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ISSN 0350-350X
GOMABN 52, 2, 144-156
Stručni rad / Professional paper

UPGRADING OF REFINERY'S CORROSION MANAGEMENT SYSTEM

Abstract

Beside purchasing crude oil maintenance cost is the second major element of refinery operational expenditures and hence its influence on refinery profit margins is very high. According to a comprehensive US survey it is estimated that about 40% of refinery maintenance costs are in association with corrosion caused failures. It is also indicated that 10 – 40% of the corrosion costs (according to the type of industry) can be avoided with operating appropriate corrosion management systems. Moreover indirect costs of corrosion (Loss of Gross Margin – LGM) due to unscheduled unit shutdowns and environmental pollution can be even one magnitude higher then direct costs. Corrosion failures not only increase direct maintenance costs and indirect costs but are associated with high risk of accidents the frequency and severity of which has an increasing tendency worldwide.

It was realized that the ambitious profit goals of MOL Group Refining cannot be accomplished without maintaining high asset availability by focusing on prevention and significantly reducing the frequency of corrosion failures. Refining management launched the 3A (Anti-corrosion Application and Actions) initiative and a Corrosion Team was established with the following tasks: 1. Setting up effective corrosion management organizational structure for all MOL Group refineries. 2. Supporting work of Maintenance by unified corrosion failure reporting, compiling central corrosion database and applying advanced corrosion monitoring and inspection techniques. 3. Elaborating methodology for calculation of valid costs of corrosion prevention and mitigation. 4. Dissemination of corrosion information and refinery best practices, raising knowledge level and commitment of employees by regular training and education.

The above strategic goals have been broken down in short and medium term action plans and development projects according to the actual corrosion management status of each refinery. It is expected that after successful execution of the above projects corrosion caused failures as well as associated maintenance costs and risk of accidents could be minimized with increase in profitability of refining.

Key words: *petroleum refinery, corrosion management system*

UNAPREĐENJE SUSTAVA UPRAVLJANJA PROCESIMA KOROZIJE U RAFINERIJAMA

Sažetak

Uz kupnju sirove nafte trošak održavanja je drugi glavni čimbenik rafinerijskih operativnih troškova, te je time i njegov utjecaj na profitabilnost rafinerijskih marži vrlo visok. Prema sveobuhvatnoj anketi provedenoj u SAD-u, procjenjuje se da je oko 40 % rafinerijskih troškova održavanja povezano s kvarovima uzrokovanim korozijom. Ona je također pokazala da se 10 do 40 % troškova uzrokovanih korozijom (ovisno o vrsti industrije) može izbjeći ako se primjenjuju odgovarajući sustavi za upravljanje korozijom. Štoviše, neizravni troškovi korozije zbog neplanskih zaustavljanja proizvodnje i zagađivanja okoliša mogu biti čak za red veličine veći od izravnih troškova. Kvarovi uzrokovani korozijom ne samo da povećavaju izravne troškove održavanja i neizravne troškove, već su povezani s visokim rizikom od nesreća čija učestalost i ozbiljnost rastu u cijelom svijetu.

Zaključeno je da se ambiciozni ciljevi vezani uz dobit rafinerija MOL Grupe ne mogu postići bez značajnih ulaganja u postrojenja, usredotočenosti na prevenciju i značajnog smanjenja učestalosti kvarova zbog korozije. Upravljačke strukture u rafinerijama pokrenule su 3A inicijativu (Anti-corrosion Application and Actions, protukorozijska primjena i aktivnosti), a ustanovljen je i tim za koroziju sa zadacima: 1. Postavljanje učinkovite organizacijske strukture za upravljanje korozijom za sve rafinerije MOL grupe. 2. Potpora rada službe Održavanja prema ujednačenim izvješćima o kvarovima zbog korozije, sastavljanje središnje baze podataka o koroziji te primjena naprednih tehnika praćenja i nadzora korozije. 3. Razrada metodologije za izračun stvarnih troškova radi sprječavanja i ublažavanja korozije. 4. Širenje informacija o koroziji i najboljoj rafinerijskoj praksi, podizanje razine znanja i predanosti zaposlenika obukom i obrazovanjem.

