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Paper Number: 2016-03

Evaluation of the Implementation of 50 Key Performance Indicators to Control Corrosion in Water Treatment and Steam Generation Facilities in a SAGD plant

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Abstract

This paper present the application of the 5-M methodology: Modeling, Mitigation, Monitoring, Maintenance and Management for controlling corrosion in water treatment and steam generation systems of a Steam Assisted Gravity Drainage (SAGD) plant.

Fifty (50) key performance indicators (KPIs) have been used to evaluate and track implementation of corrosion control strategies in the facility.

Introduction

Main purpose of Water Treatment and Steam Generation facilities is to produce steam for injection into the well. The heat from steam reduces the viscosity of the crude oil, allowing it to flow to the surface. The Water Treatment facility treats the raw water (from wells, rivers, lakes) to achieve the quality required for steam generation and the Steam Generators generate steam for injection into the well.

Internal corrosion is the principal risk affecting the Water Treatment and Steam Generation systems.

Context of Corrosion Control

Water Treatment and Steam Generation systems are the core of a SAGD plant. Any leak can shut down the whole operation and compromise the entire production. Corrosion and damages can occur by thirteen (13) different mechanisms in the Water Treatment and Steam Generation facilities. Therefore the risk of corrosion is high.

Internal Corrosion - Model

The main material of construction of the Water Treatment and Steam Generation facilities is primarily carbon steel, but a few components have been constructed from stainless steel. The following main mechanism of corrosion and mechanical/metallurgical damages have been identified. All the damages mechanism are defined by using published literature, industry knowledge and experience in similar facilities.

Aqueous Corrosion: Depending of the water source (wells, rivers, lakes, etc.) oxygen can be present or not. Water from wells is typically free of oxygen; however oxygen could get into the system through the tank's vent (not blanketed) increasing the potential to this damage. Therefore accelerated corrosion occurs in areas of the facility where oxygen ingresses. Carbon dioxide could be also present reducing the pH and increases its corrosivity.

Microbiologically Influenced Corrosion (MIC) & Under Deposit Corrosion (UDC): These damages can be expected in dead legs in piping, bottoms of tanks, filters, vessels, and areas experiencing low flow or stagnant conditions. The potential for under-deposition increases when water is not chemical treated and when streams carry deposits.

Erosion / Erosion Corrosion: It can be expected due to the presence of solids in areas of turbulence, e.g., downstream of pressure let down valves and change of direction sections, with sharp bends.

Hydrochloric Acid (HCl) Corrosion: HCl is used to treat water and is very aggressive to most common material of construction. Main components in this service are internally coated. Severe corrosion will occur if the lining fails or damaged.

Boiler Water / Condensate Corrosion: Will occur due to dissolved gases (mostly due to oxygen and to some extent due to CO_2) in boiler feed water and condensate systems.

Chloride Stress Corrosion Cracking (ClSCC): Austenitic stainless steels can suffer from ClSCC in chloride containing environment. Main factors influencing ClSCC includes temperature, chloride concentration, pH and dissolved oxygen.

Caustic Cracking: This damage occurs primarily in carbon steel piping and equipment exposed to caustic, and areas of high residual stress (i.e. adjacent to non-post weld heat treated (non-PWHT'd regions)). Cracking susceptibility increases with increasing caustic concentration and temperature.

Creep and Stress rupture: Will occur at high temperatures when components can slowly deform under the yield stress. This damage mechanism is expected for the steam generator equipment.

Short term overheating: This damage may be caused by temperature excursions (due to lack of temperature control). Presence of fouling/deposits on the surface at the steam generator equipment facilitates short term overheating.

Mechanical Fatigue: All equipment exposed to cyclic stresses will suffer from mechanical fatigue, e.g., flow direction during operation may lead to cyclic stress. This damage mechanism is expected at internal welds of vessels subjected to counter flow direction.

Thermal fatigue: Materials may suffer from thermal fatigue when sudden variation of temperatures occurs. Steam Generators equipment's, and mixing tee where hot and cold streams are mixed, will be susceptible to this kind of degradation.

Lining / Coating Failure: All internally coated or lined components will fail if it is damaged. Failure of lining/coating will accelerate the corrosion of metal.

Internal Corrosion - Mitigation

Several mitigation strategies are employed to control internal corrosion of Water Treatment and Steam Generator facilities. Some common mitigation strategies are discussed in the following paragraphs.

Aqueous Corrosion is mitigated by the injection of oxygen scavenger to reduce the concentration of oxygen and by avoiding the ingress of oxygen into the systems using blanket gases.

