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Corrosion threats and strategy to secure mechanical integrity of Dung Quat refinery

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Summary

This article summarises some key results of several analysis of corrosion issues in Dung Quat refinery and the selected strategic action plan for this critical matter. Since corrosion is a natural process which happens along the lifetime of the plant, the strategy for securing its mechanical integrity will be updated time by time in line with the site conditions and the company's inspection and corrosion policy.

Key words: Corrosion under insulation (CUI), corrosion under pipe support, corrosion of dead legs, risk-based inspection (RBI).

1. Introduction

Dung Quat refinery, well known as the first refinery installed in Vietnam, was successfully commissioned in 2009 and started its commercial operation since May 2010. The plant was designed to process Bach Ho (a local light sweet crude oil) and a mixed crude of Bach Ho and Dubai (at 85%/15%) at a capacity of 6.5 million tons per year. The refinery is sited on the coast of Viet Thanh bay and under the equatorial monsoonal climate [1].

Similar to other refineries and petrochemical plants, corrosion is a real challenge to the plant operator. Thanks to low sulphur feedstocks, internal corrosion at Dung Quat refinery plant would principally not be as serious as in the refineries processing high sulphur crudes. In contradiction to internal corrosion, due to severe conditions of the coastal weather, external corrosions have been confirmed as the most serious problem threatening safe and reliable operation of the plant.

In order to secure the operational availability of the refinery, a vision of achieving zero corrosion incidents was set by the plant operator. Establishment of a pro-active risk mitigation culture supported by effective corrosion management systems and advanced technologies are the key strategies applied in BSR.

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2. Corrosion challenges in Dung Quat refinery

There are many different types of corrosion recognised in industries. According to API 571, there are more than sixty damage mechanisms listed to refinery and petrochemical plants [2]. In order to effectively manage the mechanical integrity of the plant, a risk-based inspection (RBI) study was conducted to identify which damage mechanisms happened at what level of vulnerability for each or groups of equipment and piping sections.

Based on analysis of the occurrence frequency and the potential impacts of corrosions in the plant since the commercial operation, three groups of external corrosion issue were identified as the most harmful to the mechanical integrity of the plant. The next paragraphs will provide some brief descriptions of these matters by its level of risk to the plant.

Firstly, corrosion under insulation (CUI) was recognised as a "silent killer" mechanism in the plant due to a high number of damages recorded. Mentioned in NACE Standard Practice SP0198, "Corrosion under insulation has been occurring for as long as hot or cold equipment has been insulated for thermal protection, energy conservation, or process stabilisation" [3]. In Dung Quat refinery plant, the level of threat by CUI was fast-tracked by the local weather conditions with a high humidity and salty air and a very long monsoon season (approximate of two months continuously). In addition, it is believed that the existence of chlorides in the atmosphere accelerates CUI damages.