Navedeni strateški ciljevi su raščlanjeni unutar kratkoročnih i srednjoročnih planova i razvojnih projekata u skladu sa stvarnim stanjem korozije u pojedinoj rafineriji. Očekuje se da će nakon uspješne provedbe navedenih projekata kvarovi uzrokovani korozijom, i s tim povezani troškovi održavanja i rizik od nesreća biti minimizirani uz povećanje profita rafinerija.

***Ključne riječi**: rafinerija nafte, sustav upravljanja korozijom*

Introduction

It has been recognized and known for long time worldwide that corrosion has a serious impact on plant operation and safety. According to an international survey [1] made by DNV based on the evaluation of 1800 refinery failure cases the severity of the accidents are increasing and there is a growing tendency in refinery material damage costs.

Another survey [2] made by MARSH Property Risk Consulting in the topic of Large Property Damage Losses in the Hydrocarbon-Chemical industries unveils that losses in the refinery industry have continued to increase over the last years (Figure 1). This report reviews the 100 largest property damage losses that have occurred in the hydrocarbon processing industries (including Refineries, Petrochemicals, Gas processing, Upstream, Terminals and distribution) since 1972. One of the most important findings regarding Refineries in the report is that the most frequent causes, besides the wrong material selection (wrong metallurgy) and the incidents occurring during startup or shutdown processes, are corrosion relevant.

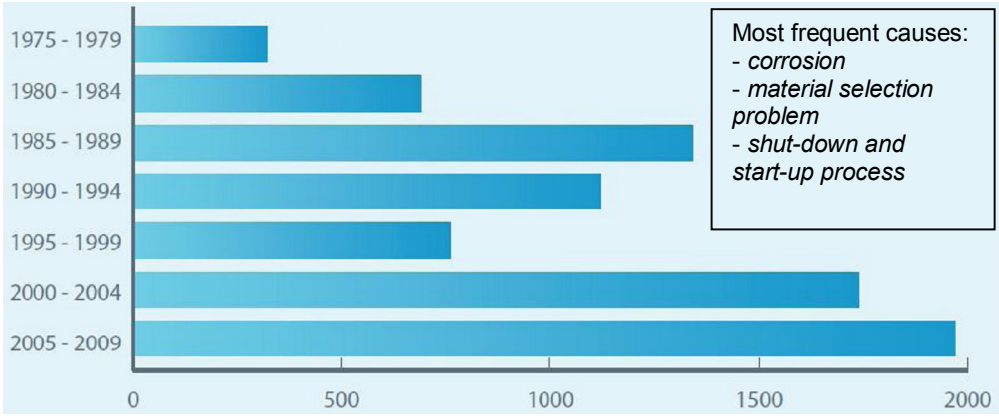

Figure 1: Refinery Losses in 5-year intervals
(Source: MARSH ENERGY PRACTICE, The 100 Largest Losses 1972 – 2009, Large Property Damage Losses in the Hydrocarbon Industries)

The latest example is the case of Port Arthur (Texas) refinery of Motiva Enterprises where the heat intensified corrosion, caused by a few gallons of caustic soda (caustic embrittlement), brought down the largest US refinery just after startup of the complex following a 10 000 MUSD development aiming at doubling the capacity of the unit. Reconstruction costs are estimated more than 300 MUSD and every day refinery remains shut Motiva lost 1.5 MUSD in profit margin. Fortunately, no injuries and fatalities were associated with the accident.

Not like in the case of the Venezuelan Amuay refinery, with one of the world's largest processing capacity of 1 million barrels per day, which was practically destroyed by an explosion and escalating fires in August 2012. In this accident 41 people were killed and 80 injured, the material losses are under investigation. The initial cause was a gas leak, however, its corrosion origin was not explicitly reported yet. According to analysts and an engineering firm's recent report the refinery suffered serious mismanagement, delays in major maintenance and underinvestment for safety measures.

At Duna Refinery a serious failure of the high pressure amine absorber (K101) in HDS-MIC unit was observed in March 2012 [3]. During regular testing of pressure vessels under the planned turnaround hydrogen blistering has been found on several internal areas of the said amine absorber. Furthermore, more detailed testing revealed that corrosion occurred in 25 mm depth of the 52 mm thick vessel wall covering more than 1 m^2 surface. HDS-MIC unit pre-treats FCC feed vacuum fractions and processing Delayed Coker heavy gas oil (CHGO) while providing gasoline, gas oil and vacuum fractions. Failure in HDS-MIC causes feed shortage in FCC, ETBE and HFA units. Due to the 15-day-long production loss (delay in the planned restart of HDS unit) the total Loss of Income accounted for approx. 9.3 MEUR, while the direct maintenance cost was 0.45 MEUR.