MIC is mitigated with the injection of chemical, as sodium hypochlorite which mitigates bacterial grow.

UDC is mitigated by avoiding areas of low flow or stagnation areas where solids can settle down and accumulate

HCl corrosion mitigation includes selection of appropriate metallurgy (nickel alloys) or maintaining the integrity of the internal linings. Integrity of linings may be ensured by taking due care during application, adopting and following the paint manufacturer’s recommended installation and maintenance procedures.

Boiler water / Condensate corrosion is mitigated by monitoring the pH value and chemical injection, if necessary, to properly control pH. Oxygen ingress into the system is avoided in order to reduce the corrosion.

ClSCC damage is reduced by upgrading the components to a more resistant material. API Technical Report 938-C is a good reference for establishing the susceptibility for this damages mechanism based on chloride composition, temperature and steel grade.

Caustic Cracking is effectively prevented by means of a stress-relieving heat treatment. A heat treatment at 1150°F (621°C) is considered an effective stress relieving heat treatment for carbon steel. Also, avoiding steam out of non PHWT carbon steel can effectively prevent this damage.

Creep, Stress rupture and short term overheating are reduced by minimizing hot spot and localized temperature excursions and by controlling flame impingement.

Mechanical Fatigue is reduced by design that minimizes stress concentration of component or by selecting a material with a design life sufficient for its intended service.

Thermal Fatigue is reduced by controlling rates of heating and cooling during start up and shutdown and designing the components with sufficient flexibility to accommodate the differential expansion caused by the temperatures variations.

Internal Corrosion - Monitoring

Proper monitoring techniques are used to monitor the amount of corrosion or damages. Each type of damage (general, localized, pitting, and cracking) are monitored with the applicable Non

Destructive Examination (NDE) techniques. Condition Monitoring Location (CML) are identified by considering the potential location for corrosion to occurs, type of corrosion (general, localized or pitting) or other damages as cracking.

External Corrosion – Model, Mitigation, and Monitoring

External corrosion is not a main concern in Water Treatment and Steam Generation facilities.

Measurement

Target values are established for the key process streams that could predict the occurrence of corrosion. Some key process control include maintenance of inlet water's pH between 9 – 11 and dissolved oxygen (DO) concentration to less than 5 parts per billion. Water values is also sampled and monitored at different locations of the Water Treatment and Steam Generation facilities.

Maintenance

In the Water Treatment and Steam Generation facilities, as any other process facility, process variations are expected. Fundamental understanding of the process/operating conditions variations resulting in damage mechanisms are required in order to establish the inspection program and maintenance activities to keep the components in an acceptable risk level. Any applicable maintenance activity that include repairs, should be based following the requirements of the design codes to each asset.

Management

Establishing an appropriate management system for the Water Treatment and Steam Generation facilities is the key to control corrosion damages. Good communication strategies have been established between internals departments (operation, process, inspection and corrosion) and external contractors. Corrosion management is based on the result of a corrosion study performed and the frequency of inspection are established considering the maximum value of corrosion damages. Figure 1 and Table 1 details the stages of implementation of 50 KPIs.

Acknowledgement

Lloyd's Register Energy Canada is acknowledged for providing me with the opportunity to conduct this study. Sri Ashokkumar and Sankara Papavinasam have shared their experience and provided guidance for carrying out this study.

