes (Figure 6).

![Figure 4. Dependence of electrical conductivity on frequency response of the active component for the sediments from same tank.](image1)

![Figure 5. Dependence of electrical conductivity on frequency response of the active component for the Ashchisay oil.](image2)

The economic effect of the proposed developments and recommendations is significant. For example, Vertical Stock Tank with Pontoon 5000 m$^3$ in accordance with the operating rules are subject to sediment wash out in the following cases:

- before conducting a full technical diagnosis (for sheet assembly: periodicity 1 time in 20 years for a life of up to 20 years and 1 time in 10 years for a life more than 20 years; for roll
assembly: frequency of 1 time in 10 years for a life of up to 20 years and 1 time in 8 years with a service life more than 20 years).

- before carrying out repair work;
- when dismantling the tank;
- with periodic release from mechanical deposits, oil sludge;
- when changing the brand of petroleum products.

The overall dimensions of the Vertical Stock Tank with Pontoon 5000 m$^3$ are as follows: diameter = 22.8 m, height = 11.94 m. Geometric volume of this tank is 4875 m$^3$, while the useful capacity is 4620 m$^3$, and in the presence of a pontoon - is 4002 m$^3$.

**Figure 6.** Improved design of an oil tank. 1 – outlet nozzle; 2 – inlet nozzle; 3 – dielectric stem; 4 – device for contactless monitoring of phase homogeneity and phase interface.

For this type of oil tank average cost of one clean out procedure is around 1.0 million rubles (14.6 KUSD), excluding estimated overhead costs, miscellaneous costs, taxes and mandatory payments. At the same time, the following measures are envisaged:

- Installation / dismantling of equipment for degassing;
- Cleaning with brushes and scrapers of the inner surface of the tank at a height;
- Degassing the tank using fans;
- Clean out of bottom sediments with water;
- Pumping out washed out bottom sediments (emulsions) by a pumping unit;
- Flushing the inner surface of the tank;
- Steaming the surface of technological pipelines and equipment inside the tank;
- Wiping surfaces with rags (walls, lower deck of the pontoon, pontoon racks, pontoon guide, etc.);
- Handling of the inner surface of the tank from solid deposits with the subsequent removal of oil sludge from the tank.

Due to installation of inlet and outlet nozzles on the diametrically opposite side and the use of electrophysical methods for monitoring the phase boundary, the cost of mandatory measures for cleaning the tank is reduced by 20% due to the reduction in the number of bottom sediments.
4. Discussion and Conclusion

1. Efficiency of oil tanks operation is achieved due to the use of a new monitoring device for remote parameter control, modern methods of information visualization, and monitoring of oil homogeneity and the oil-water interface in tanks, which altogether improves the quality of the pumped oil.

2. One of main advantage of new method – that it allows to reduce the operation cost of the tank by timely efficient clean out, re-design of inlet and outlet nozzle arrangement on the diametrically opposite side of the tank and, as a result, the increase of mean time between maintenance.

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