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OILY-WATER TANK OPERATIONAL RELIABILITY ANALYSIS IN AN OIL AND GAS FACILITY

ANALIZA RADNE POUZDANOSTI REZERVOARA ZA MEŠAVINU NAFTA-VODA U NAFTOM-GASNOM POSTROJENJU

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- cone roof
- cathodic protection
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Ključne reči
- skladišni rezervoar
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- katodna zaštita
- pregled

Abstract

The paper deals with one of the most general classifications of atmospheric tanks according to their roof type in oil and gas plants. An overview of recommended time frames for inspection of storage tanks is given, depending on their structural characteristics. A detailed view of the storage tank with cone roof is shown, after it was taken out of service for examination purposes. An appropriate necessary random scheme is created for ultrasonic examinations of the tank bottom as its most critical element. Damages observed during the inspection are analysed in detail and remediation plans are prescribed in order to return the inspected tank to its correct condition for further uninterrupted long-term continuous operation.

Izvod

U radu je prikazana jedna od najopštijih podela atmosferskih rezervoara u skladu sa tipom njihovih krovova u naftnim-gasnim postrojenjima. Dat je pregled preporučenih vremenskih perioda za pregled skladišnih rezervoara u zavisnosti od njihovih konstrukcionih karakteristika. Prikazan je detaljan pregled skladišnog rezervoara sa konusnim krovom nakon njegovog stavljanja van upotrebe za potrebe inspekcije. Izrađena je odgovarajuća potrebna random šema za potrebe ultrazvučnog pregleda dna rezervoara, kao njegovog najkritičnijeg elementa. Pregledom uočena oštećenja su detaljno analizirana i propisani su planovi za sanaciju kako bi se rezervoar vratio u ispravno stanje za dalji nesmetan kontinuiran rad.

INTRODUCTION

Storage tanks are used to store fluids such as crude oil, intermediate and refined products, gas chemicals, waste products, water/product mixtures. Important factors such as volatility of the stored fluid and desired storage pressure and temperature result in tanks being built of various types, sizes, and materials, /1/. Storage tanks (often called e.g. atmospheric tanks) in the petroleum industry are normally used for fluids having a true vapour pressure less than atmospheric pressure. Vapour pressure is the pressure on the surface of a confined liquid caused by the vapours of liquid. Vapour pressure increases with increasing temperature. Crude oil, heavy oils, gas oils, furnace oils, naphtha, gasoline, and non-volatile chemicals are usually stored in atmospheric storage tanks. Many of these tanks are protected by pressure-vacuum vents that limit the pressure difference between the tank vapour space and the outside atmosphere to a few ounces per square inch.

Non-petroleum industry uses of atmospheric tanks include storage of a variety of chemicals and other substances operating in closed-loop systems not vented to atmosphere and with pressure control and relief devices as required.

These tanks may be designed and operated as low-pressure storage tanks according to the requirements of API 620 standard, /2, 3/.

Additional use of atmospheric storage tanks can include liquid (both hydrocarbon and non-hydrocarbon) storage in horizontal vessels, storage of process liquids, or granular solids in skirt-supported, or column-supported tanks with elevated cone bottoms (non-flat bottom), and process water/liquids in open top tanks.

In general, there are many classifications of storage tanks according to many criteria, such as dimensions, shapes, and working parameters. One parameter for storage tank classification, often used, is type of their roof, as follows, /2/:
- storage tanks with cone roof (Figs. 1 and 2), /4/;
- storage tanks with umbrella roof;
- storage tanks with geodesic dome roof;
- self-supporting dome roof tanks;
- pan type floating-roof tank;
- annular pontoon floating-roof tank;
- double-deck floating-roof tank;
- cable supported internal floating roof tank;
- plain breather roof tanks;

- balloon roof tanks;
- tank with vapour dome roof;
- welded horizontal tank supported on saddles;
- plan hemispheroids storage tanks;
- noded hemispheroid storage tanks;
- plan spheroid storage tanks;
- plain hemispheroid with knuckle radius storage tanks;
- noded spheroid storage tanks, /2/.

Figure 1. External view of tank with cone roof.

