VAŽNOST ISPITIVANJA DOBOŠASTOG RAZMENJIVAČA TOPLOTE NAFTA-NAFTA ZA POTREBE ODRŽIVOG RAZVOJA I ZAŠTITU ŽIVOTNE SREDINE

IMPORTANCE OF INSPECTION OF THE OIL-OIL SHELL AND TUBE HEAT EXCHANGER FOR NEEDS OF SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL PROTECTION

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Postrojenja za stabilizaciju nafte omogućavaju rekuperaciju i komercijalnu eksploataciju nafte koja se izdvaja iz gasa dopremljenog iz buštoine. Kondenzovani topli tečni ugljovodonici koji su prečišćeni iz prirodnog gasa mogu se koristiti za zagrevanje fluida koji dolazi u proces u kome se vrši njegovo razdvajanje na lakše i tečne komponente. U radu je prikazan pregled razmenjivača toplote nafta-nafta i objašnjen značaj inspekcije u pogledu održivog razvoja i zaštite životne sredine. Debljina materijala merena je ultrazvučnom tehnikom. Određivanje stepena korozije i preostalog radnog veka razmenjivača toplote izvršeni su prema API 510 I API 572 standardu. Vizuelni test je otkrio određena mehanička oštećenja i površinsku koroziju, metoda inspekcije penetrantskim metodama nije detektovala prsline u zavarenim spojevima u vreme pregleda.

Ključne reči: *dobošasti razmenjivač, inspekcija, nedestruktivne metode, brzina korozije, preostali vek trajanja*

Plant for oil stabilisation is enable to recovery and commercial exploitation of oil which is rectified from excavated raw gas. Condensed hot liquid hydrocarbons that are separated from natural gas can be used to heat the fluid that enters the process in which it is separated into liquid and lighter components. This paper presents the inspection of an oil heat exchanger and explains the importance of inspection regarding sustainable development and environmental protection. The thickness of the material was measured by ultrasonic technique. Determination of corrosion rate and remaining life of oil-oil shell and tube heat exchanger is performed according to the API 510 and API 572 standards. The visual test revealed some mechanical damages and surface corrosion; a liquid penetrant inspection method showed no cracks at the time of inspection.

Key words: *Oil-oil heat exchanger, inspection, non-destructive methods, corrosion rate, remaining life*

1 Introduction

Heat exchangers and heat and mass transfer play an important role in the efficiency of energy systems and the protection of the human environment. Pollution reduction involves heat transfer and heat exchangers to a large extent. Sustainable energy development includes reducing final energy consumption, improving overall conversion efficiency, and using renewable energy sources [1]. Environmental pollution is the release of any substance into the air, water or soil that is harmful to the quality of life, while thermal water pollution is the release of heated water that can kill or injure aquatic organisms [2].There have been several attempts to define criteria for assessing the sustainability of market products. One of the criteria for defining the sustainability of the product is the optimized design of the energy system, which includes the structure and parameters of the system design to reduce energy costs closely related to available material, financial resources, environmental protection and government regulations, as well as safety, reliability, availability and sustainability. The next criteria important for this work are design longevity and life cycle design. Optimal life cycle selection for elements requires maintenance and inspection and testing of the elements themselves which may lead to retrofitting procedures. The energy system and its subsystems must be designed to meet sustainability through each life cycle phase [3]. Determining corrosion rates and remaining service life is an important aspect of heat exchanger life cycle design.

In this paper, the test plan is presented, including the methods and test results, the corrosion rate and the remaining service life of the oil heat exchanger are calculated, in order to ensure the quality of production, the protection of the environment and living beings.

Plan of inspection is done according to API 510 [4], inspection and calculation of oil heat exchanger according to API 572 [5], ASME sec VIII, div 1 and 2 [6].

2 Technical data

Table 1 presents design data of the oil heat exchanger and Figure 1 shows the inspected oil heat exchanger.

