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Importance of examination of collector for impurities after oil purification for human and environmental safety

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Abstract *The collector for impurities is a temporary tank that collects condensate from the condenser after oil purification process.. Large-scale distillation towers use a reflux system to achieve more complete product separation. The collector, or accumulator, serves as a distribution point for reflux and distillate. This paper deals with a collector that uses water and light hydrocarbons as a working fluid, and is designed to operate under a pressure of 12 bar and a temperature of up to 91° C. Considering the working fluid, and work at elevated pressure, it belongs to the category of pressure vessels of a high level of danger. Its maintenance and regular inspection are a mandatory step in the prevention of failures and/or accident, and thus also in the protection of people and the environment. The paper describes tests of collector for impurities after oil purification and their importance; including a liquid penetrate inspection, ultrasonic measurement and visual inspection. Corrosion rate that occurs during the interaction of the working medium and the material of the collector was estimated such as and appropriate remaining working life. RBI analysis is performed.*

Keywords *Collector, hydrocarbons, nondestructive methods, remaining life, RBI*

1. INTRODUCTION

In engineering practice, the lifetime of a specific plant and individual devices (apparatus, machines, etc.) implies the following stages: development, dimensioning and production technical documentation, production of the device, checking the functionality of the device after production, plant construction, i.e. installation of devices in a suitable complex system, verification functionality after installation, maintenance, etc. For each of these stages there are developed technical regulations, as well as professional services that supervise them. During the lifetime of use, there are many factors that affect the lifetime of the device, such as working conditions, working medium, etc [1]. For that reason periodical inspection is very important and must follow developed regulations.

Impurities content undesirable components such as carbon-dioxide (CO_2), hydrogen-sulfide (H_2S), nitrogen (N_2), water, etc. can cause health issues, corrosion of process units, and poorer calorific values [2]. Damage and/or failure of the apparatus affect the environment. Damages/failures occurred at oil and gas plants can be catastrophic for the environment.

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Chemical and petrochemical facilities generate many dangerous phenomena; these dangerous events must be mitigated by protection layers to reduce the risk to an acceptable level [3]. Some working medium, operating conditions and/or the environment condition can cause corrosion, which results in the loss of material, i.e. a reduction in the thickness of the device's wall. A critical reduction in wall thickness leads to leaks and failure, and corrosion is estimated to account for 19% of the failure factor [4].

In this work, the inspection of the collector for impurities after oil purification is investigated by visual examination (internal and external), liquid penetrate testing and ultrasound measurement. The corrosion rate and remaining life were estimated [5-8]. Suppose the equipment's or components remaining life the engineer can perform the necessary maintenance and be able to plan the replacement of the piece of equipment [9, 10].

In oil&gas and the petrochemical industry, the application of the RBI API methodology, which represents the process of creating an inspection scheme, is of great importance. To effectively integrate risk evaluation and benefit evaluation and facilitate investment decision making, it is firstly needed to analyze risk factors [11-13]. This method is based on the assessment of the probability of failure with the consequences of that failure. In oil&gas and petrochemical plants, a certain percentage of equipment represents a high risk and is given more attention, i.e. more time and money, while less money is allocated for maintenance for equipment that carries a lower risk. In this paper, the RBI inspection of the collector which is in long time service in one upstream oil plant has been calculated and discussed, pointing to the importance of the safety and economy of the plant.

2. TECHNICAL AND EXPERIMENTAL DATA

The collector for impurities after oil purification process is shown in Figure 1.

Technical data are listed in Table 1.

The collector was subjected to external and internal visual inspection, liquid penetrates inspection and ultrasonic measurement. Corrosion rate and remaining life were determined and estimated while RBI analysis was conducted according to the requirements of API 581.

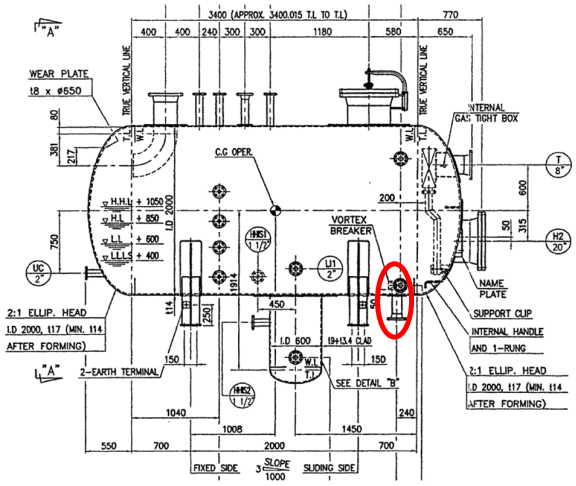

Fig.1. Technical drawing of the collector for impurities after oil purification

Table 1 Technical data

Material	Carbon steel-SA516 Grade70
Working medium	Light carbons and water
Fluid density	0.553 oil/0.986 water kg/dm^3
Design pressure	12.0 bar
Design temperature	91°C
Operating pressure	8.7 bar
Operating temperature	55°C
Joint efficiency	0.85 (spot radiography)
Capacity	13.1 m^3
Year of production	2003