From the aforementioned examples it seems that corrosion does not only increase the risk of accidents which frequency and severity have also an increasing tendency worldwide, but are closely associated with maintenance costs and indirect costs of a refinery. In general it is said [4] that there are two components to the cost of corrosion, the direct and indirect cost. The direct cost of corrosion includes the annual expenditures spent on, inter alia, maintenance and repair, corrosion control techniques such as coatings, linings, chemical treatment, cathodic protection, high allows and non-metallic materials. Inspection and testing costs are also part of the cost of corrosion. Indirect costs result from planned and unplanned shutdowns, excess capacity, redundant equipment, loss of product, loss of equipment efficiency due to corrosion, contamination of product, and over-design. Indirect costs due to lost or deferred production can reach many times the cost of replacing or repairing corroded equipment but are often difficult to estimate.

According to a NACE report [5] it is estimated that about 40 % of refinery maintenance costs are in association with corrosion caused failures. Moreover indirect costs of corrosion (Loss of Gross Margin – LGM) due to unscheduled unit shutdowns and environmental pollution can be even one magnitude higher then direct costs. It is also indicated that 10 – 40 % of the corrosion costs (according to the type of industry) can be avoided with operating appropriate corrosion management systems.

Corrosion status of MOL group refineries

In recent years, the most important strategic targets of Refining (safety, mechanical availability and profitability) have been jeopardized in an ever increasing extent by frequent, unexpected unit shutdowns caused mainly by corrosion failures. There are several reasons of them. Firstly, refiners are facing ageing production units, that means the operational life of more and more equipment and piping are far beyond their designed lifetime. Secondly, in the last two decades, refineries purchased more and more “opportunity crudes” on the spot market resulting in unpredictable changes in the corrosivity of refinery production streams. Thirdly, to gain better and better quality products meeting with the more stringent environmental requirements and EU directives refiners adapted more and more destructive technologies.

And finally due to economic considerations some production units within the refinery operates in “stop and go” mode resulted in more frequent unit shutdowns and start-ups. The fact that the extent of the corrosion related issues in MOL refineries have reached a critical level is well proven by the increasing frequency of unscheduled unit shutdowns and the associated financial losses. These expensive and hazardous corrosion events (T201 amine regenerator in DC, K101 amine absorber in HDS, frequent leakages of gasoline pipelines, failures of heat exchanger tubes in HDS and GOK3, main column in FCC, etc.) primarily increased the direct maintenance costs needed for restoring operability of failed equipment (1,64 MEUR in 2010, 1,98 MEUR in 2011 and 1,14 MEUR in Q1 2012). Together with the above mentioned direct costs, corrosion related unexpected failures in key processing units (FCC, HDS, GOK, AV units) can also cause significant - sometimes one order of magnitude higher - Loss of Gross Margin (15,52 MEUR in 2010, 6,44 MEUR in 2011, and 18,36 MEUR in Q1 2012).

