STEM-Corrosion™

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Aim Corrosion Management: Perfect Key Performance Indicators

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ABSTRACT

Asset integrity management (AIM) ensures that the assets perform effectively and efficiently for the entire duration of their designed life. Implementation of AIM process requires evaluation of all risks. One of the risks to oil and gas infrastructures is corrosion. Therefore, controlling corrosion risk is a key component of AIM. The 5-M methodology is available to develop and implement strategies to control corrosion. The 5-M methodology consists of five individual elements: modeling, mitigation, monitoring, maintenance and management.

The 5-M methodology implementation requires establishment of several key performance indicators (KPIs). These KPIs track corrosion control implementation of an asset for its entire life, i.e., during design, construction, commission, operation, and abandonment stages.

This paper illustrates fifty (50) KPIs. Industry surveys and failure analysis formed the basis for the development of these 50 KPIs. The paper also explains cost effectiveness of various KPIs.

1. INTRODUCTION

Between the sources of the hydrocarbons and the locations of their use as fuels, there is a vast network of oil and gas industry infrastructures. The oil and gas industry includes production, transmission, storage, refining, and distribution sectors. The conventional oil and gas production sector includes drill pipe, casing pipe, downhole tubular, acidizing pipe, water generator, gas generator, wellhead, production pipeline, gas dehydration facility, oil separator, lease tank, and waste water pipeline. The non-conventional oil and gas production sector in addition includes truck-shovel, truck, conveyer belt, hydro-transport pipeline, and steam injection well.

Failure in any of these units not only decreases or stops production, but also negatively impacts the downstream sectors such as transmission pipelines and refineries. This paper describes 50 KPIs to control corrosion of the oil and gas production infrastructures.

2. THE 5-M METHODOLOGY

The oil and gas industry is striving to reach “zero failures” due to corrosion. The overall objective of the 5-M methodology is to help the industry to attain this goal. The 5-M methodology consists of five individual elements: model, mitigation, monitoring, maintenance and management.

1. The primary function of model (Step 1) is to predict if a given material is susceptible to a particular type of corrosion in a given environment and to estimate the rate at which the material would corrode in that given environment.
2. The objective of Step 2 – Mitigation - is to develop a mitigation strategy if Step 1 (model) predicts that the corrosion rate is high, i.e., that at this corrosion rate the minimum thickness of material used as corrosion allowance is inadequate.
3. The objective of Step 3 - Monitoring - is to ensure that the pipeline is performing in the way the model, (Step 1) predicts and that the mitigation strategy (Step 2) is adequate.
4. All these strategies would fail if a good maintenance strategy was not developed and implemented.
5. Corrosion management integrates corrosion control strategies with overall AIM.

2.1. Model

The primary function of modeling is to predict if a given material is susceptible to a particular type of corrosion in a given environment and to estimate the rate at which the material would corrode in that given environment. Laboratory experiments and/or previous field experience help in obtaining the information. Model helps the corrosion professionals to establish material of construction, corrosion allowance (i.e., material wall thickness to account of loss due to corrosion) and to decide if additional corrosion control strategies are required. Model also helps to identify locations in oil and gas production sectors that are susceptible to corrosion and the anticipated corrosion rates in those locations.

2.2 Mitigation

The objective of Step 2 – Mitigation - is to develop a mitigation strategy if Step 1 (model) predicts that the corrosion rate is high, i.e., that at the corrosion rate anticipated under operating conditions, the minimum thickness of material used as corrosion allowance is inadequate. Time tested and proven methodologies to control internal corrosion are cleaning, corrosion inhibitors, and internal liners and to control external corrosion are coatings and cathodic protection.

2.3 Monitoring

The objective of Step 3 - Monitoring - is to ensure that the corrosion rate under operating conditions is equal or less than that predicted in Step 1 (model) and that the mitigation strategy (Step 2) is adequate.

Corrosion monitoring may occur in three stages:

- In the laboratory, at the design stage, to evaluate the suitability of a given material in the anticipated environment.
- In the field, during operation, to determine the actual corrosion rate.
- In the field, during operation, to ensure that the material is continued to be safe under the field operating environment, i.e., to ensure that the corrosion allowance thickness has not been exceeded.