3. RESULTS AND DISCUSSION

3.1. Survey of collector for impurities after oil purification

The collector was shut down for periodical inspection [14, 15]. The inspection covers the conditions of the external metal surfaces, protective coatings and all other external attachments.

Ladders, stairways, platforms, walkways foundations and supports and anchor bolts are in good condition.

The flange on the nozzle F1 (Fig.2) was found to be distorted. This condition of the flange has been spotted also during previous inspection in 2017. The flange is probably distorted during construction period. The flange and nozzle were checked visually and cracks were not spotted. Leaking has not been observed on this location while the vessel was in operation. All other nozzles were found in good condition.

Fig. 2 The flange at the lower nozzle F1 (4") was found distorted, but leaking has not been observed while the vessel was in service

The grounding connections and cables were found to be in good condition. Electrical resistance has been checked by appropriate department and its value is 3.06 Ohms which is in line with the recommendations [15].
All gauge connections, sight glasses and safety valves were found to be in good condition.
External protective coating and external metal surfaces are in good condition.
The internal periodical inspection covers the integrity of internal metal surfaces, main weld joint, nozzle weld attachment and its internal components.
Pitting corrosion can be observed on the lower part of the vessel, Figure 3, especially from 5 to 7 o'clock position). Maximum depth of the pits was found to be 3 mm (only for one pit). Majority of the pits were between 1.0 to 2.0 mm deep. All pits have depth less than corrosion allowance, so according to API 510 Section 7.4.3 this can be ignored. Interior of the elliptical head of the collector has been found corroded in time of examination and also small pits were observed on circular weld joint (shell-head). Additional UT scanning has been performed for needs of estimation of circular weld joint and minimum value thickness in this area from the outside. Minimum measured value of thickness obtained by this scanning was found to be 10.43 mm. Here should be mentioned that this damaging is caused by corrosion and erosion effects.

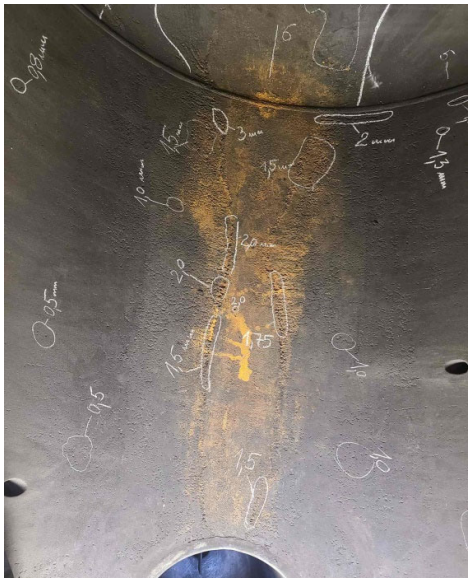

Fig.3. Pitting corrosion has been observed on the lower part of the shell (from 5 to 7 o'clock position) - majority of the pits are between 1.5 to 2.0 mm deep

The back head of the vessel is corroded (Fig 4). Damaging is caused by corrosion and erosion effect. UT scanning has been performed from the outside. Minimum thickness was found to be 10.43 mm on the left elliptical head.
Penetrant testing results are presented in the Figure 5.
There is no sign of cracks and other irregularities on the inspected locations.

Fig. 4. Left head - close up view on the corroded surface (whole elliptical head has been scanned and minimum thickness was found to be 10.43 mm)

