AUTOMATIC TUBE CLEANING SYSTEM (ATCS) INSTALLATION IN SULFIDE RETRIEVAL MONOETHANOLAMINE TREATMENT PLANT: CASE STUDY AND FOULING GLOBAL PERSPECTIVES

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Chemi Sugarmen[1]**, Udi Siboni**[1]**, and Ruth Volansky**[2]

[1] CQM Ltd., Moshav Tirat Yehuda 51, Israel 73175, csugarmen@cqm-tech.com

[2] Paz Ashdod Refinery Ltd., vruth@@pazar.co.il

ABSTRACT

Automatic cleaning of heat exchangers and condensers tubes by means of sponge balls is well known since the early fifties, with expanding application from steam power plants to process industry to industrial cooling and air conditioning systems. Main benefits bottom-lined in cost savings are generally considered as: elimination of maintenance down-time and need for chemical and more efficient operation of process and plant.

This paper presents the design and performance assessment of an Automatic Tube Cleaning System (ATCS) implementations, in a hydrogen sulfide retrieval Monoethanolamine treatment Plant in Paz Ashdod Refinery, one of the two refineries in Israel. Patented by CQM for the balls injection and trapping methods, their unique operation benefits are revealed and resulting O&M cost savings are evaluated in details. The paper concludes by presenting the main costs of heat exchangers fouling and opening a view on fouling mitigation as meeting the main goals of global energy efficiency instruments.

INTRODUCTION

The most common solution to fouling is periodic **off-line** cleaning of the heat exchanger, either by mechanical or chemical methods, which has several drawbacks:

- Requires process shutdown for cleaning.
- Fouling accumulates between treatments gradually increases performance degradation.
- Harmful to the environment: the residues and cleaning chemicals require special disposal.

The costs of fouling and its off-line cleaning approach can be divided to four groups [1]:

- **Decreased productivity**: due to escalated efficiency degradation and to loss of production during planned or unplanned shutdowns. These are considered to be the main cost of fouling.
- **Higher maintenance costs**: for removing fouling deposits and for chemicals or other operating costs of antifouling devices. Typically 8% of the maintenance costs of a process plant could be attributed to heat exchangers fouling.
- **Higher energy consumption**: in many processes extra electricity, fuel or process steam is needed to overcome the effects of fouling. Between 1% and 5% of the energy consumed by the industrial sector is used to overcome fouling.
- **Excess heat transfer area**: the design excess surface area for fouling varies between 10% - 500%, with an average around 30%. Such excess area may correspond to additional capital cost of 25%. This also includes costs of stronger foundations for heavier or redundant heat exchangers, provisions for extra space and increased transportation and installation costs.

Evidently, off-line cleaning cannot be considered an adequate solution for the fouling problem, and is only used for lack of better technology. Hence there is an endless market for fouling mitigation and **on-line** cleaning.

The CQM ATCS is installed on heat exchangers and keeps them clean without intervention. The system periodically injects into the tubes sponge balls that are slightly larger in diameter than the tubes themselves. The natural pressure head pushes the balls through the tube that is thus rubbed clean. The balls are trapped on the outlet of the heat exchanger, where they are prepared for the next cleaning cycle. By providing on-line cleaning, the ATCS should be in fact considered as a leading fouling mitigation method.

PROCESS BACKGROUND

Paz Ashdod Refinery began operating in 1973 and has the ability to process around 4 million tons of crude oil per year.

PRODUCTION PLANT - AREA A: REFINERY PLANT

This area is the first station in the process of refining the crude oil. After the compositions of the crude oil is determined, it is pumped through a series of heat exchangers, rinsed with water to remove salts, and heated to a temperature of 370° C. The refining process in Area A is divided into three stages:

Initial refining

The heated crude oil is channeled to the first distillation column that separates it into various fractions, according to the boiling temperature of each. These fractions are further processed to make them suitable for use.

Vacuum refining

The heavy oil undergoes further heating and is refined in a vacuum distiller that allows additional distillates to be obtained, among them heavy vacuum diesel that is used as fuel for the catalytic cracking.

Thermal cracking

The heavy part, the fuel oil that remains in the vacuum after the refining, undergoes thermal cracking at a high temperature. The thermal cracking reduces viscosity, allowing additional light distillates to be obtained.

PRODUCTION PLANT - AREA B: TREATING AND BLENDING PLANT

The products obtained in the initial refining are not yet ready for use. These facilities improve the quality of the fractions through a two-stage process:

1. Sulfur cleaning and removal of other pollutants by catalytic processes.
2. Further refining and distillation to obtain products that meet required quality and standards.

Sulfur Cleaning

The sulfur is removed by a reduction of the mercaptans with hydrogen, in order to obtain hydrogen sulfide. This reaction requires temperatures of 260° - 430°C.

The hydrogen sulfide gas $H_2S_{(g)}$ obtained from the reaction is absorbed by the mixture passing through an Amine solution.