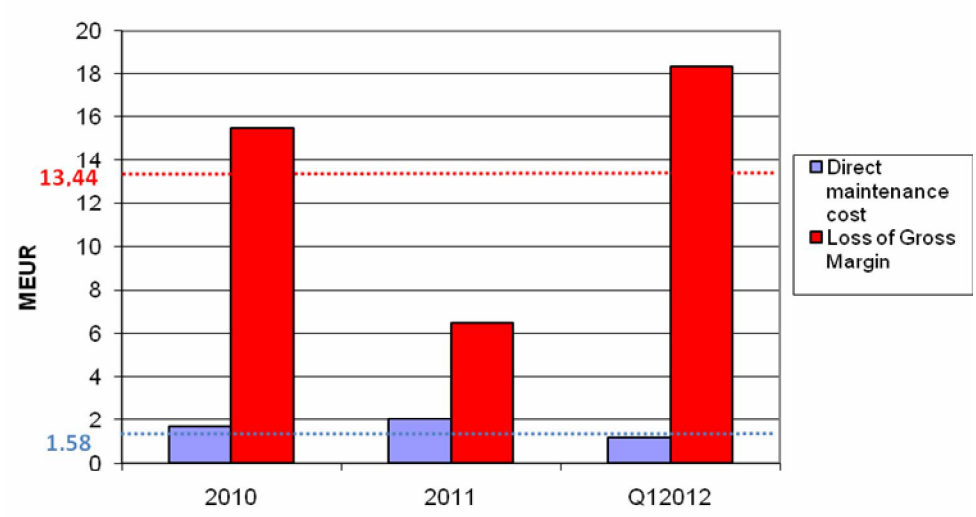

Figure 2: Corrosion associated costs at MOL Danube Refinery

To illustrate better the aforementioned facts the direct maintenance costs and the Losses of Gross Margin from Y2010 to Q1,2012 in annual breakdown are presented in Figure 2 that can be the basis for the Corrosion Upgrading Project Program post evaluation. [6] It is well illustrated by the above numbers how great is the influence of corrosion prevention on the profitability of refineries. After successful execution of the 5-year Project Program we estimate 25 % reduction in corrosion related direct maintenance cost and 50 % reduction in Loss of Gross Margin caused by corrosion failures. This means about 0,4 MEUR and 6,72 MEUR savings according to the selected baseline depicted on the above figure.

Actions taken to reach the strategic goals in corrosion management

Having already seen the above trends, in Q4 2009 a comprehensive survey on Group level was made to assess efficiency of the anti-corrosion activities in our main five refineries. It concluded that the efficiency of the current corrosion management system is very low, and further allocation of resources and complete renewal of the organization is needed. The following conclusions were drawn to be tackled in the future:

- No dedicated organization or person responsible for the management of anti-corrosion activities, neither at refinery nor at Group level;
- Few corrosion experts are working isolated, without significant impact on the corrosion management;
- While the refineries process almost the same crude, their anti-corrosion remedies/solutions (material selection, chemicals) are very different;
- Practically there is not any kind of information flow in corrosion related topics, we do not learn from each other's corrosion failures, best practices are not incorporated into MOL specifications;
- Corrosion costs are not separately collected from maintenance costs, no LCA calculations are made for anti-corrosion solutions;
- No regular corrosion education or training, no easily accessible central database is available in MOL Group.

Anti-corrosion applications and actions initiative

Based on the aforementioned serious conclusions, Refining management launched the 3A (Anti-corrosion Applications and Actions) initiative and refinery Corrosion Teams were created with the following strategic targets:

1. Setup effective corrosion management organizational structure for all MOL Group refineries, based on harmonized principles
2. Support the work of Maintenance by elaboration of unified corrosion failure reporting, central corrosion database and introduce state-of-the art corrosion monitoring and inspection techniques
3. Elaborate of methodology for calculation of valid costs of corrosion prevention and mitigation. Use SAP(ORACLE) for providing sound base for project type decisions about corrosion protection investments
4. Disseminate corrosion information and refinery best practice, raise knowledge level and commitment of MOL employees by regular training and education.

New organization for corrosion management

As a first step a new organizational structure was developed to be able to successfully manage the strategic goals of the 3A initiative in each refinery within MOL Group. Figure 3 shows the new organizational structure established in Duna Refinery (DR). Having regard to the local factors in all MOL Group refineries establishment of more or less the same organizational structure is under progress.