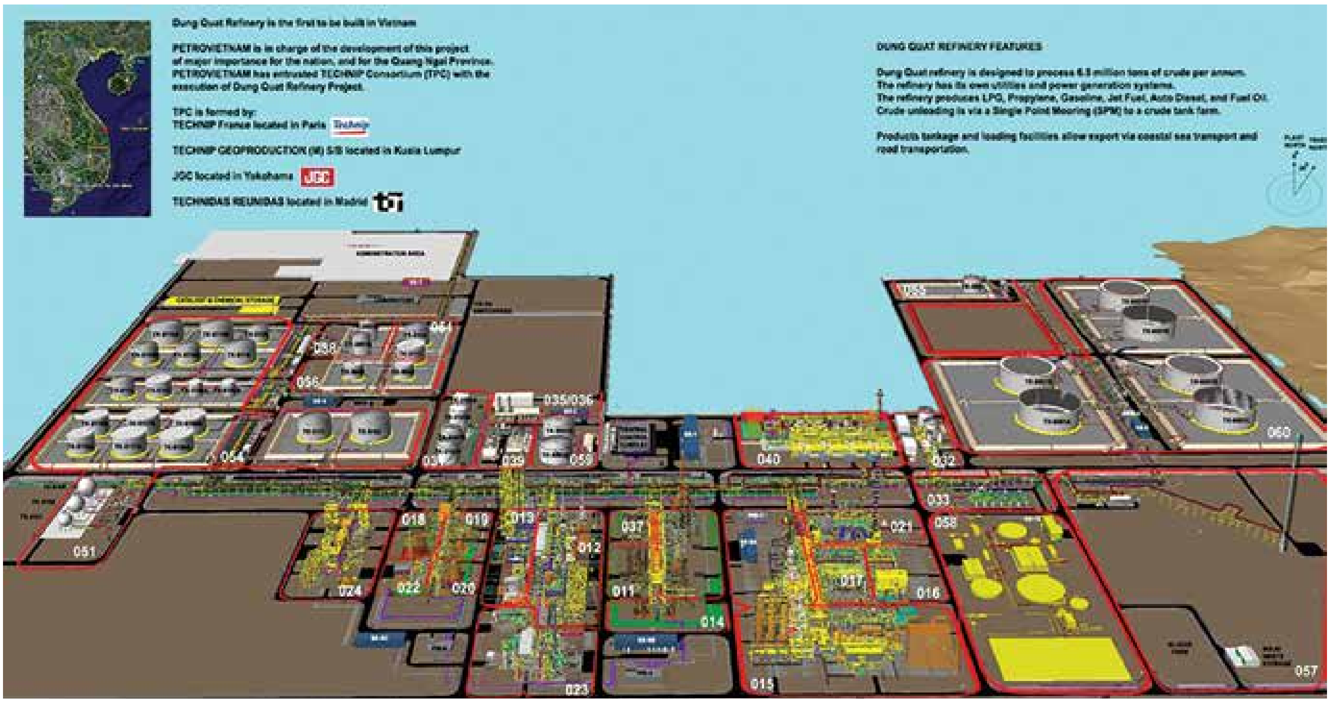

Figure 1. *Dung Quat refinery plant.*

Secondly, corrosion under pipe supports (CUPS) was acknowledged as a critical damage factor to the piping system. Similar to CUI, local climate and weather conditions facilitate CUPS damage. As a result of high corrosion rate to a large number of pipe's supports, mitigation of CUPS requires huge resources from maintenance team.

Thirdly, corrosion of dead legs attracts great attention of inspection teams because of a concentration of additional damage mechanisms in comparison with the remaining sections of the pipelines and equipment. For example, while microbiologically induced corrosion is commonly present in most of the dead legs, the by-pass spool of a control valve may additionally contain some layers of sediment which causes corrosion under deposit or, in case of drains normally may accumulate water which facilitates galvanic corrosion, etc. Subsequently, numerous amounts of dead legs fixed in the plant introduce real tangible challenges for inspection and operation teams in terms of management.

Other from above, failure mechanisms which have a significant frequency of occurrence or are potentially existing in the system but their impact to the plant availability have not yet been confirmed or have been resolved are not listed in detail. Some of them can be named herein such as refractory degradation, erosion-corrosion, atmospheric corrosion, wet H_2S damage (blistering/HIC/SOHIC/SSC), fuel ash corrosion, ammonium chloride corrosion, thermal fatigue, mechanical fatigue, amine corrosion, amine stress corrosion cracking, and high temperature hydrogen attack (HTHA), etc. In order to secure the mechanical integrity of the plant, an effective and systematic corrosion strategy is critically required.

Figure 2. *Image of a CUI.*

3. Strategies to overcome corrosion challenges in BSR

By consolidating related data, relevant analysis has been conducted to set up strategies to overcome the corrosion challenges of the plant. The key strategic management actions for some next few years focus on: i) competency development or employment of inspectors; ii) implementation of inspection management system;

and iii) application of new technologies for early risk detection and proactive risk migration. In parallel, the technical strategy to effectively handle the most concerned corrosion mechanism is highly required. Successful implementation of the strategy allows the company to take full advantages of operating the plant at maximum uptime, efficiency, and safety.

3.1. Management strategy

Corrosion and inspection management system (CIMS) is the essential tool for managing inspection plan of a very large quantity of stationary equipment and pipelines installed in the plant. BSR has fully utilised a dedicated CIMS software as the central tool for corrosion and inspection management in accordance with API RP 580 [4]. All mechanical assets are registered into the system together with their related engineering data. Then, on the basis of risk-based inspection study, detailed inspection plans will be developed for each of the equipment or piping system. A very simple workflow will be configured to the system allowing convenient usage by inspection engineers. Subsequent inspection data will be uploaded into CIMS system for detailed analysis using software built-in functions. Analysis results will then be used by corrosion engineers for determining next inspection date of the concerned asset.

A mechanical integrity dashboard was additionally developed by BSR inspectors providing main KPIs such as the number of assets having a remaining lifetime of less than 4 years, re-certification compliance, and inspection schedule compliance rate, etc.

As an important part of the management system, inspection procedures and guidelines perform a critical role in guaranteeing the quality and effectiveness of mechanical integrity management. The risk-based concept is the key to ensure resources are allocated to equipment and piping ranked as high risk. Therefore, inspection procedures are updated with detailed strategies for more effective management of corrosion threats.

Based on the concept of "incidents are preventable", a monitoring system was intensively upgraded in order to detect signs of corrosion as earlier as possible. The corrosion parameter monitoring system was configured to screen real time process data from the plant's Distributed Control System and Laboratory Information Management System. Data analysis will be conducted and advanced inspection technologies will be used in order to verify any potential signs of damages. All identified corrosion threats will be updated to the CIMS system for immediate actions.