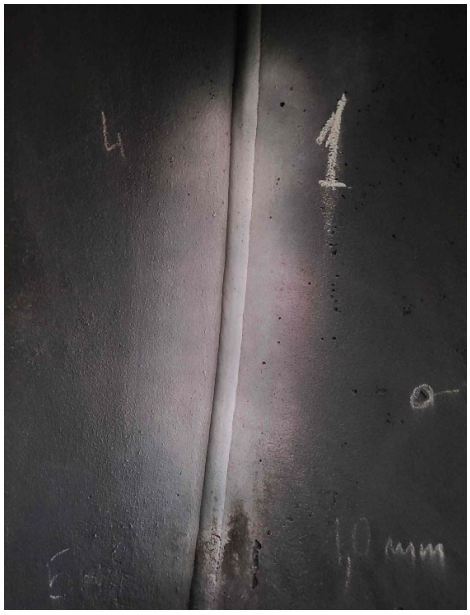

Fig.5. Liquid penetrate inspection performed on weld 1

3.2 Corrosion rates and remaining life

Operating pressure of the collector is 8.7 bar (as per vessel design data), but in reality this pressure is even lower. Maximum pressure is limited to 12 bar by the pressure safety valves. Limiting the pressure to maximum 10 bar will provide additional corrosion allowance of 1.87 mm (actual thickness - required thickness for 10bar = 10.43 mm - 8.56 = 1.87 mm). For this purpose, PSV which protect the collector should be additionally adjusted according to this pressure limit (10 bar).

During one of the first examination of the collector pitting corrosion was observed on the lower part of cylindrical shell and on left elliptical head. This situation was detail analyzed and after that injection of corrosion inhibitor CH1038 was started on 09-Dec-2009.

Here should be mentioned that corrosion inhibitor-CH1038 is belonging to blend of aliphatic amines and aminic derivates in high boiling point aromatic solvent. Result of this activity was manifested in corrosion rate reduction and slow growth of pit depth.

According to previous thickness measuring Corrosion Rate (CR) was calculated according to [16,17] for period 2009 to 2022:

CR (long-term) = (11.0-10.43)/11.25=0.05067 mm/year

CR (short-term) could not be certainly determinated because previous and actual thickness readings are almost the same.

Hence, value of Corrosion Rate (long-time) was adopted as a relevant:

CR=0.05067 mm/year.

Remaining Life (RL) of the vessel is:

RL = (actual minimum thickness - required thickness) / corrosion rate (LT)

RL = (10.43 mm - 8.56 mm) / 0.05067 mm/year

RL = 36.9 years

4. RBI calculation

RBI analysis is method of estimation of process equipment which including in itself the most probably damage mechanisms which can appear at appropriate process equipment depending on working mediums in the equipment (and their process parameters) and material from which equipment is made. Calculation of risk in API 581 [12] RBI involves the determination of a probability of failure (POF) combined with the consequence of failure (COF) presented by the following equitation:

$$R(t) = P(t) * C(t)$$

The probability of failure is calculated as following [5]:

$$P_f(t) = gff * D_f(t) * F_{MS}$$

The risk for the presented collector for impurities after oil purification is calculated according to [12] and the most important results have been summarized in Table 2. The risk is calculated at the RBI date, the age at the RBI date is 20 years, while a Probability of failure at RBI date is $1.17*10^{-3}$.

Table 2 Calculation results summarized for the collector for impurities @ RBI date

Art	0.29361
Inspection Effectiveness Category	B
Damage Stage	
Total Damage Factor	72.23
POF with inspection, failures/yr	00.001193
Final Consequence Area	492
The final financial consequence	4760000
Risk, m2/yr	1.3
Risk €/yr	12680

The final consequence area is 946m², and the Total damage factor is 42.66 at RBI date.
Table 3 presents numerical values associated with POF and Area-Based COF Categories taken from API 581 standard. In this analysis, these values have been taken as referent values for the iso-risk plot and risk matrix.

Table 3 Numerical values associated with POF and Area-Based COF categories [12]

Cat.	Probability Category (1,2)		Consequence category (3)	
	Probability range	Damage factor	Range cat.	range (m2)
1	$P_f(t) \le 3.06E\text{-}5$	$D_f \le 1$	A	CA ≤ 9.29
2	$3.06E\text{-}5 < P_f(t) \le 3.06E\text{-}4$	$1 < D_f \le 10$	B	9.29 < CA ≤ 92.9
3	$3.06E\text{-}4 < P_f(t) \le 3.06E\text{-}3$	$10 < D_f \le 100$	C	92.9 < CA ≤ 929
4	$3.06E\text{-}3 < P_f(t) \le 3.06E\text{-}2$	$100 < D_f \le 1000$	D	929 < CA ≤ 9290
5	$P_f(t) > 3.06E\text{-}2$	$D_f > 1000$	E	CA > 9290

According to results presented in Table 2 and categories presented in Table 3, the presented collector for impurities after oil purification belongs to category B3 @ RBI date– medium risk. The results have been presented in the Iso-risk plot for the consequence area in Figure 5.

