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Evaluation of Key Performance Indicators (KPIs) to Control Corrosion of a Gas Transmission Pipeline

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1.Introduction

Integrity management ensures that the assets are reliable for the entire duration of their design life. To ensure reliability of assets, all risks should be evaluated and controlled. One of the risks to oil and gas infrastructures are corrosion. The 5-M methodology is effective to develop and implement strategies to control corrosion. The 5-M methodology consists of five individual elements: modeling, mitigation, monitoring, maintenance and management. Implementation of 5-M methodology requires 50 key performance indicators (KPIs).

This assignment analysis 50 key performance indicators and evaluate the status of implementation of those 50 KPIs in "Transmission pipeline" sector. Pipeline transmissions are safe, reliable and convenient when compare to other modes of operation. Hydrocarbons transported through pipeline by pressure differential. Pressure is primary source of stress that in turn causes the decrease in wall thickness. The majority of oil and gas transmission pipelines are constructed using carbon steel. By regulation external surface of pipeline are protected with coating and backed up with cathodic protection.

This particular transmission discussed in this case study transports gas to a delivery point where the gas is used as fuel. Table 1 provides a summary on how the status of each KPI was evaluated and they were ranked.

Table 1: Criteria for Evaluation of KPIs

Status of Implementation	Score	Colour code (See Fig. 1)

Properly implemented	0 to 1	Green
Inadequately implemented	2 to 3	Yellow
Poorly implemented	4 to 5	Red

2.Context of Corrosion Control

The context of corrosion is established using 5 KPIs – 1, 2, 3, 4 and 5. These 5 KPIs analyse how the infrastructure is segmented (KPI 1) , what is the risk due to corrosion in each segment (KPI 2), what is the location of infrastructure (KPI 3), what is the overall corrosion risk (KPI 4) and what is age and remaining life of infrastructure (KPI 5).

Data collected on the pipeline indicate that overall the status of those 5 KPIs are not managed well.

KPI 1: The infrastructure is divided into manageable segments. However, efforts need to be put to divide the infrastructure into segments of uniform characteristic. Therefore a KPI score of 4 has been assigned.

KPI 2: For corrosion risks, external corrosion is not considered. So, external corrosion risk need to be evaluated. The risk due to different mechanisms of corrosion in each segment has not been established except internal pitting corrosion. Therefor a KPI score of 3 has been assigned.

KPI 3: The factors impacting the risks relates to location are not known and they need to be ascertained. Therefore a KPI score of 4 has been assigned.

KPI 4: The overall corrosion risk is product of KPI 2 and KPI 3. With the information obtained by author, it is not possible to estimate the overall corrosion risk. Therefor a KPI score of 5 has been assigned.

KPI 5: The infrastructure has been in operation for 20 years without known corrosion related incidences. However, no effort is made to understand the status of the infrastructure. Therefore, the corrosion risk is assumed to be high and a KPI score of 5 has been assigned.

3.Internal corrosion – Model

Model is primary tool to predict a corrosion rate based on carefully conducted laboratory experiment and/ or field experiment. It is important that model used to establish corrosion rate is relevant to the actual mechanism of corrosion of given material/environment combination.

KPIs 6, 7, 9, 10, 11, 12, 14, 39 and 40 summarize the implementation of Internal corrosion model.

KPI 6: Based on the contents, carbon steel seems to be the correct choice of material even though no information pertaining to material consideration is available or the basis for selection

of material for example lab experiment or case history. Therefore KPI score of 3 has been assigned.

KPI 7: Since the anticipated life and mitigated corrosion rate are not known, it is hard to estimate how much of 5mm wall thickness is designated for allowance. Based on typical corrosion allowance for carbon steel, this 5mm thickness is less than required allowance level. Therefor KPI score of 4 has been assigned.

KPI 8: Infrastructures are designed and built to operate at certain boundary conditions – commonly known as Integrity Operating Windows. There may be situation where the infrastructure be operated beyond the operating boundary conditions. Hence it influences on internal corrosion should be understood. Based on contents, the performance of this KPI considered as inadequately implemented, since there is no enough information regarding beyond "normal operating condition". Therefore KPI score of 2 has been assigned.

KPI 9: The oil and gas infrastructure is continuum, therefore failure in upstream segment may accelerate corrosion and impact the corrosion strategies of the segment under consideration. Based on content, the potential influences of upstream operations are understood and some communication plan is in place. But there is no proper report of this short term impacts of abnormal condition. Therefore KPI score of 3 has been assigned.