3.2. Advanced technology employment strategy

Since corrosion is mostly hidden to human eyes, the utilisation of new technologies is essential to identify and confirm the existence of damage. BSR inspectors were en-

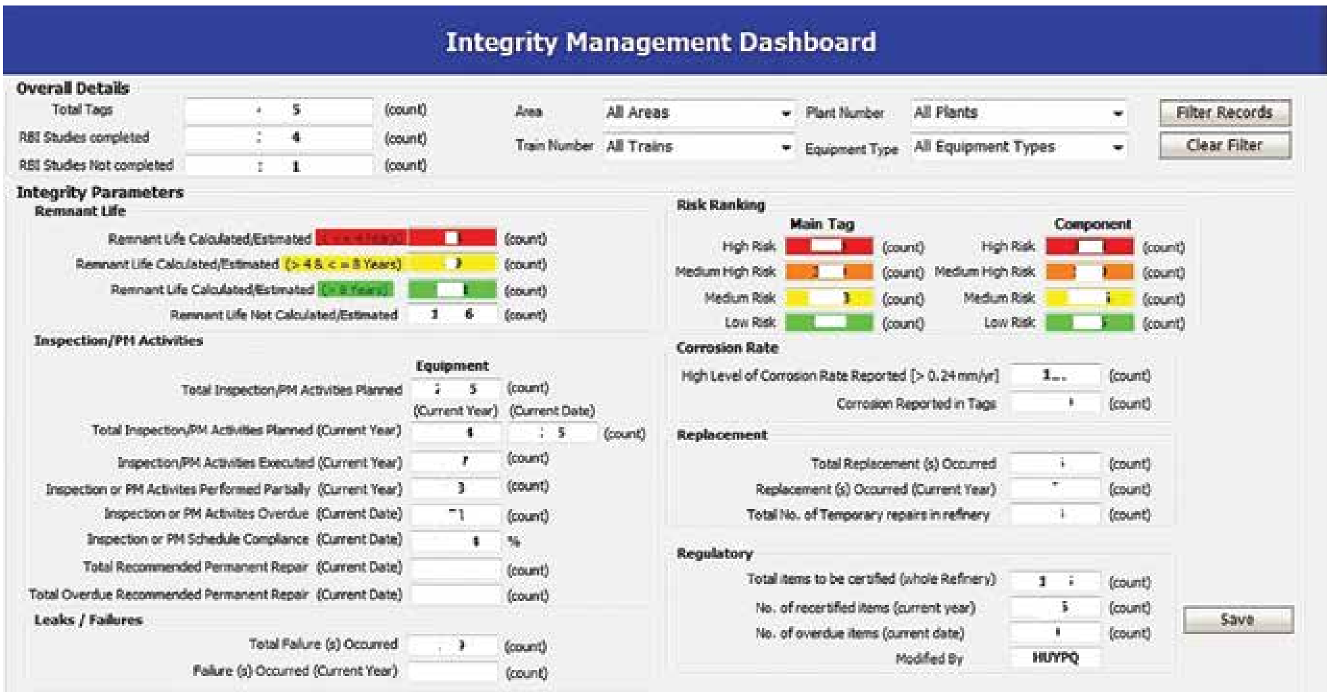

__Figure 3.__ CIMS dashboard window.

couraged to discover the newest technologies available in the market and study for the application.

From 2016, BSR inspectors have completed their study for using a combination of thermographic camera and gamma scan together with the traditional ultrasonic thickness measurement to evaluate refractory degradation.

In 2017, in order to detect "phantom chlorides", BSR laboratory settled the in-house procedure for testing organic chloride.

Recently, BSR inspection team is completing its study for deep exploitation of infrared thermography and guided wave ultrasonic testing techniques which help to detect CUI in a very short time and at very high accuracy without spending a lot of time and money to open insulation.

In the meantime, and with effective supports of the upgraded inspection management system, strategic technical solutions were developed with high priority in order to mitigate the mechanical integrity risks caused by the most severe mechanism as mentioned above.

The intensive CUI surveillance programme uses three layers of data, including visual inspection, thermography images and guided wave ultrasonic testing. By taking great advantage of thermography and ultrasonic techniques, the process for finding suspected CUI location was shortened hundreds of times while delivered much higher accuracy and was extremely cost-effective compared with the traditional method. Furthermore, this in-house CUI inspection method was able to find suspected CUI locations in a straight section of pipelines and equipment which is normally out of any traditional guidelines. By investigating the identified CUI corrosion, a systematic improvement was adopted in order to mitigate risks by CUI from the plant. Some of the main improvement areas include the strength of the protective layer, the application of thermal sprayed aluminium, and preventive maintenance for insulation, etc.