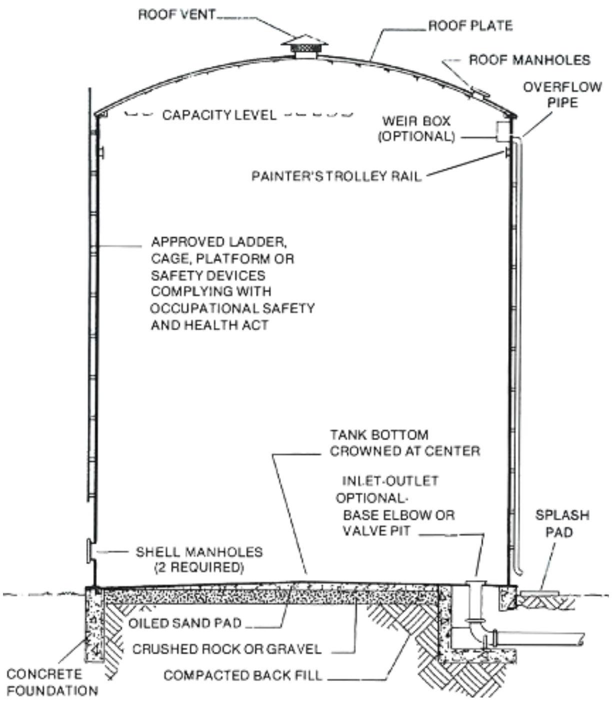

Figure 2. Installation scheme of tank with cone roof.

Between previously mentioned types of storage tanks, the most common used type of atmospheric tank in the oil and gas plant is storage tank with cone roof primarily due to its simplicity of construction. Taking into consideration facts that problems of these storage tanks in their service life in available literature have not been sufficiently investigated, and the very goal of the paper is that these problems are analysed in a proper manner.

Reasons for the overview and creating the ultrasonic random thickness scheme

Atmospheric storage tanks are expected to operate over long periods and corrosion at the bottom of the tanks can cause serious problems, /5/, such as the release of substances with adverse consequences for humans and environment /6, 7/. The basic reasons for inspection are to determine the physical condition of the tank and to determine the type, rate and causes of damage mechanisms and associated deterioration. This information should be carefully documented after each overview. Information and data gained from inspection contributes to the planning of future inspections, repairs, replacement, and yields a history that may form the basis of a risk-based inspection (RBI) assessment, /8-11/. The petroleum industry is committed to protecting the environment as well as the health and safety of its employees and the public at large. Therefore, minimizing the incidence of leaking petroleum storage tanks is a high priority in the industry. Corrosion (especially) of tank bottom is the prime cause for deterioration of steel storage tanks and accessories. Locating and the measuring the extent of corrosion is a major reason for storage tank inspection. If left unchecked, tank deterioration can progressively lead to failure which may have adverse effects, such as endangering personnel, environmental and property damage, and business interruptions, /1/. For needs of the previously mentioned method for tank bottom evaluation is creating an appropriate ultrasonic random scheme for conducting storage tank overview. An example of an ultrasonic random scheme for tank bottom is presented in Fig. 3.

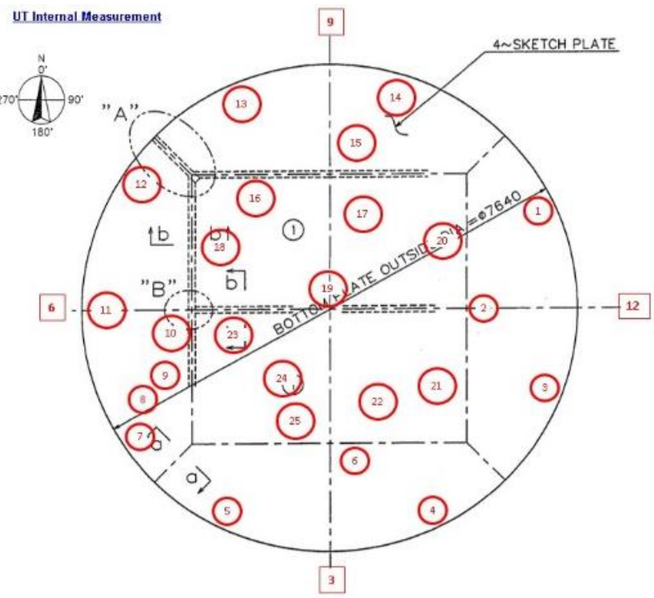

Figure 3. Ultrasonic random scheme for tank bottom overview.