KPI 10: The potential influences of this sector operation on the operation of downstream are understood and even though there is some communication plan is in place. It is not well evaluated and documented. Analysis of this root cause will improve the project design and reduce corrosion. Therefore KPI score of 3 has been assigned.

KPI 11: It seems that all corrosion mechanisms are not considered to determine the most prominent ones. However, the two corrosion mechanisms considered seem relevant. Therefore KPI score of 2 has been assigned.

KPI 12: Anticipated maximum corrosion rate is not established; however, based on industry experience, approximate value is provided and that could be uniform and maximum corrosion rate. Based on content, the performance of this KPI is inadequately implemented. Therefore KPI score of 2 has been assigned.

KPI 14: No internal corrosion related accessories are installed and there is no information regarding involvement corrosion professional. Therefore KPI score of 4 has been assigned.

KPI 39: When maintenance carried out, steps should be taken to decrease its influence on internal corrosion. Internal corrosion rate should normally decrease after maintenance. However, reduction may not be possible in some situation. The collected data indicate that the corrosion rate before and after maintenance is same. Action such as meeting and discussion with corrosion, maintenance and operations personnel should be taken to identify opportunities to reduce the

corrosion rate by altering the operating and maintenance procedure. Therefore KPI score of 3 has been assigned

KPI 40: The collected data indicate there are no monitoring or mitigation strategies in place and hence there is no way comparing the percentage difference in corrosion rate. Therefore KPI score of 5 has been assigned.

4.Internal corrosion – Mitigation:

If model indicates that wall thickness loss due to corrosion would exceed the corrosion allowance within design life of the infrastructure, the steps should be taken to mitigate the corrosion. The following 4 KPIs 16, 17, 18 and 19 summarize the status of implementation of internal corrosion mitigation strategies. These 4 KPIs analyse based on model decision should be made whether to implement mitigation or not (KPI 16), implementation of appropriate mitigation strategies (KPI 17), targeted mitigated corrosion rate (KPI 18) and effectiveness of mitigation strategies (KPI 18).

KPI 16: There is no mitigation strategy for internal corrosion, assuming that the gas is dry and hence non-corrosive. Therefore KPI score of 4 has been assigned.

KPI 17: There is no mitigation strategy for internal corrosion, assuming that the gas is dry and hence non-corrosive. Therefor KPI score of 4 has been assigned

KPI 18: No information on the corrosion rate is available and no information on whether wall lost due to corrosion would exceed allowance or not. Therefore KPI score of 5 has been assigned.

KPI 19: There are no mitigation strategies in place and there is no possibility of finding its effectiveness. Hence KPI score of 5 has been assigned.

5.Internal corrosion – Monitoring:

It is important to ensure that the corrosion, under the field operating conditions, proceeds according to the anticipated low rate so that infrastructure lasts for its designated service period. Various techniques are used to monitor the corrosion rate at different stages. It is important that to select appropriate material and corrosion mitigation strategies, to ensure that the material and mitigation strategies selected continue to be effective in the operating environment.

KPIs 24, 25, 26, 27, 32 and 33 evaluated the statues of implantation of internal corrosion – Monitoring strategies.

KPI 24: There was no monitoring or inspection for internal corrosion, assuming that the gas is dry and non-corrosive. Hence KPI score of 5 has been assigned.

KPI 25: Data collected indicated that there is no monitoring technique and there is no monitoring probe in place to monitor the infrastructure. Hence KPI score of 5 has been assigned.

KPI 26: There is no monitoring technique in place to compare the corrosion rate from different technique. Therefore KPI score of 5 has been assigned.

KPI 27: This KPI describe the importance of accuracy of internal corrosion monitoring techniques. Since the data indicates that there is no monitoring technique in place, hence KPI score of 5 has been assigned.

KPI 32: This KPI describe the frequency of inspection. By performing inspection at close intervals, the required frequency of inspection may be established. Since there is no inspection, KPI score of 5 has been assigned.

KPI 33: This KPI describe difference in corrosion rate between monitoring and inspection technique. Since there is no indication of monitoring and /or inspection technique to establish the corrosion rate, KPI score of 5 has been assigned.

6.External corrosion – Mitigation:

The KPIs 20, 21, 22 and 23 summarize the status of implementation of external corrosion mitigation strategies.