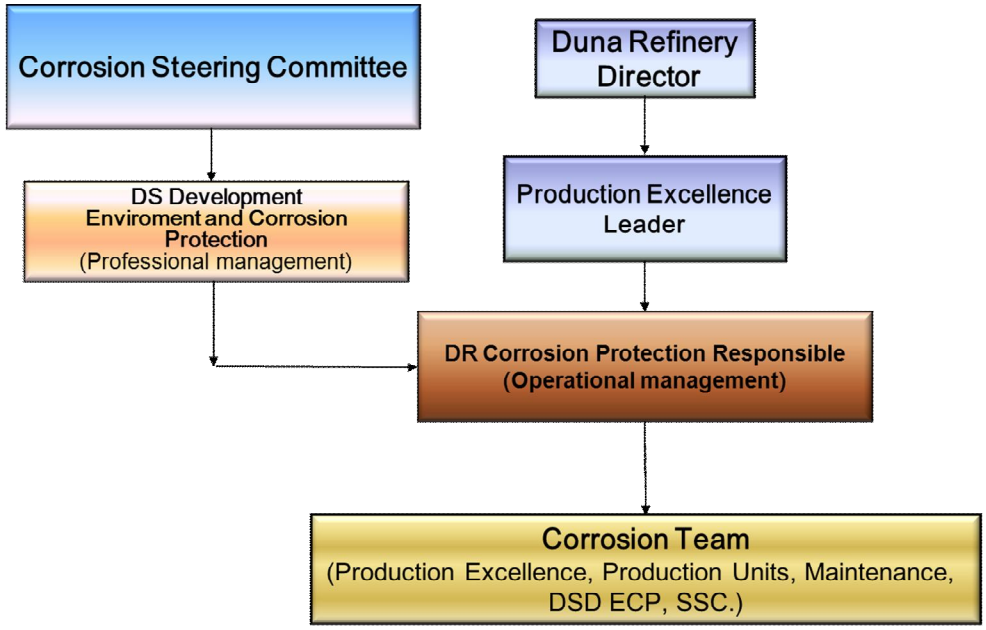

Figure 3: Structure of the new organization for corrosion management

The main responsibilities of the full-time Corrosion Protection Responsible, assigned by Refinery director and employee of Production Excellence, are to harmonize the work among the organizations concerned, to ensure the optimal spending of costs allocated for corrosion protection in DR, to disseminate, within the widest range possible, the professional information necessary for modern corrosion protection and to adopt the best practical experiences of other refineries. This person has process knowledge, operational experiences and special corrosion protection knowledge. The Corrosion Protection Responsible also manages the work of the Corrosion Team and provides the necessary information for the effective team's work. The Corrosion Team consists of delegates from the following organizations experienced in corrosion protection or other material sciences: Maintenance Management, Production Excellence, Production Units, DS Development, SSC for providing maintenance in DR. Main functions of the Corrosion Team are as follows:

- calculate the corrosion costs and to budget the corrosion protection expenses
- qualify the projects from corrosion point of view, to maintain the MOL specifications
- develop and manage a uniform corrosion database
- supervise the corrosion monitoring systems
- provide a passive corrosion protection expert background
- investigate, document and feedback the incidents of corrosion damages, etc.

Group level 3A activity is managed by Group level Corrosion manager under the supervision of the Corrosion Steering Committee of concerned leaders of Refining, Maintenance, Production Excellence, DS Development, HSE and SSC. Corrosion Steering Committee allocates the necessary resources to be able to implement actions in line with the Corrosion Upgrading Project Program.

The refinery corrosion protection is a complex activity the efficiency of which is based on the harmonized work of the concerned players and organizational units (operators, process engineers, maintenance personnel, developers and service providers). The basis of this harmonized work is the continuous exchange of information and the professional management applying the state-of-the-art principles and methods of corrosion protection.

Roundtable discussions in each refinery

At one of the Group Refining Meeting each MOL Group refinery presented its self-assessment about their applied corrosion management system. The presentations showed the strengths and the weaknesses of each Refinery, but the overall rating was moderate. Based on the corrosion status presented, Roundtable discussions were organised at each sites in order to be able to develop the Corrosion Upgrading Roadmap for all refineries. In Danube Refinery, before the roundtable discussions questionnaire survey was carried out aiming at assessing the level of corrosion related information available in DR. The other aim was that these questions would be selected for topics at the later organized roundtable discussion. Seven preliminarily screen questions were sorted out and delivered to nearly 400 employees including leaders, technology experts, unit operators at different levels. The answers were collected anonymously through SPS sites with the possibility of „No information" answer on a 0-7 scale rating. More than 30% of the targeted participants sent back their answers. Following questions were sent out:

1) How appropriate is chemical corrosion protection in DR?
2) Are suitable corrosion competencies available in DR?
3) What is the level of corrosion monitoring in DR?
4) How effective is the follow up of corrosion cost?
5) What is the quality of corrosion documentation in DR?
6) How effectively are conclusions from corrosion failure events are shared and utilized?
7) How conscious is the process of selection of construction materials in DR?