Calculation of initial internal overview interval

The time interval after initial service until the first internal inspection shall not exceed 10 years unless a tank has one or more of: leak prevention, detection, corrosion mitigation, or containment safeguards, as listed in Table 1. The initial inspection overview date shall be based on incremental credits for additional safeguards in Table 1, which are cumulative. The initial overview interval shall not exceed 20 years for tanks without a release prevention barrier, or 30 years for tanks with a release prevention barrier.

Table 1. Calculation of tank inspection intervals, according to tank additional protection.

No	Tank additional protection	Add to initial interval
1	Fiberglass-reinforced lining of the product side of the tank bottom installed per API 652	5 years
2	Installation of an internal thin-film coating as installed per API RP652	2 years
3	Cathodic protection of the solid-side of tank bottom installed, maintained, and inspected per API RP651	5 years
4	Release prevention barrier installed per API 650, Annex I	10 years
5	Bottom corrosion allowance greater than 0.150 inch	(Actual corrosion allowance-150 mils)/ corrosion rate
6	Bottom constructed from stainless steel material that meets requirements of API 650, Annex SC, and either Annex S or Annex X; and internal and external environments have been determined by a qualified corrosion specialist to present very low risk or cracking or corrosion failure	10 years
	Corrosion rate to be 15 mpy, or as determined from Annex H, Similar Service	-

As an alternative to establishing the initial interval in accordance with previously mentioned and Table 1, the initial internal overview and reassessment can be established using RBI inspection assessment, /4/.

Storage tanks equipped with linings and/or cathodic protection systems

When internal corrosion is experienced or expected on storage tanks, tanks can be lined with a variety of corrosion resistant materials such as coatings of epoxy or vinyl, fiberglass poured or sprayed concrete, alloy steel, aluminium, rubber, lead, synthetics as HDPE, or Hypalon and glass.

Cathodic protection systems are often provided for control of external bottom corrosion, and combined with internal linings, may also be used to protect tanks bottom internally, /1/. Cathodic protection is a technique for preventing corrosion by making the entire surface of the metal protected as the cathode of an electrochemical cell. There are two systems of cathodic protection, galvanic and impressed current. A general scheme of one cathodic protection system with impressed current is shown in Fig. 4, /5/.

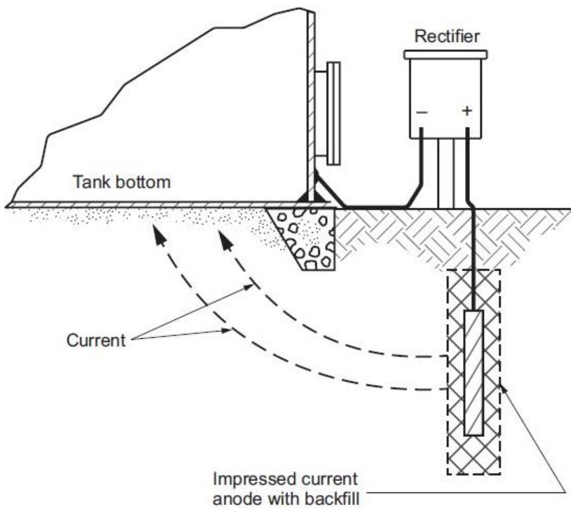

Figure 4. Cathodic protection system with impressed current.

Analysis of storage tank with cone roof overview

Analysis of further reliability of storage tank for needs of its further continual work was performed after the tank was pulled out from regular service during forced turnaround. Design data of the overviewed storage tank with cone roof are shown in Table 2 and in the text below.

Table 2. Design data at the storage tank.

Item	Design material	Design thicknesses
Shell (Course number 1)	ASTM A36M	6.40 mm
Shell (Course number 2)	ASTM A36M	5.50 mm
Shell (Course number 3)	ASTM A36M	5.00 mm
Shell (Course number 4)	ASTM A36M	5.00 mm
Bottom plates	ASTM A36M	9.00 mm
Roof plates	ASTM A36M	6.50 mm

The tank has been in service for more than 18 years, and the interior tank side is coated with a thin layer of paint. The working medium is oily water coming from a previous unit in the plant for needs of further working medium rectification. The storage tank is also equipped with a cathodic protection system with impressed current. Calculation of internal overview interval (IOI) from initial service: IOI = 10 years (initial) + 2 years (internal thin film) + 5 years (cathodic protection system) = 17 years. Properties of the working medium: corrosively-high, toxicity-middle.