Sulfur Recovery

The sulfur is recovered by heating the solution to release the hydrogen sulfide and oxidizing it in the air to obtain clean sulfur.

In the catalytic cracker, the fuel is channeled with a stream of hydrogen over a platinum catalyst. During this process, the chemical structure of the fuel is changed and high-octane gasoline is obtained for use by modern engines.

THE AMINE TREATMENT PLANT

The amine absorption process removes hydrogen sulfide or carbon dioxide from a gaseous mixture. The amine solution flows down through the absorber column where it is exposed to the gaseous mixture rising up through the tower. The amine solution, now contaminated with hydrogen sulfide or carbon dioxide, is discharged from the bottom of the tower to a steam stripper. It runs counter to the steam that strips away the hydrogen sulfide or carbon dioxide. The amine solution is then returned to the top of the absorption column for reuse.

Refinery amine treatment systems can be fine-tuned to increase reliability, lower operating costs, reduce corrosion and increase treating capacity. At the Ashdod refinery Monoethanolamine (MEA) is used.

MEA

Monoethanolamine (MEA) was introduced to the industry as on of the first amines used extensively in gas treating service. MEA is very popular in refinery gas/ liquid treating service and has many advantages that some of the newer amines introduced into the industry have not been able to match. MEA removes both H_2S and CO_2 and is very reactive towards COS, all of which are of concern in refinery combined treating systems. Another advantage of MEA is the fact that due to its low boiling point, slipstream thermal reclaiming may be employed. This has proven to be beneficial in refinery service where HSS accumulation and MEA degradation have been issues.

At the final stage of its recycling, the hydrogen sulfide is cooled to 38°C in a water cooled tube & shell heat exchanger (tagged 151-C5). During this process, the remaining water vapor in the H_2S is condensed. A cooling tower supplies the water for cooling. Our discussion below refers to this heat exchanger.

THE FOULING PROBLEM

The problem of fouling in heat exchangers cooled by cooling towers is well-known and widely researched, and will therefore not be discussed herein.

Originally, the heat exchanger was clogged by scale and silt (Fig.1) and the heat exchanger capacity diminished to the point where external cooling, in the form of water spray over the condenser case, had to be used (Fig. 2). The external cooling was only a partial remedy, and moreover added corrosion and soiled the surroundings.

The inadequate condensation phase caused many malfunctions in the Sulfur recovery plant installed after the Amine Unit, and in extreme cases even disrupted production.

When the heat exchanger clogged, the effluent gas temperature climbed to above 70 °C and some water penetrated the Sulfur recovery plant which exacerbated clogging by corrosion particles, and required plant and production shutdown. Cleaning the heat exchanger twice yearly did not solve the problem, as the exchanger got clogged soon after each cleaning Disruption of the Sulfur retrieval Plant costs tens of thousands of US $ per day. This cost is amplified when the crude oil is of high sulfur content.

Fig1: Clogged H_2S Cooler: mud and scale.

Water would reach the sulfur recovery plant and cause serious clogging and corrosion problems. On hot days external cooling was required, and water was sprayed onto the condenser case.

Characteristics of the H_2S cooling heat exchanger: tube and shell, 4 water cooling passes, 156 tubes 0.75 inch dia, length 6 m. The ATCS diameter is 6 inch on the heat exchanger outlet pipe, where the ball strainer is installed.

Fig.2: External cooling for the H_2S Cooler

THE SOLUTION

The C.Q.M ATCS (described in further details below, providing both on-line fouling mitigation and cleaning, was installed in October 2003, during plant renovation. Prior to the ATCS installation the heat exchanger was manually cleaned with acid and high pressure water.

As of today the ATCS is continuously operating, maintaining the heat exchanger tubes clean (Fig. 3) and providing the benefits and savings described below.

Fig.3: Clean H_2S Cooler by CQM's ATCS

THE RESULTS

1. GENERAL

It was obvious that cleaning the clogged condenser will create big energy savings. The complexity of the referenced process made it necessary to use computational simulation tools. A process model was built with HYSYS and after several simulations using various conditions the data was fed to the Horizontal Multipass Flow TEMA HTRI model for computing the output and other condenser data.

2. ASSUMED HEAT EXCHANGER GEOMETRICAL AND PROCESS DATA

Cooling Tower:

Temperature Differential: 7- 8 °C

Tower Temp: 32 °C

Heat Exchanger:

Cooling water rate in condenser: varied for a constant pumping power

H_2S flow rate: 2364 m^3/hr

Gas Inlet Temp: 90 °C

Cooling Water Outlet Temp: 40 °C

3. SIMULATION RESULTS

The simulations results are presented in the following Table which also present for some measures the rate of improvement (in brackets). All data not presented above in Para. 2 are simulations results.