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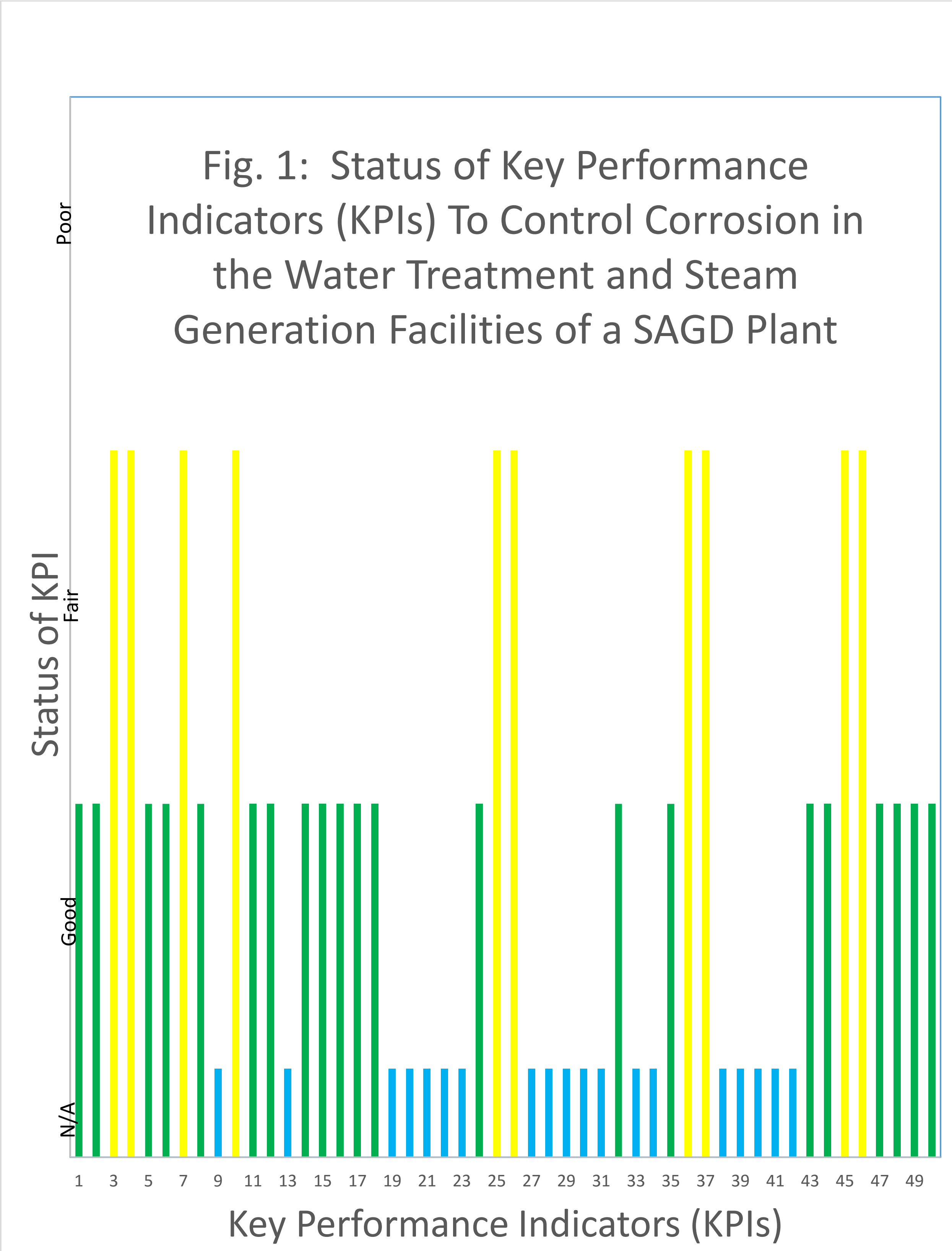

Fig. 1: Status of Key Performance Indicators (KPIs) To Control Corrosion in the Water Treatment and Steam Generation Facilities of a SAGD Plant
Status of KPI
Poor
Fair
Good
N/A
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
Key Performance Indicators (KPIs)

Table 1: Status of Implementation of KPIs to Control Corrosion in the Water Treatment and Steam Generation Facilities of a SAGD Plant

KPI No.	KPI Description	Ranking	Remarks/Comments
1	Segmentation of the infrastructure	Good	The facility segmented based on corrosion loop/circuits
2	Corrosion Risk	Good	High corrosion risk. 13 Corrosion/Mechanical damages
3	Location of the infrastructure	Fair	Located in an industrial area
4	Overall corrosion risk (Risk time consequences)	Fair	Corrosion affects mostly the oil production and the operation of the facility. Influence of corrosion to environment is relatively low.
5	Life of the infrastructure	Good	Brand new facility
6	Materials of construction	Good	Materials are mostly appropriate to the service
7	Corrosion Allowance (CA) (wall thickness)	Fair	CA was assigned at the design stage
8	Main Operating conditions	Good	The facility is Indented to run at normal operating conditions
9	Potential upset conditions in the *upstream* sector affecting this sector	N/A	No information available
10	Potential upset conditions in the *downstream (very next area or equipment)* sector affecting this sector	Fair	Would affect the production, but no additional information is available as this is a brand new facility
11	Mechanisms of corrosion	Good	All corrosion mechanism were identified; including cracking and mechanical/metallurgical damages
12	Maximum Corrosion rate (Internal)	Good	Established based on published literature, and experience with similar facilities
13	Maximum Corrosion rate (External)	N/A	Not applicable
14	Installation of proper accessories during construction	Good	Required accessories were placed during construction.
15	Commissioning	Good	All the commission activities were properly performed
16	Mitigation to control internal corrosion - is it necessary?	Good	Yes as water is known to cause corrosion
17	Mitigation strategies to control internal corrosion	Good	Mitigation strategies were recommended based on corrosion conditions.
18	Mitigated internal corrosion rate, target	Good	Target of corrosion/minimal wall were stablished