CUPS issue has been deeply investigated by the company's corrosion committee and resulted in a strategy. For the avoidance of CUPS, immediate actions are required such as the installation of protective media between the pipe and support. In long-term and future projects, main-

No.	Item	Unit	Spec	Min	Max	Average	Quick comment
1	Iron	mg/kg	**1.00 max.**	0	0.58	**0.12**	Very low iron content & stable pH: corrosion situation is on moderate level
2	pH	-	**8 - 10**	9	9	**9**	
3	Chloride	mg/kg	**10 - 20**	2.30	16.30	**7.28**	
4	Ammonia	mg/kg	**2000 max.**	1,023	1,375	**1,254**	
5	Sulfide	mg/kg	**2000 max.**	348	724	**498**	
6	Delta P overhead	Kg/cm²g		0.54147	0.65272	**0.60**	Stable delta P, a certain NH_4Cl salts deposition forms in the system but not fouling, removed by water
7	Electrical conductivity	µS/cm				**5,079**	

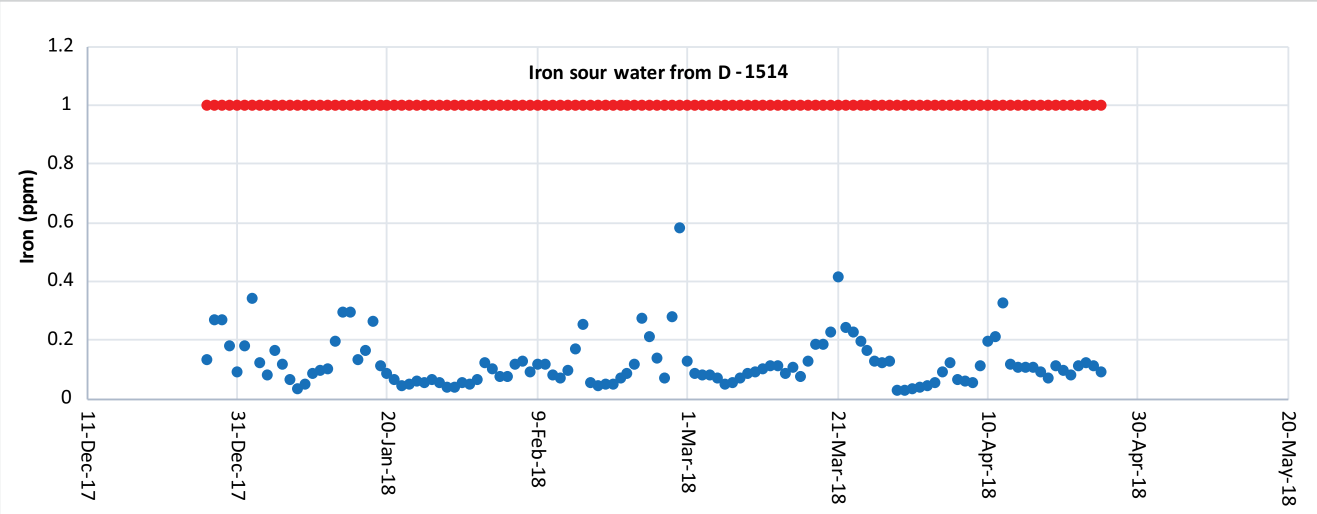

***Figure 4.** An example of corrosion monitoring of sour water.*

Figure 5. *Surveillance of wet insulation (area in red) by thermography camera.*

taining unique practices by having the shoe at the contact location of the pipe and support will help avoidance of CUPS.

The strategy for dead legs was recently reviewed and updated in accordance with API RP 2611 [5]. By employing the definition of dead leg in API PR 2611, some additional type of dead leg was added to the list. The updated list of dead legs demanded to enrich the inspection and testing methods for the detection of corrosion in these specialised objects. As soon as the inspection strategy was approved, all applicable solutions and practices such as line flushing or even removal of dead legs where possible, etc. were implemented in the plant.

4. Conclusions

Thanks to RBI study and utilisation of the modern monitoring system, corrosion threats have been properly addressed by BSR and appropriate strategies have been developed in a timely manner to secure the mechanical integrity of the plant. In parallel with enrichment of the management system, employment of advanced technologies is highly required in order to timely and effectively detect corrosion. Since the operational availability of the plant was maintained in the second quartile, as the latest result of refinery ranking by a well-known international organisation, it is understood that the strategy for securing the mechanical integrity of BSR has been successfully initiated.

Now and in the future, "aging equipment present a challenge to managing the integrity of plants" [6]. In order to maintain the mechanical integrity of the plant, in addition to implementation of the management system and new technologies, BSR needs to focus on developing and continuing the pro-active risk mitigation culture with the involvement of all employees. The culture will drive the continuous improvement process for the better mechanical integrity of the refinery and the sustainable development of the company.

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