	Fouled HX	**Cleaned HX**
Gas Flow Rate – kg/s	2,364	2,364
Gas Inlet Temp. - °C	90	90
Gas Outlet Temp. - °C	70	40
Wall Temp. min/max - °C	65/83.9	33.9/66.4
CW Inlet Temp. - °C	32	32
CW Inlet Temp. - °C	40	40
CW Flow Rate – kg/s	38.8	61.0
CW Pressure Drop Coefficient	1.422	0.903 (-37%)
Effective Overall Temp. Difference - °C	44.3	24.2
Overall Heat Transfer Coefficient - kcal/m2·h·°C	123.3	352.2 (+285%)
Fouling factor – 1/U	0.003	0.0004
Cooling Capacity - kcal/h	309,600	487,000 (+157%)

The simulations were performed based on two measured heat exchanger H_2S outlet temperatures:

- 70 °C of a clogged condenser which was measured just before shutdown

- 40 °C of a clean condenser which was measured 156 after the ATCS installation

4. WATER SAVINGS FOLLOWING THE DISCONNECTING OF EXTERNAL COOLING

External cooling was used 5 months per year, 12 hours per day, total of 1,800 hours per year.

The 2 inch pipe providing the water has 26 holes, 3 mm diameter. The measured water flow from one hole is 189 liter/hour, calculating the total sprayed water per year of 8,845,200 liter,

At the cost of water of US $ 1 / cubic meter, the total savings provided by the avoidance of the external water cooling is US $8,845 / year.

5. THE TOTAL ACHIEVED SAVINGS

Operational savings:

Manual cleaning (manpower costs) ca. US $2,500 per year

Sealing: US $600 per year

Savings due to continual operation of the Sulfur Retrieval Plant: US $40,000 - 50,000 per year.

Savings of external water cooling US $8,845 per year.

TOTAL SAVINGS US $ PER YEAR

Condenser cleaning	2,500
Sealing	600
Continuous operation of the Sulfur Retrieval Plant	50,000
Spray water savings	8,845
Total	**$61,945**

It should be emphasized that this amount doesn’t reflect the increase of the plant productivity contributed by keeping the heat exchanger constantly at its highest design efficiency. It also doesn’t include costs of consequential unscheduled shutdowns which occurred a few times along the 30 years of the plant operation. Unfortunately these were not recorded.

CQM ATCS

The main advantages of CQM ATCS over other on-line automatic cleaning products (sponge balls, brushes and tube inserts) are:

- Excellent thorough cleaning: balls are periodically injected at a single shot carried by the fluid and reaching all tubes, both central and peripheral.
- Simple design: delivering high reliability, rapid installation, low maintenance, and high viability to cost sensitive markets.
- Wide range of sizes: suitable for a wide variety of heat exchangers, from small condensers in air conditioning, to large industrial applications. One shop for all plant cleaning systems.
- Better ball trapping mechanism: In other solutions, balls are frequently lost in the system, causing damage to downstream equipment, environment concerns and higher cleaning system operating costs.
- Better control of the cleaning process: cleaning periods are customizable to maintain a high level of performance, and minimize balls wear.

CQM has installed more than 2,000 ATCS around the world, delivering value to several markets:

- Central air conditioning systems and industrial refrigeration: up to 25% savings in energy costs, as well as typically 600 tons of GHG per 1000 T.R per year.
- Industrial processes: significant increase in productivity and reduction of operation and maintenance costs.

SUMMARY DISCUSSION

The main cost of fouling is due to decrease in productivity, which in the case studied here accounts for 80% of total cost.

Energy efficiency methods aim to both avoid GHG and increase both the potential and actual productivity of existing infrastructures (e.g. more kWh from existing power plants). The Table below presents how a substantial contribution to the energy efficiency aims is made by implementing on-line fouling cleaning and mitigation solutions:

Inefficient fouling mitigation thus not only costs plenty money, it also pollutes and necessitates more energy production, more power plants, etc. The usage of these energy and resources can be significantly reduced using effective fouling mitigation measures. Therefore, online cleaning of heat exchangers should become a high priority in the effort to promote private, national and global energy efficiency interests.

REFERENCES

[1] Prof. Dr.-Ing. H. Müller-Steinhagen, 2000, Introduction, *Handbook Heat Exchanger Fouling – Mitigation and Cleaning Technologies,* pp. 24-25

OFF-LINE Fouling Cleaning Implications	**ON-LINE Fouling Cleaning Implication**	**Energy Efficiency Implications**		
		Cost Savings	**More power from existing infrastructures**	**Saves GHG**
Productivity Decrease	**Productivity increase**	√	√	√
	Operation at maximum design efficiency	√	√	
	Avoiding plant shutdown	√	√	
Increase of Initial Investment	**Decrease of heat transfer areas**	√		√
	Eliminate of fouling monitoring equipment	√		√
Increase of O& M Costs	**Decrease of energy consumption**	√	√	√
	Reduce of pressure losses	√	√	√
	Reduce of O&M costs	√		
	Minimizing chemicals usage	√		√
	Decrease of managerial effort	√		
		PRIVATE Interest	**STATE Interest**	**GLOBAL Interest**