Table 1: Status of Implementation of KPIs to Control Corrosion in the Water Treatment and Steam Generation Facilities of a SAGD Plant

KPI No.	KPI Description	Ranking	Remarks/Comments
19	Percentage time efficiency of internal corrosion mitigation strategy	N/A	Not applicable yet (new facility)
20	Mitigation to control external corrosion - is it necessary?	N/A	Not evaluated (only internal)
21	Mitigation strategies to control external corrosion	N/A	Not evaluated (only internal)
22	Mitigated external corrosion rate, target	N/A	Not evaluated (only internal)
23	Percentage time efficiency of external corrosion mitigation strategy	N/A	Not evaluated (only internal)
24	Internal corrosion monitoring techniques	Good	Applicable NDE where defined based on damage type
25	Number of probes per square area to monitor internal corrosion	Fair	Condition Monitoring Location (CML) were stablished
26	Internal corrosion rate, from monitoring technique	Fair	No information is currently available, as this is a brand new facility. But estimated corrosion rate would be adjusted based on information from the internal monitoring technique
27	Percentage difference between targeted mitigated internal corrosion rate and corrosion rate from monitoring technique	N/A	Not available, as this is a brand new facility
28	External corrosion monitoring techniques	N/A	Not evaluated (only internal)
29	Number of probes per square area to monitor external corrosion	N/A	Not evaluated (only internal)
30	External corrosion rate, from monitoring technique	N/A	Not evaluated (only internal)
31	Percentage difference between targeted mitigated external corrosion rate and corrosion rate from monitoring technique	N/A	Not evaluated (only internal)
32	Frequency of inspection	Good	Time based regular frequency established

Table 1: Status of Implementation of KPIs to Control Corrosion in the Water Treatment and Steam Generation Facilities of a SAGD Plant

KPI No.	KPI Description	Ranking	Remarks/Comments
33	Percentage difference between targeted mitigated internal corrosion rate or corrosion rate from monitoring techniques and corrosion rate from inspection techniques	N/A	To be determined as this is a brand new facility
34	Percentage difference between targeted mitigated external corrosion rate or corrosion rate from monitoring techniques and corrosion rate from inspection techniques	N/A	Not evaluated (only internal)
35	Measurement data availability	Good	Target values were stablished for the key process parameters
36	Validity and utilization of measured data	Fair	Measured data is used to adjust corrosion damage/rates
37	Procedures for establishing the maintenance schedule	Fair	Not evaluated as this is a new facility
38	Maintenance activities	N/A	Not evaluated as this is a new facility
39	Internal corrosion rate, after maintenance activities	N/A	Not evaluated as this is a new facility
40	Percentage difference between targeted mitigated internal corrosion rate or corrosion rate from monitoring or inspection technique (whichever is decided in activity 27) and corrosion rate before maintenance activities	N/A	Not evaluated as this is a new facility
41	External Corrosion rate, after maintenance activities	N/A	Not evaluated (only internal)
42	Percentage difference between targeted mitigated external corrosion rate or corrosion rate from monitoring or inspection technique and corrosion rate before maintenance activities	N/A	Not evaluated (only internal)
43	Workforce - Capacity, education, and training	Good	General corrosion activities are supported by a third party
44	Workforce - Experience, knowledge, and quality	Good	General corrosion activities are supported by a third party
45	Data management - data to database	Fair	Corrosion related date (key parameters for the stream and thickness measurements) are

Table 1: Status of Implementation of KPIs to Control Corrosion in the Water Treatment and Steam Generation Facilities of a SAGD Plant

KPI No.	KPI Description	Ranking	Remarks/Comments
			captured in appropriate commercial software
46	Data management - data from database	Fair	Thickness reading / key process quality values are available from the software database
47	Internal communication strategy	Good	Communication strategies related to integrity of the equipment are stablished
48	External communication strategy	Good	Communication strategies related to integrity of the equipment are stablished
49	Corrosion management review	Good	Corrosion studies (internal concerns) have been performed by third party in consultation with plant personal, integrity team, and maintenance team.
50	Failure frequency	Good	Brand new facility. No failure has happened.