To estimate the remaining storage tank thickness, ultrasonic measurement is performed, as shown in Figs. 5-6.

According to the created ultrasonic thickness schemes, ultrasonic thickness measurements are conducted on the cylindrical shell and tank bottom. Figure 5 is related to tank cylindrical shell while Fig. 6 is related to tank bottom. Tank bottom measuring points are shown in Figs. 7 and 8, according to the prepared random ultrasonic scheme. Values of measured thicknesses are shown in Tables 3-4. Obtained values of tank bottom thicknesses are additionally analysed and it is concluded that the inspected tank bottom is near the end of its service life, so tank bottom repair is strongly required in order to avoid possible fluid leakage in the future.

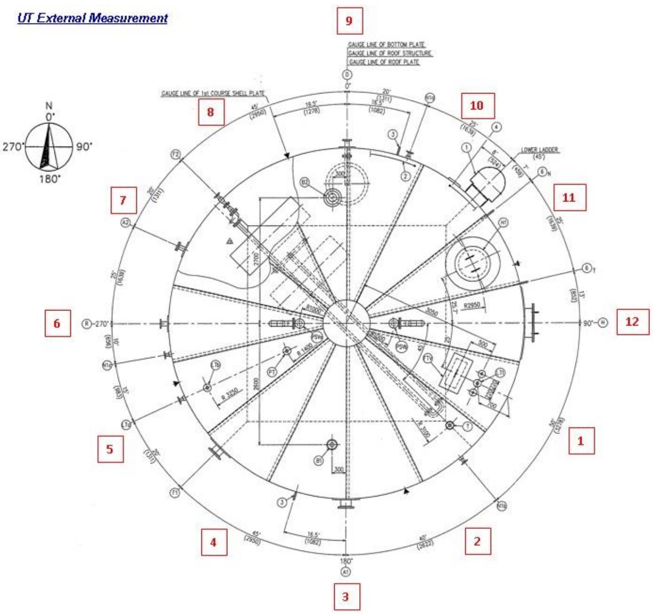

Figure 5. Ultrasonic scheme - cylindrical shell.

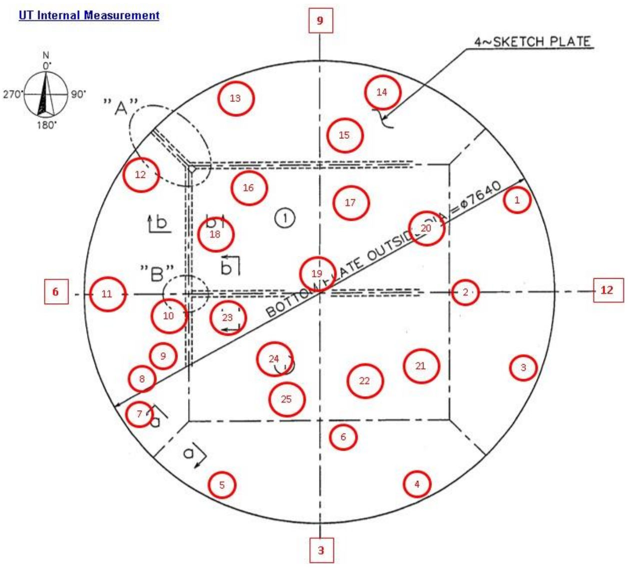

Figure 6. Ultrasonic scheme - tank bottom.

Figure 7. Thickness measuring points according to the created random ultrasonic schemes.

Figure 8. Thickness measuring points according to created random ultrasonic schemes.

Table 3. Cylindrical shell-measured thickness values.