Table 1 Design data of oil-oil shell and tube heat exchanger

	Shell side	Tube side
Design pressure (bar)	13	33
Design temperature (ºC)	128	100
Operating temperature (ºC)	98/70	45.7/70
Test pressure (bar)	16.9	42.9
Weld join efficiency (%)	0.85	0.85
Fluid	Stabilized condensate (Hot-oil)	Wet oil (entering in process)
Volume (S/H) (m^2)	4354/2.49	
Material of construction	SA516 Grade 70	

3 Plan for inspection

Several criteria should be considered when developing an effective inspection plan. The primary goal of the plan is to organize inspections (and supporting activities) that enable the owner to assess the condition of the pressure vessel.

Care should be taken to ensure that the inspections provide the information required to perform any applicable analyses, in a timely fashion, without imposing detrimental effects on the equipment.

The frequency with which a pressure vessel should be inspected depends on several factors, including the rate of damage, the corresponding remaining useful life, and the risk of failure.

Maximum internal or external inspection intervals should be in accordance with API 510. Scheduling of shutdowns for maintenance or inspection is usually arranged through the collaboration of process, maintenance, and inspection groups.

The actual time for inspection will usually be determined through the collaboration of process, mechanical, and inspection groups, or by the mandate of a jurisdiction.

Table 2 presents inspection plan for recertification of the oil heat exchanger.

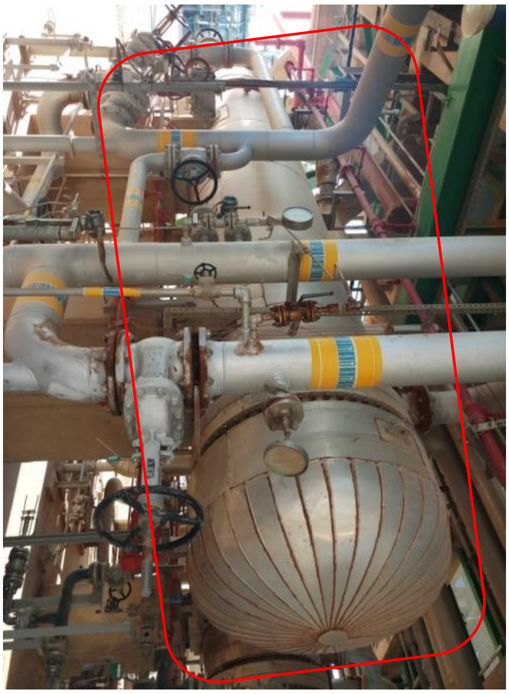

Figure 1. Oil-oil shell and tube heat exchanger

3.1 Visual inspection activities of the shell and tube heat exchanger

External and internal inspection were conducted on the vessel. External inspection covers the condition of the external metal surfaces, protective coatings and its external components.

External metal surfaces were in good condition in time of inspection. Corrosion under insulation was not observed in time of inspection.

The appearance of the tube bundle after cleaning reveals that no corrosion occurred, and the metal surfaces are crack and damage free as presented in Figure 2.

Figure 2. The tube bundle after cleaning

Internal inspection covers the conditions of the internal metal surfaces and its internal components. Exterior of tube bundle on accessible places was found in good condition and interior of tubes were inspected by boroscope. Tubes were inspected according requirements of the API 570 and API 574 standards. Surface corrosion is found at the internal side of tubes, and should be monitored. The corroded surface is presented in Figure 3 [8].