After evaluating the responses (see Figure 4) 5 out of 7 questions, the lowest ranking ones, were selected for round table discussion topics. In the Round table discussion program five roundtables were set up from members of high level leaders to different experts and each of the 5 questions as a topic for debate were discussed in details. As the result of this brainstorming the ideas were prioritized according to the investment demand and the achievable benefits. The lowest investment required and highest benefited ones were selected for further discussion.

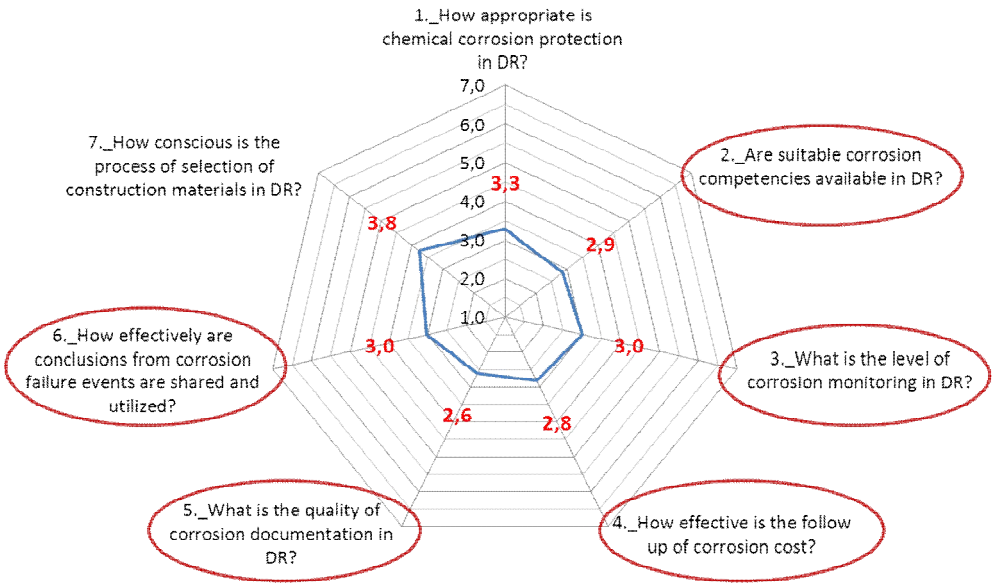

Figure 4: Evaluation of the questionnaire survey – roundtable discussion.

Corrosion upgrading technology roadmap

Using the information resulted from the outcomes of roundtable discussions for each refinery and to collect and visualize the next steps to reach the targets in corrosion management, Corrosion Upgrading Roadmap was prepared by the integrated 3A Corrosion Teams. In this Roadmap (see in Figure 5 a part of the entire Roadmap) the strategic goals of the corrosion upgrading activity are highlighted.

The potential answers to the corrosion challenges are formulated and the main enablers and capabilities needed for the successful mitigation are listed. A timeframe for the implementation of anti-corrosion steps are also given for each refinery. The tasks identified are planned to be solved from different resources including OPEX, MINOR CAPEX and project CAPEX.

Based on the common Corrosion Upgrading Roadmap mid-term corrosion action plans (Corrosion Upgrading Project Program) for each refinery was decided to launch. Development of the integrated corrosion management of MOL Group Refining is complex process which starts by creating corrosion teams, short- and medium-term action plans leading to different Corrosion Upgrading Project Programs of each individual refinery. This process needs different time frame for the individual refineries corresponding to their recent status in corrosion management.