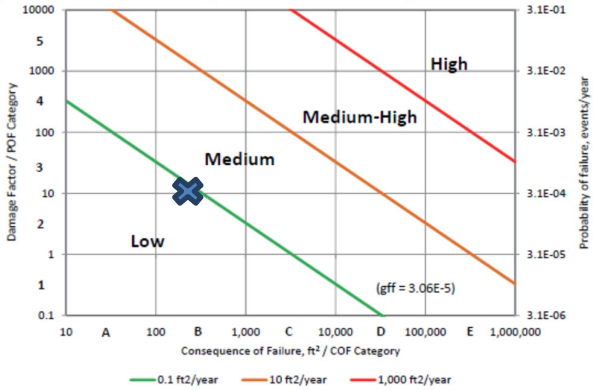

Fig.6 Iso-risk Plot for the Consequence area. The vessel belongs to medium risk

Table 4 presents Numerical Values Associated with POF and Financial-Based COF Categories taken from API 581.

Table 4 Numerical values associated with POF and financial-based COF categories [12]

Cat.	Damage factor	Range cat	Consequence category range ($)
1	$D_f \le 1$	A	FC ≤ 10000
2	$1 < D_f \le 10$	B	10000 < FC ≤ 100000
3	$10 < D_f \le 100$	C	100000 < FC ≤ 1000000
4	$100 < D_f \le 1000$	D	1000000 < FC ≤ 10000000
5	$D_f > 1000$	E	FC > 10000000

According to results presented in Table 2 and categories presented in Table 4, the damage factor belongs to Category 3 and Financial Consequence to Range category D.
The risk category of collector for impurities from standpoint of financial consequences is D3 and belongs to medium risk, very close to medium-high risk. That is presented in the Iso-risk plot for financial consequences in Figure7.

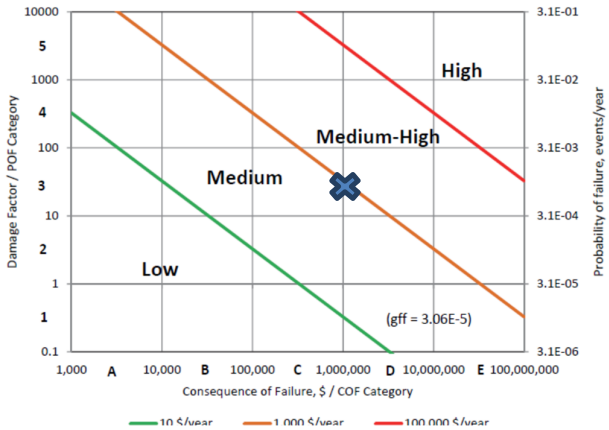

Fig.7 Iso-risk Plot for Financial Consequence. The collector for impurities belongs to medium risk

Figure 8 presents the balanced risk Matrix for Consequence Area and Financial Consequence. After detail analysis of the relevant parameters related to probability of failure (POF) it's combined with the consequence of failure (COF) can be concluded that the collector for impurities belongs to category of medium risk.

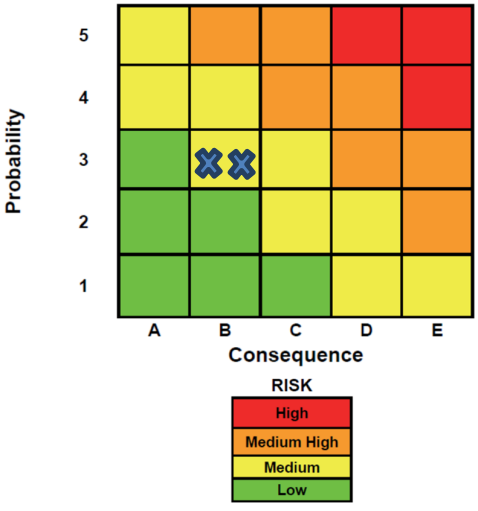

Fig.8 Balanced Risk Matrix for Consequence area and Financial Consequence [5]

5. CONCLUSION

This paper presents the inspection of collector for impurities after oil purification, determination, and analysis of remaining service life, corrosion rate. RBI inspection is applied and calculated in detail. From the presented the next could be concluded:

- All of the essential sections/components of the presented collector for impurities after oil purification satisfy the API 510 and API 572 Code requirements for maintenance inspection/examination hence, presented vessel is safe to operate until the next scheduled inspection.
- Corrosion rate is extremely high affecting the remaining life which is 36.9 years.
- Collector for impurities after oil purification belongs to medium risk, for Consequence Area while for the financial consequence it practically entering in the medium-high risk area.

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