2.4. Maintenance

All strategies (selection of appropriate materials that can withstand corrosion in a given environment, development of appropriate models to predict the behavior of the system, implementation of mitigation strategies to control corrosion and monitoring of system to ensure that the corrosion of the system is under control) would fail if a good maintenance strategy was not developed and implemented. A comprehensive and effective maintenance program requires implementation of five interdependent entities:

- Equipment
- Workforce
- Data
- Communication, and
- Associated activities.

2.5. Management

Corporate management implements a top-down approach (risk-avoidance, goal-based and financial-oriented) to minimize the risk from corrosion. On the other hand, corrosion professionals estimate risk in a bottom-up approach (field-experience, fact-based and technical-oriented). Corrosion management provides a vital and seamless link between the top-down corporate management approach and the bottom-up corrosion professional approach. In a way, the corrosion management is a combination of art and science to balance financial and technical requirements.

Corrosion management is thus a systematic, proactive, continuous, ongoing, technically sound and financially viable process of ensuring that the people, infrastructure and environment are safe from corrosion. The activities of corrosion management include:

- Evaluation and quantification of corrosion risks during design, construction, operation, shutdown and abandonment stages, and identification of factors causing, influencing and accelerating these corrosion risks.
- Establishment and implementation of organizational structure, resources, responsibilities, best practices, procedures and processes to mitigate and monitor corrosion risks.
- Maintenance and dissemination of corporate strategy, regulatory requirements, finance, information affecting corrosion and records of corrosion control activities.
- Review the success of implementation of corrosion control strategies and identify opportunities for further correction and improvement.

3. KEY PERFORMANCE INDICATORS (KPIs)

Implementation of the 5-M methodology requires several key performance indicators (KPIs). The number of KPIs depends on the level of risk and on the timing of implementation of corrosion control strategies. It is essential to develop and list as many as KPIs. Without such an explicit list, it would be difficult to control corrosion and to demonstrate due diligence in corrosion control implementation.

Industry surveys and failure analysis have identified 50 minimum KPIs to implement effective and economic corrosion control strategies. Detailed descriptions of all 50 KPIs are available elsewhere[1]. Table 1 lists the 50 KPIs and Table 2 presents categories of them.

Figure 1 presents status of KPIs in one oil production field. In Fig. 1, green colour indicates successful implementation of the KPI, yellow colour indicates adequate implementation of the KPI, and red indicates non-implementation of the KPI. Successful implementation of all 50 KPIs would result in a score of 50 or less (0 to 1 for successful implementation, 2 to 3 for inadequate implementation, and 4 to 5 for non-implementation). From Fig. 1, the overall KPI score of this oil production field is 95.

Comparison of Fig. 1 and Table 2 indicates that opportunities exist to improve internal corrosion mitigation strategies, maintenance activities, and corrosion management practices in the particular oil production field.

Cost of implementing 50 KPIs may vary. Figure 2 presents a general cost estimate for implementing KPIs. Comparison of Fig. 1 and Fig. 2 reveals that:

- only 59% of the cost required to completely implement the KPIs is spent on this oil production field
- additional 10% increase of cost (to fully implement KPIs 9, 16, 17, 18, 19, 43, 44, 45, 46, 47, and 48) would decrease the overall KPI score to 73 and
- additional 10% cost would bring all KPIs to “successful” and “adequate” levels of implementation and would consequently reduce all corrosion risks to “low” and “medium” levels.

Thus explicit listing of KPIs helps to balance the cost of corrosion control and reduction of corrosion risk.

4. STAGES OF IMPLEMENTING KPIs

The implementation of KPIs occurs in different situations:

- In conceptual and design stages. This will increase the capital expenditure (CAPEX), but will decrease operating expenditure (OPEX). This is the ideal stage for developing strategies to implement the KPIs.
- In normal operation stage. This will increase OPEX, but will bring immediate benefit.
- In abnormal operation stage. Failure of similar asset will require evaluation of all assets.
- During change of management. When a new asset is acquired evaluation of the implementation of KPIs will quickly provide corrosion control status of the asset and provide guidelines to progressively implement strategies to decrease the corrosion risk of the asset.