No	Shell course 1 (6.4 mm)	Shell course 2 (5.5 mm)	Shell course 3 (5.0 mm)	Shell course 4 (5.0 mm)
1	6.7 mm	6.8 mm	NA	NA
2	6.6 mm	6.3 mm	NA	NA
3	6.7 mm	6.3 mm	NA	NA
4	6.7 mm	7.5 mm	NA	NA
5	6.4 mm	6.7 mm	NA	NA
6	6.9 mm	6.6 mm	NA	NA
7	6.9 mm	6.1 mm	NA	NA
8	6.6 mm	6.2 mm	NA	NA
9	6.7 mm	6.3 mm	NA	NA
10	6.8 mm	6.3 mm	6.0 mm	5.8 mm
11	6.6 mm	6.2 mm	NA	NA
12	6.8 mm	6.6 mm	NA	NA

NA - not available

Table 4. Tank bottom - measured thickness values.

Location	Min. thickness (mm)	Location	Min. thickness (mm)
1	3.8 mm	14	4.6 mm
2	3.7 mm	15	5.5 mm
3	2.7 mm	16	4.7 mm
4	4.9 mm	17	5.3 mm
5	5.3 mm	18	5.7 mm
6	3.2 mm	19	7.6 mm
7	2.9 mm	20	3.4 mm
8	3.8 mm	21	4.5 mm
9	4.4 mm	22	2.6 mm
10	5.5 mm	23	5.2 mm
11	3.6 mm	24	5.5 mm
12	4.9 mm	25	3.3 mm
13	5.6 mm	26	-

Together with thickness values, internal coating thickness is measured and found to conform to design specifications. According to the previously presented, it is concluded that decreasing of thickness is coming from the ‘soil side’ of the tank bottom, because the coating on the internal side of the tank bottom is found to be in good condition in time of inspection. For finding the root causes of tank bottom decreasing thickness, additional analysis of the cathodic protection of operating devices has been undertaken. The cathodic protection system cabinet (Fig. 9) was opened, and current and voltage values were found at zero value.

Figure 9. Cathodic protection cabinet after opening and current stimulation from control room.

The main power switch was put in appropriate positions and additional stimulations of currents from the plant control room were performed for determining impressed current anodes. According to current/voltage values in control room displays, it is established that sacrificial anodes were fully spent. Considering these facts, the root cause of accelerated corrosion of tank bottom is found. Functionality of the overflow protection system is tested during cathodic protection system analysis. According to instrumentation values in the control room, the system is found to be working properly.

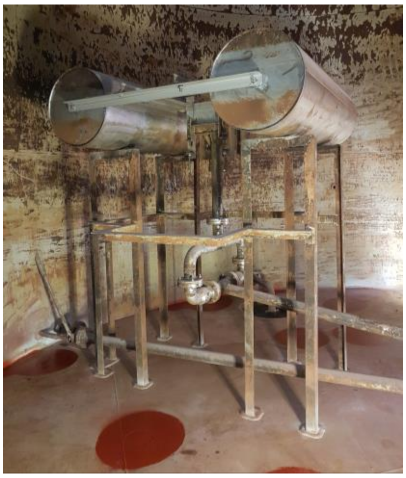

Figure 10. Overflow protection system was tested in detail and proper work is confirmed.

For needs of tank bottom full repair, full cutting of existing tank bottom plates and their replacement with new ones is required, and installation of the new cathodic protection system. It should also be mentioned that before starting tank bottom repair processes and installing a new cathodic protection system, a detailed techno-economic analysis of the new cathodic protection system should be prepared that should determine the future place for installing new anodes in terms of their efficiency and reliability in service life. In terms of all previously mentioned, it should be established whether it is better to excavate a new deep ground bed for anodes near the storage tank or is it better to make a new tank bottom above the existing one, and place sacrificial anodes in space (filled with appropriate material) between two bottoms. An appropriate tank engineer and a cathodic specialist should be engaged for these estimations.

CONCLUSIONS

According to all previously mentioned, it is concluded that the inspected storage tank is not reliable for further long term continual service, and that tank bottom repair and installation of new anodes are strongly proposed in order to avoid near tank bottom fluid leakage, and thus pull out of service the whole unit where the storage tank is installed, also following huge financial loss. Here, is should also be mentioned that before any repair activities, a techno-economical analysis should be prepared for the new cathodic protection system in order to provide adequate solutions and further prolong continual operation. An appropriate tank engineer and cathodic protection specialist should also be involved in the preparation of this study.

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