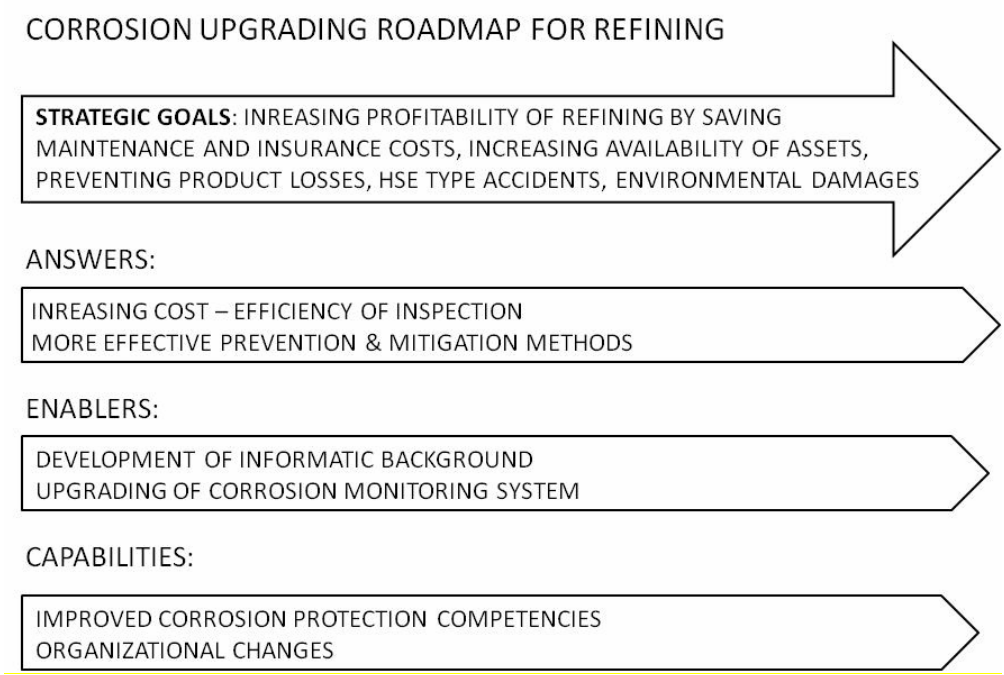

Figure 5: Part of the Corrosion Upgrading Roadmap

Corrosion upgrading project program

For Duna Refinery the mid-term (2012-2016) Corrosion Upgrading Project Program (Figure 6) containing the most urgent development tasks was formulated by the Corrosion Team. The total planned cost of this Project Program is about 5.5 MEUR for five years. Here in after some of the tasks (specific actions) are presented that have been broken down by the project program pillars.

I. Development of corrosion competency

- Based on the assessment of corrosion competencies already exists in the refinery a corrosion competency map is to be prepared.
- Identified competency gaps is to be filled by:
  - Launching basic level on-the-job training course for employees affected by corrosion.
  - Basic corrosion training for experts dealing with corrosion issues.
  - Postgraduate education of Corrosion Team members in cooperation with universities.
  - Preparing database of outside experts available for consulting.

- Organizing special presentation series and workshops with selected internal and external presenters.
- Assessment of currently existing laboratory potential for corrosion and metallographic testing within MOL Group and listing available external laboratories.