5. SUMMARY

- This paper highlights the importance of developing and implementing key performance indicators to effectively and economically control corrosion using oil production sector as an example.
- It describes the 5-M methodology and 50 KPIs to achieve this goal.
- It explains the inter relationship between KPI implementation and cost benefit.
- It discusses various situations the KPIs may be implemented.

6. REFERENCES

1. S. Papavinasam, “Corrosion Control in the Oil and Gas Industry”, 1020 pages (October 2013), Gulf Professional Publication (Imprint of Elsevier), ISBN: 978-0-1239-7022-0.

Table 1: Key Performance Indicators (KPIs) to Develop Effective and Economical Corrosion Control Strategies[1]

KPI Number	KPI description	Stages of implementation
1	Segmentation of the infrastructure	Conceptual
2	Corrosion risks	Conceptual
3	Location of the infrastructure	Conceptual
4	Overall corrosion risk (Risk times consequence)	Conceptual
5	Life of the infrastructure	Conceptual
6	Materials of construction	Design
7	Corrosion allowance (wall thickness)	Design
8	Main operating conditions	Design
9	Potential upset conditions in the upstream sector affecting this sector	Design
10	Potential upset conditions in this sector affecting downstream sector	Design
11	Mechanisms of corrosion	Design
12	Maximum corrosion rate (Internal)	Design
13	Maximum corrosion rate (External)	Design
14	Installation of proper accessories during construction	Construction
15	Commissioning	Commission
16	Mitigation to control internal corrosion – is it necessary?	Operation
17	Mitigation strategies to control internal corrosion	Operation
18	Mitigated internal corrosion rate, target	Operation
19	Percentage time efficiency of internal corrosion mitigation strategy	Operation
20	Mitigation to control external corrosion – is it necessary?	Operation
21	Mitigation strategies to control external corrosion	Operation
22	Mitigated external corrosion rate, target	Operation
23	Percentage time efficiency of external corrosion mitigation strategy	Operation
24	Internal corrosion monitoring techniques	Operation
25	Number of probes per square area to monitor internal corrosion	Operation
26	Internal corrosion rate, from monitoring technique	Operation
27	Percentage difference between targeted mitigated internal corrosion rate and corrosion rate from monitoring technique	Operation
28	External corrosion monitoring techniques	Operation
29	Number of probes per square area to monitor external corrosion	Operation
30	External corrosion rate, from monitoring technique	Operation
31	Percentage difference between targeted mitigated external corrosion rate and corrosion rate from monitoring technique	Operation
32	Frequency of inspection	Operation
33	Percentage difference between targeted mitigated internal corrosion rate or corrosion rate from monitoring techniques and corrosion rate from inspection technique	Operation

34	Percentage difference between targeted mitigated external corrosion rate or corrosion rate from monitoring techniques and corrosion rate from inspection technique	Operation
35	Measurement data availability	Operation
36	Validity and utilisation of measured data	Operation
37	Procedures for establishing the maintenance schedule	Operation
38	Maintenance activities	Operation
39	Internal corrosion rate, after maintenance activities	Operation
40	Percentage difference between targeted mitigated internal corrosion rate or	Operation
41	External corrosion rate, after maintenance activities	Operation
42	Percentage difference between targeted mitigated external corrosion rate or corrosion rate from monitoring or inspection technique and corrosion rate before maintenance activities.	Operation
43	Workforce - Capacity, education, and training	Operation
44	Workforce - Experience, knowledge, and quality	Operation
45	Data management - Data to database	Operation
46	Data management - Data from database	Operation
47	Internal communication strategy	Operation
48	External communication strategy	Operation
49	Corrosion management review	Operation
50	Failure frequency	Operation

Table 2: Key Performance Indicators to Implement Effective and Economical Corrosion Control Strategies

5 M Elements	KPI identification	Number of KPIs
Model (Internal corrosion)	**6, 7, 9, 10, 11,** 12, **14,** 39, 40	9
Mitigation (Internal corrosion)	16, 17, 18, 19	4
Monitoring (Internal corrosion)	24, 25, 26, 27, **32,** 33	6
Model (External corrosion)	**6, 7, 9, 10, 11,** 13, **14,** 41, 42	9
Mitigation (External corrosion)	20, 21, 22, 23	4
Monitoring (External corrosion)	28, 29, 30, 31, **32,** 34	6
Measurement (sub-set of monitoring)	35, 36	2
Maintenance	8, 15, 37, 38, 43, 44, 45, 46	8
Management	1, 2, 3, 4, 5, 47, 48, 49, 50	9
		50*

*7 KPIs are common for both internal and external corrosion (Indicated in bold letters in the Table 2).