KPI 20: External surface is protected with coating and backed up with CP. This KPI is properly implemented and hence score of 1 has been assigned

KPI 21: There is no information about the inspection of external surface during commissioning. But the external surface is protected with CP and mitigation strategy in place to control the external corrosion. Therefore KPI score of 2 has been assigned

KPI 22: This KPI describe the targeted mitigated corrosion rate. The targeted mitigated corrosion rate must reduce corrosion rate to lower value, Since collected data indicates that there is no anticipated maximum corrosion rate was established, KPI score of 5 has been assigned.

KPI 23: This KPI describes the effectiveness of mitigation strategy. Even though there is mitigation strategy in place, but data does not describe its effectiveness of mitigated corrosion rate. Therefore KPI score of 5 has been assigned

7.External corrosion – Model:

KPI's 6, 7, 9, 10, 11, 13, 14, 41 and 42 summarize the status of implementation of external corrosion model.

KPI 6: The external surface was protected with coating and backed up with CP. If the external surface protected with coating and backed up with CP, there is no corrosion, as long as it works properly. However; coating may undergo different modes of failure during service. In order to avoid or well prepare for that, model need to develop to simulate field failure. Data indicates there is on such model.

KPI 7: There is no information about what type coating and its effectiveness in that environment.

KPI 9: Potential influence of upstream is understood and some communication plan in place.

KPI 10: Potential influence of upset conditions in this sector is understood and some communication plan in place.

KPI 11: It seems that all corrosion mechanisms are not considered to determine the most prominent one.

KPI 13: Anticipated maximum corrosion rate is not established; however based on industry experience, approximate value is provided and that could be uniform and not maximum corrosion rate.

KPI 14: There is CP installed for external corrosion and there is no information regarding involvement corrosion professional. Therefore KPI score of 4 has been assigned

KPI 41: Data indicates there is no change in corrosion rate before and after maintenance activities. Therefore a KPI score of 3 has been assigned

KPI 42: The collected data indicate there are no monitoring or mitigation strategies in place and hence there is no way comparing the percentage difference in corrosion rate. Therefore KPI score of 5 has been assigned

8.External corrosion – Monitoring

KPIs 28, 29, 30, 31, 32 and 34 summarize the status of implementation of external corrosion monitoring.

KPIs 28, 29, 30: Overall status of those KPIs are very poor. There is no monitoring techniques in place to evaluate performance of coating and CP.

KPI 31: This KPI describe the importance of accuracy of external corrosion monitoring techniques. Since the data indicates that there is no monitoring technique in place, hence KPI score of 5 has been assigned.assigned.

KPI 32: No inspection technique is deployed and hence no frequency is established.

KPI 34: No corrosion rate is available from inspection technique because no inspection technique is employed. Therefor KPI score of 5 has been assigned.

9.Measurement

Proper data is required to identify corrosion condition in the segment and also the reliability of the measurement and lag time between measurement and integration of measured data with other corrosion parameter should be consider before using the data for the corrosion management process. KPIs 35 and 36 summarize the status of implementation of measurement techniques.

KPI 35: No measurement strategy is implemented to measure parameters relevant to corrosion.

KPI 36: Since no measurement strategy is implemented no data is available.

10.Maintenance

KPIs 8, 15, 37, 38, 43, 44, 45 and 46 summarize the status of implementation of maintenance activities. Overall status of those KPIs are fair enough.

KPI 8: Infrastructures are designed and built to operate at certain boundary conditions – commonly known as Integrity Operating Windows. There may be situation where the infrastructure be operated beyond the operating boundary conditions. Hence it influences on internal corrosion should be understood. Based on contents, the performance of this KPI considered as inadequately implemented, since there is no enough information regarding beyond "normal operating condition". Therefore KPI score of 2 has been assigned.

There are no information regarding commissioning of the pipe (KPI 15), operating conditions (KPI 8), procedure to implement maintenance (KPI 37), maintenance activities (KPI 38), employees and their responsibilities (KPI 43), collection of data (KPI 45) and procedure to obtain data (KPI 46). These parameters directly or indirectly influence the corrosion.

11.Management

KPIs 47, 48, 49 and 50 summarize the status of implementation of management strategies. There is no internal (KPI 47) or external (KPI 48) communication strategy exists. However, no failure due to corrosion has occurred (KPI 5) during the review period (20 years) indicating low probability for corrosion. However, continued operation under these conditions will eventually lead to failures. Therefore regular meetings should be held to evaluate the status of the pipeline (KPI 49).