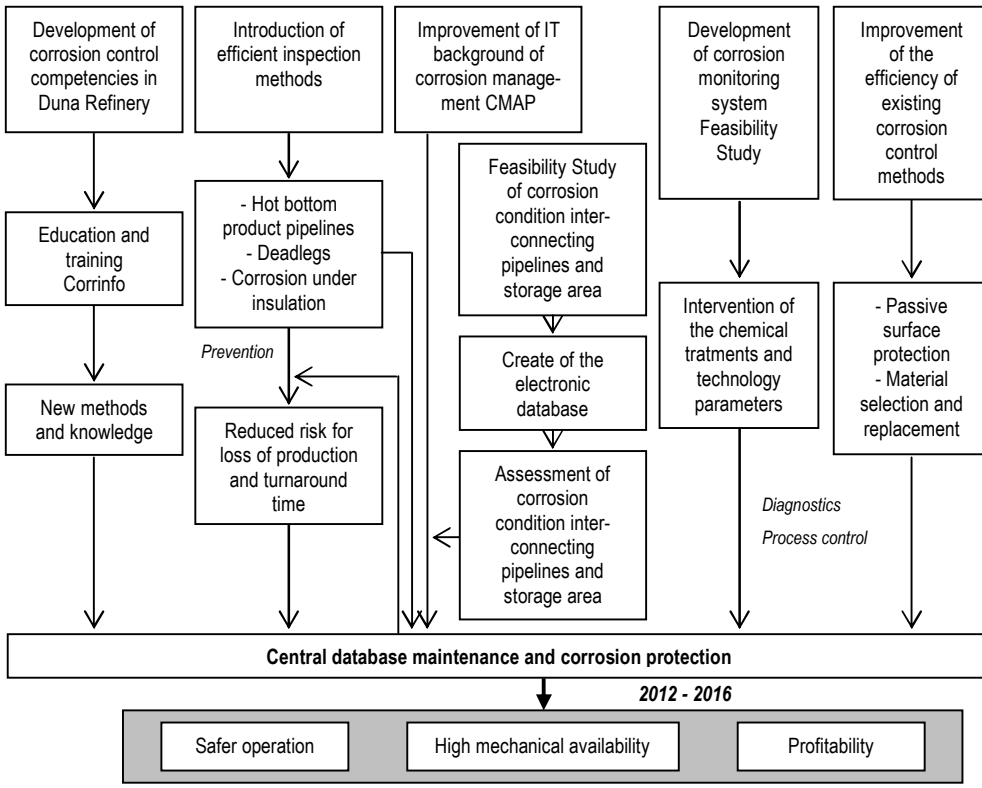

Figure 6: Structure of Corrosion Upgrading Project Program 2012-2016

II. Application of efficient inspection methods

- Fill up the existing RBI (Risk Based Inspection) database with updated technological and analytical information.
- Statistical evaluation of existing UT data, calculating trends and expected lifetimes.
- Purchase handy UT testers for unit operators to make quick, informative assessment of wall thicknesses on critical equipment.

- Deeper involvement of Corrosion Team and other co-departments to the preparatory work of minor and big turnaround's inspection planning.
- Delegate area responsible persons inside Maintenance for continuous searching introduction of new inspection methods.

III. Corrosion management it background improvement

- Unified, interconnected corrosion data bases for MOL Group refineries (CORRINFO) is to be compiled.
- Based on EFC recommendations unified corrosion failure reporting is to be elaborated in order to share the conclusions, lessons learnt from failure investigations.
- Display relevant corrosion information in FIR (Refinery Information System) as monthly reports.
- Further improvement of corrosion costs monitoring system in SAP (involvement of minor Capex and reconstruction items + indirect costs; more detailed classification of corrosion failure types).
- Preparation of corrosion map (CMAP) for key processing units and integration of the existing corrosion related databases.

IV. Corrosion monitoring system development

- Current corrosion monitoring systems are to be assessed, rationalized and upgraded based on unified principles in all refineries.
- Application of new instruments (wireless technology, permanently installed UT, etc.).
- Monitor the performance of cathodic protection systems.
- Continuous control and documentation of chemical protection.
- On-line measurement of important analytical parameters (pH, conductivity, oxygen content, etc.) is to be further investigated.

V. Corrosion control methods efficiency improvement

- Increase effectiveness of chemical protection (corrosion inhibitors, neutralizers, antifoulants, etc.)
- Survey the condition of chemical dosage systems, standardize types and increase accuracy and reliability of equipment.
- Involvement of Corrosion Team in the tendering of anti-corrosion chemicals.
- Stricter supervision of the performance of chemical suppliers (KPIs).
- Extend the application of coating protections (vessel internals, heat-exchangers, heat stable, erosion-proof coating systems, etc.).
- Application of corrosion resistant, alloyed materials of construction where corrosion rates, high risk of failures and cost-benefit calculations justify it.
- Upgrade Cathodic Protection (storage tank bottoms, underground piping, remote supervisory systems, etc.).

Conclusions

Many examples showed that corrosion slowly and gradually eats up our profit and reputation if it is neglected. But the good news is that corrosion can be controlled, but at a cost. It has been estimated that 10-40% of the annual corrosion costs could be saved if an appropriate corrosion management system was in place.

In 2009 a comprehensive approach was initiated in MOL Group Refineries to (1) decrease the corrosion associated maintenance costs, (2) to reduce the revenue losses caused by corrosion related unplanned unit shutdowns and (3) to mitigate the risks of incidents and accidents caused by corrosion type failures. Development of the integrated corrosion management of MOL Group Refining is fairly complex process which starts with creating new organization for corrosion management, then assessing the current status of corrosion management in each MOL Group refineries under roundtable discussions and developing the integrated Corrosion Upgrading Technology Roadmap. As a result of these actions Corrosion Upgrading Project Program was proposed to each MOL Group refineries. This step-by-step process needs different time frame for each refinery corresponding to their current status in corrosion management.

After successful execution of the 5-year Project Program we estimate 25% reduction in corrosion related direct maintenance cost and 50% reduction in Loss of Gross Margin caused by corrosion failures. This means savings of about 0,4 MEUR and 6,72 MEUR, respectively.

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Received: 05.10.2012.
Accepted: 08.04.2013.