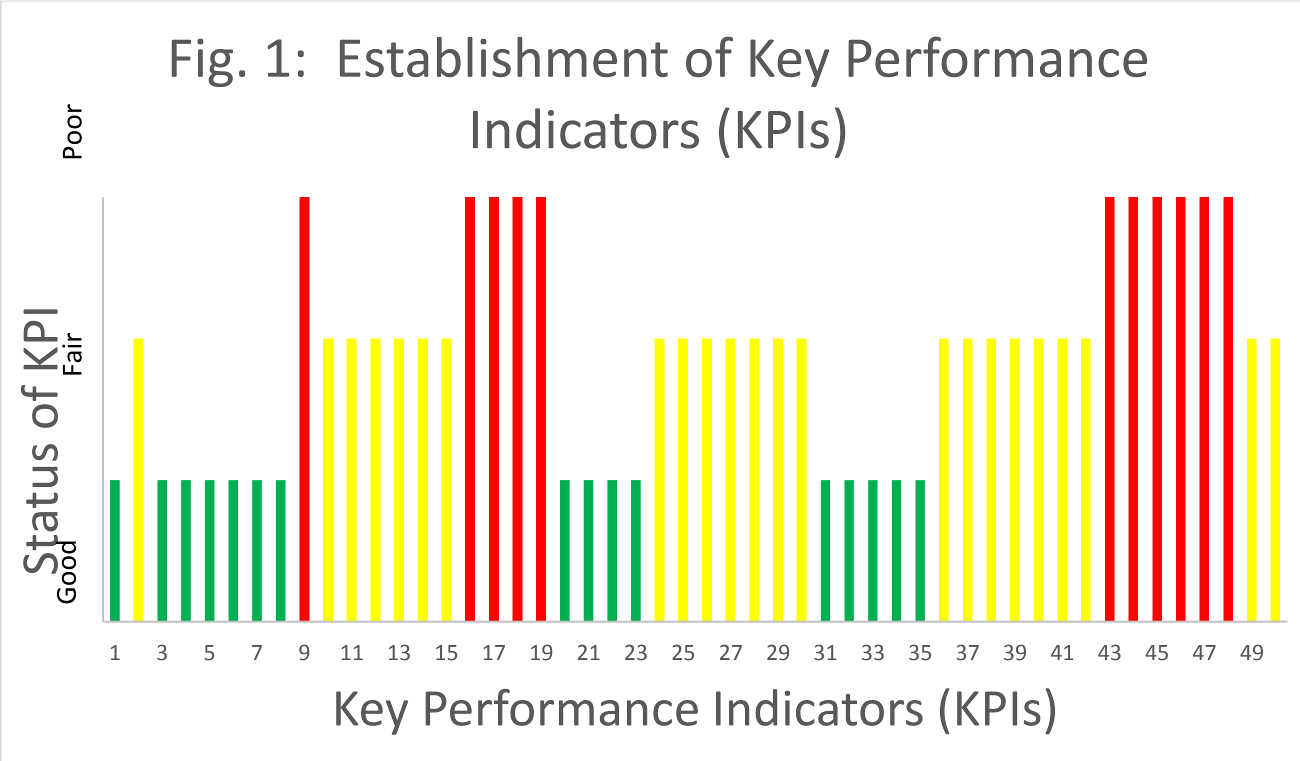

Fig. 1: Establishment of Key Performance Indicators (KPIs)
Status of KPI
Poor
Fair
Good
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
Key Performance Indicators (KPIs)