Table 2. Inspection plan for recertification pressure vessel

No.	Activity	Reference	Acceptance	Verify	Inspection Level		
		Document	**Criteria**	**Document**	**Req'**	**MOG**	**CA**
1	Review Document						
	- Drawing, Design/ Datasheet	ASME Sec. VIII	ASME Sec. VIII	General Drawing & Datasheet	Yes	R	R
	- NDT Equipment Calibration	ASME Sec. V	ASME Sec. V	Calibration Cert.	Yes	R	R
	- Previous Inspection Record	API 510	API 510	Inspection Work-book	Yes	R	R
	- Corrosion & Failure Threat	API 510	API 510	Corrosion Assessment	Yes	R	R
	- Advance NDT Procedure			NDT Procedure	No	A	R
	- Repair of Pressure Vessel			Repair Procedure	No	A	R
	- Safety Precaution			Work permit & Risk Assessment	Yes	A	R
2	Visual Inspection						
2A	External	Internal procedure	API 510	Visual Inspection Report	Yes	P	M/R
2B	Internal	Internal procedure	API 510	Visual Inspection Report	Yes	P	W
3	Extended Non Destructive Test						
3A	Scanning Wall (shell, head)	Internal procedure	ASME Sec. V	NDT Report	No	P & T	M/R
3B	Wall Thickness Check (Localized Scan)	API 510	API 510	NDT Report	Yes	P & T	M/R
3C	Hardness		ASME Sec. II	Hardness Report	No	P & T	M/R
3D	MT or PT on selected W. joints	Internal procedure	ASME Sec. V	NDT Report	Yes	P & T	M/R
3E	Other Advance NDT	API 510	ASME Sec. V	NDT Report	No	W	W
4	Calculation Check						
4A	Corrosion Rate Calculation	API 510	API 510	Calculation Report	Yes	P	R
4B	Remaining Life Calculation	API 510	API 510	Calculation Report	Yes	P	R
4C	MAWP Calculation (if derated)	API 510	API 510	Calculation Report	No	P	R
5	Hydrotesting	Internal procedure	ASME Sec. VIII	Hydrotest Report	Yes	P & T	W
6	Completed Pressure Vessel Inspection Work Book Report				Yes	P	R

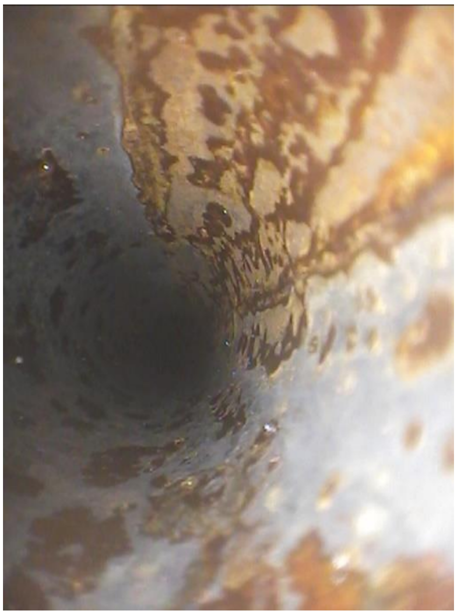

Figure 3. The corroded appearance of the internal side of the tubes

Next external inspection, internal inspection and ultrasonic thickness measurements at the same positions should be performed within next five years.

All of the essential sections/components of the vessel are safe to operate until next scheduled inspection.

3.2 Ultrasound testing of the oil-oil heat exchanger

Value of the design thicknesses of the oil-oil shell and tube heat exchanger elements are mentioned in the Table 3 below:

Table 3 Equipment technical data

No	Item	Material	Design thickness (mm)	C.A. (mm)
1	Cylindrical shell	SA516 Grade70	13.00 mm	3.00 mm
2	Shell head	SA516 Grade70	Minimum thickness 9.20 mm	3.00 mm
3	Channel	SA516 Grade70	21.00 mm	3.00 mm

The sketch and results of ultrasound thickness measurement are presented in Figure 4.