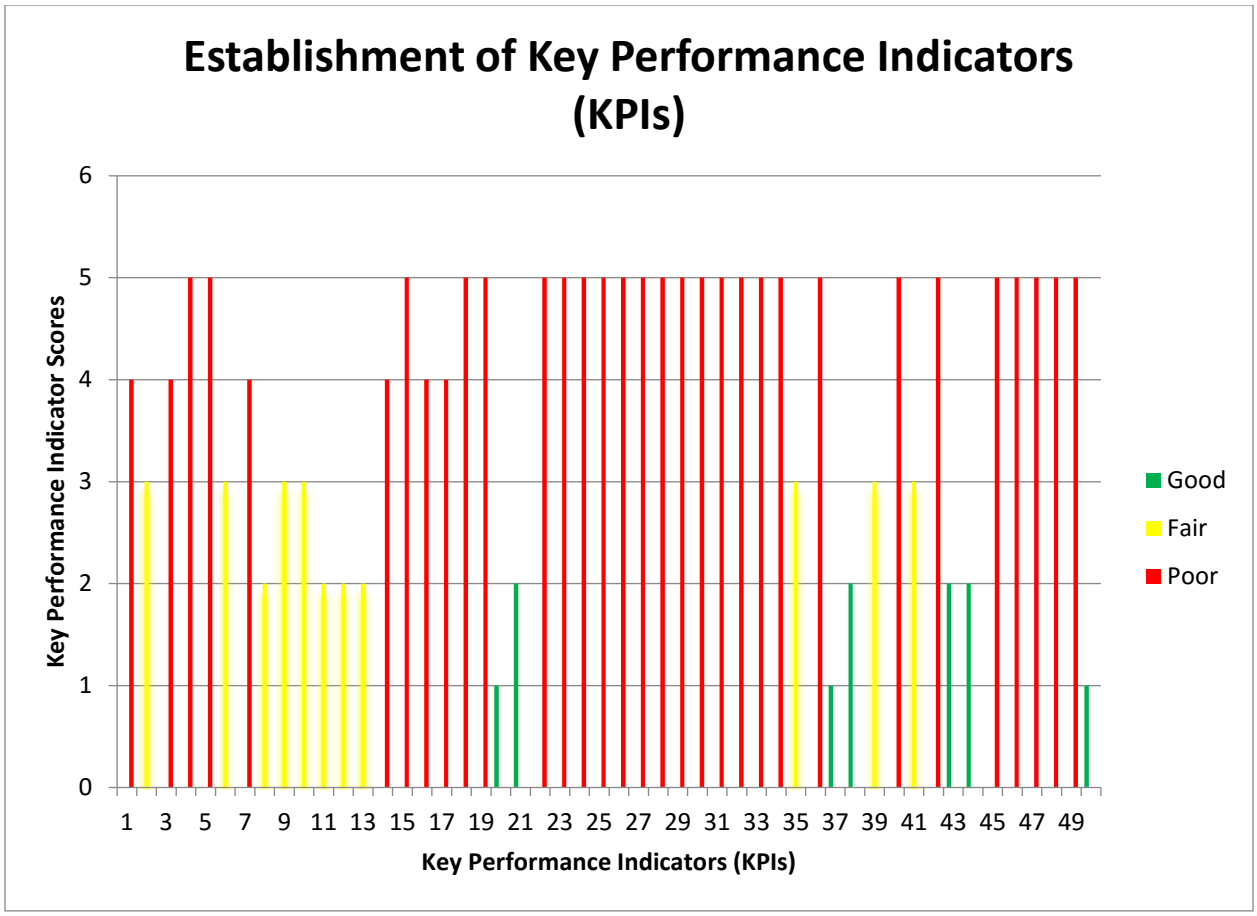

Figure 1: Status of Key performance indicators

12.Summary

This paper analyzed the status of implementation 50 KPIs to control corrosion in a gas transmission pipeline. Figure 1 summarises the status of those 50 KPIs. Overall corrosion control strategies were not considered and implemented in this pipeline. Due to low corrosivity of gas this pipeline has not experienced any corrosion related issues over its 20 years of operation. However, continued operation without considering corrosion will sooner than later lead to corrosion related failures.

13.Reference

1. S. Papavinasam, "Corrosion Control in the Oil and Gas Industry", Gulf Professional Publication (2013).