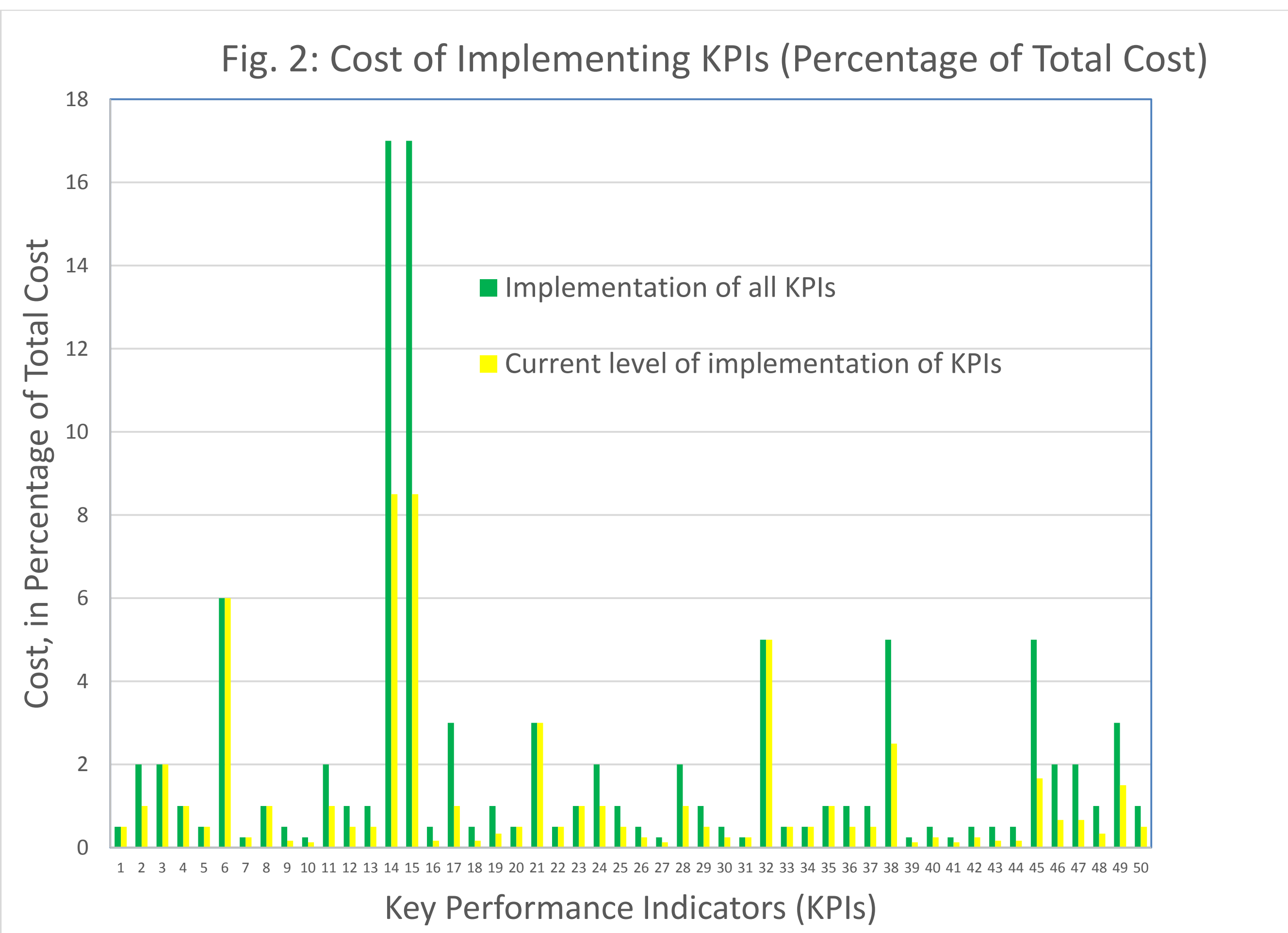

Fig. 2: Cost of Implementing KPIs (Percentage of Total Cost)
Cost, in Percentage of Total Cost
0 2 4 6 8 10 12 14 16 18
Implementation of all KPIs
Current level of implementation of KPIs
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Key Performance Indicators (KPIs)