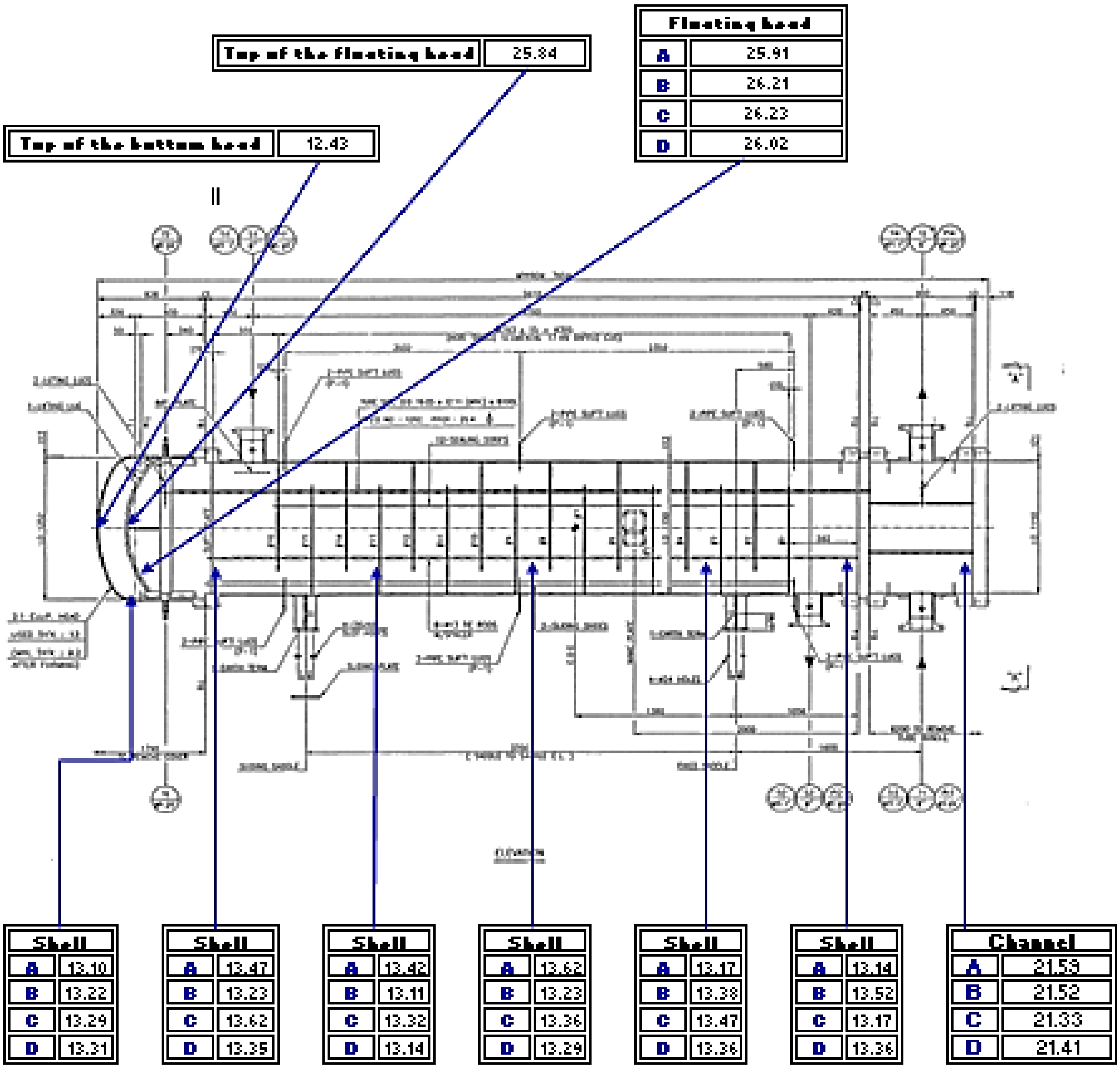

Figure 4. Sketch and results of UT thickness measuremnt of oil-oil heat exchanger

According to Figure 4 and Table 3 equipment thicknesses obtained by UT testing were found to conform to the design thicknesses.

3.3 Liguid penetrate testing of the oil-oil shell and tube heat exchanger

Sketch of liquid penetrate testing performed on oil heat exchanger is presented in Figure 5. The results of test performed at weld joint 1, weld joint 2 and weld joint 6 are presented in Figure 6 a, b and c respectively. Cracks were not found on inspected weld joints during inspection.

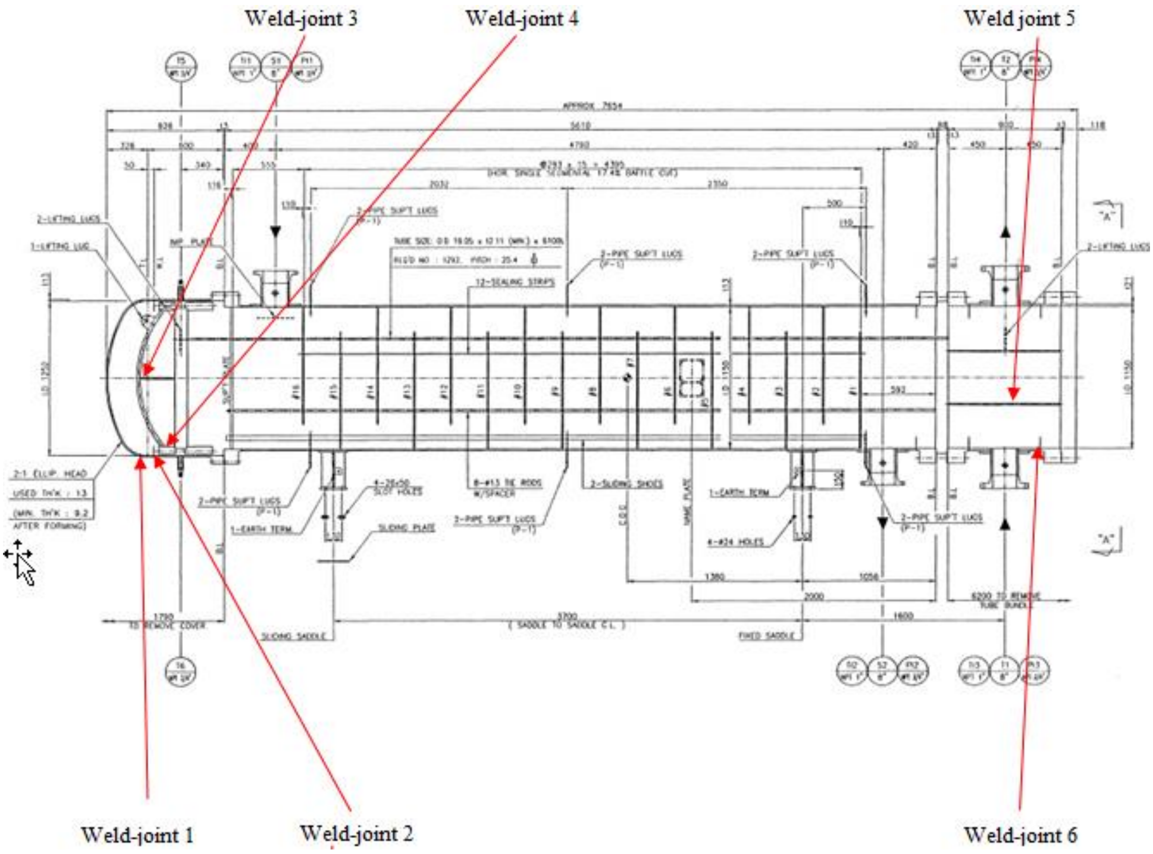

Figure 5. Sketch of PT tested equipment

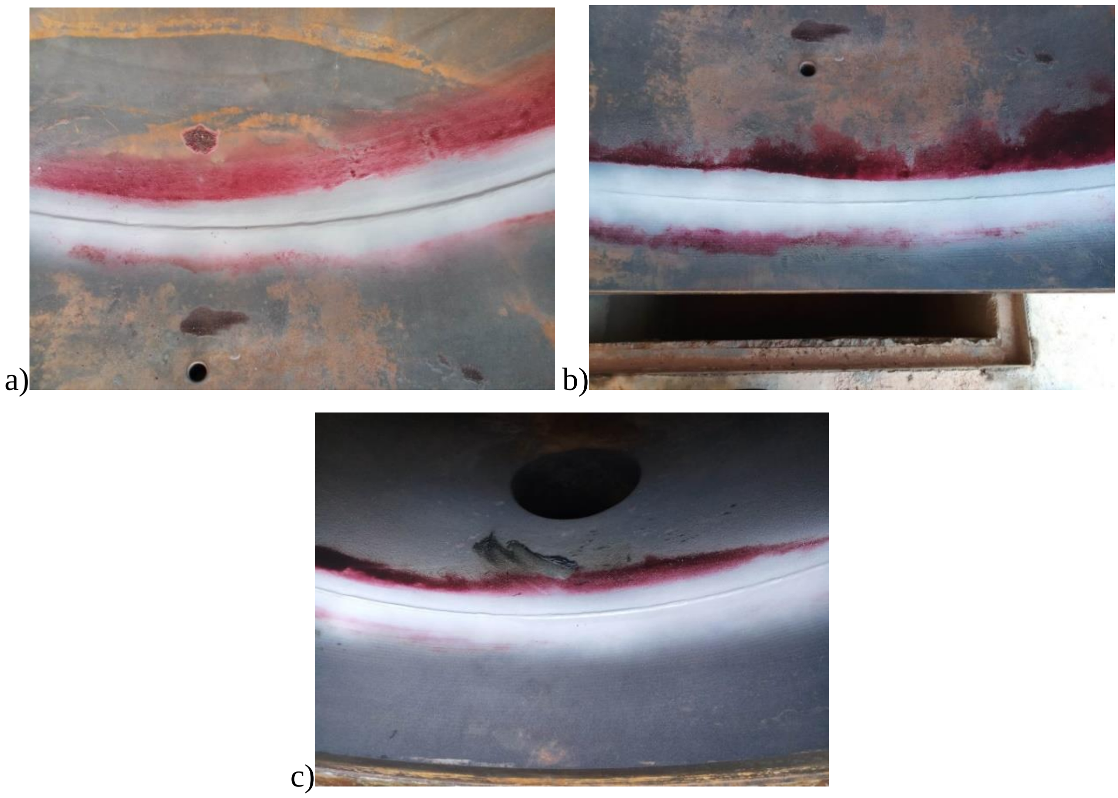

Figure 6. Results of PT tested of the weld joints a) 1 b)2 and c)6.

4 The determination of corrosion rate and remaining Life

The corrosion rate is calculated according to the API 510 and API 572 [4, 5] as a corrosion rate long time (LT) according to the following equations:

$$\text{Corrosion rate (LT)} = (t_{initial} - t_{actual})/\text{time between } t_{initial} \text{ and } t_{actual} \text{ (years)} \quad (1)$$

$$\text{Corrosion rate (LT)} = (13.208 - 13.11)/18 \quad (2)$$

$$\text{Corrosion rate (LT)} = 0.005\text{mm/year} \quad (3)$$

Remaining life of the heat exchanger (in years) shall be calculated from the following formula [8]:

$$\text{Remaining life} = (t_{actual} - t_{required}) / \text{corrosion rate} \quad (4)$$

$$\text{Remaining life is} = 22 \text{ years} \quad (5)$$

where t_{actual} is the actual thickness of a CML, in (mm), measured during the most recent inspection; $t_{required}$ is the required thickness at the same CML or component, in (mm), as the tactual measurement. It is computed by the design formulas (e.g. pressure and structural) and does not include corrosion allowance or manufacturer's tolerances [9].

According to presented results of measurements corrosion rate is 0.005mm/year and remaining life of inspected shell and tube heat exchanger is 22 years.

5 Conclusions

This paper presents the plan and results of oil-oil shell and tube heat exchanger's inspection as an important part for the environment protection and sustainable development.

The inspection included visual testing, liquid penetrate testing and ultrasound thickness measurements. The inspection revealed no corrosion or any damage and all of the essential sections/components of the oil-oil heat exchanger are safe to operate until next scheduled inspection.

Corrosion rate, calculated according API 510 and API 572, is 0.005 mm/year, hence remaining life of the oil-oil shell and tube heat exchanger is 22 years. Next external inspection, internal inspection and ultrasonic thicknesses measurements at the same position should be performed within next five years. Also grounding connections electrical resistance is recommended also to be measured according to the requirements of API 510 and API 572 standards.

6 References

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