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Role of Key Performance Indicators and its evaluation in HPCL transmission pipelines.

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ABSTRACT

Pipeline Integrity Management involves a series of activities, using systematic and comprehensive approach, to manage the safety and integrity of pipeline systems. Corrosion Control is an integral and major part of pipeline integrity management system.

Implementation of pipeline integrity management system is effectively tracked using key performance indicators (KPIs). The 5-M methodology (modelling, mitigation, monitoring, maintenance and management) implementation requires establishment of KPIs to track corrosion control implementation of an asset for its entire life. Fifty (50) KPIs have been identified to economically and efficiently control corrosion. This paper explains how to apply and implement the KPIs to control corrosion which will increase the capital expenditure, but will decrease operating expenditure during ideal stage and increase operating expenditure in normal operating stage but ensures immediate benefit to the asset.

Keywords: pipeline integrity management, key performance indicators, implement

INTRODUCTION

Hindustan Petroleum Corporation Limited (HPCL), India has laid approximately 4,000 kilometres of pipelines for transportation of Petroleum Products to ensure product availability to its Consumers and the Public at large. They vary in diameter between 10 and 24 inches. These lines are above-ground or underground. Underground pipelines are buried between 1.5 metres and 3 metres deep.

India has a variety of topography with elevation profiles, and climate in the different regions. Variety of soil, topographical and climate change in India creates corrosive environments in both the internal and external surface of the pipelines.

The material used for the construction of the most pipelines in India are of grade API 5LX46 / API 5L60 with mainly a wall thickness of 6.4 mm .The wall thickness is chosen to provide a lifetime of approximately 30 to 35 years. The external surface of the pipelines are protected with coatings and cathodic protection. The pipelines traverse through several environments and soil that have vastly different physical and chemical properties. The pipelines are subjected to localized external corrosion when coatings fail and when the cathodic protection does not adequately protect the locations where coatings have failed. To control internal corrosion inhibitors are injected.
Till date the pipeline is free from any leak due to corrosion. However with passage of time due to natural degradation of the pipeline coating and some other defects has made it difficult to maintain adequate cathodic protection level of the pipeline.

Pipelines Integrity Management (PIM) is a system that helps to maintain pipelines operations profitable and productive, conform to good industry practices, and comply with health, safety & environmental regulations. Corrosion control strategies are integral part of PIM. The corrosion control strategies ensure that all possible corrosion-related threats are identified and mitigated so that overall integrity of the pipeline is maintained. In order to ensure that the corrosion control strategies are relevant, efficient, and up-to-date at all times, their performance should be monitored and assessed on regular basis.

The 5-M methodology implementation requires establishment of several key performance indicators (KPIs).These KPIs track corrosion control implementation of an asset for entire life, i.e during design, construction, commission, operation, and abandonment stages. This paper describes status of effective implementation of 50 KPIs in HPCL India pipelines to effectively manage corrosion using the real data information. These KPIs are only guidelines for corrosion management process. The corrosion management process is an integral part of corporate due diligence.

APPLICATION OF 50 KPIs FOR CORROSION ACTIVITIES

The applicability of 50 KPIs to corrosion management activities is evaluated on design data and current (real) data of last 20 years. Detailed description of 50 KPIs are presented elsewhere (1) and are beyond the scope of this paper. The process scores each KPI as follows:

- 0 -1 for accounted for adequately
- 2-3 for accounted for inadequately
- 4-5 for not adequately accounted for.

The scoring of the 50 KPIs and the rational for the score are described in this paper.

GENERAL

The pipeline was built almost with same thickness except at river crossings and almost with same external coating. Other than that no documented evidence was available on segmentation of the pipeline. The external corrosion, external damage and internal corrosion were identified as three potential risks for the pipeline. Pipelines are almost quarter century old and having no or low corrosion risk. The pipeline is passing through very less populated rural areas and few portions of

the pipeline crossed river water. The consequence of failure is relatively medium. Overall risk from corrosion is relatively low- the system is monitored to ensure the risk remains low.

INTERNAL CORROSION

Model

The primary function of modelling 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. The pipeline was built as per pipeline standard American Petroleum Institute (API) which identifies several “product specification levels” (or grades) within each specification. The thickness of carbon steel is suitably selected considering the corrosion allowance. The corrosion allowance is established based on corrosivity of fluids, operating temperature and pressure, and use of corrosion inhibitors. The section in river crossing the pipeline had higher wall thickness of 9.4 mm. Hindustan Petroleum Corporation Limited(HPCL) India corrosion department ensures the implementation of corrosion control strategies i.e. they always obtain information on the installation of accessories and corrosion probes to monitor corrosion.

Based on the operating conditions, a study or information is collected to carry out to predict internal corrosion model. The information collected by various methods is stored as a database and used a trend to understand the further action.

Mitigation

In HPCL (India), at the design stage adequate attention is paid to select and implement corrosion mitigation strategies. Mitigation strategies can be implemented in some cases after the operation. Most mitigation strategies to control internal corrosion involve application of corrosion inhibitors. The inhibitors are mostly amine based and their concentration varies depending on the type of fluid and concentration of corrosive agents. The criteria for application or dosage of corrosion inhibitors are established based on “trial and error” method. The corrosion inhibitor concentration /dosage of 6 PPM is maintained to ensure low corrosion indication. HPCL (India) performs Pigging activity every 06 months to remove solid deposition (if any), debris (if any) and other extraneous materials from the pipe. Inline inspection tools are utilized to inspect pipelines by using intelligent pigs every 10 years. Information on the effectiveness of corrosion inhibitors are deduced from NACE standard test and use of corrosion coupons.

Monitoring

Intrusive and non-intrusive techniques are used to monitor internal corrosion via the corrosion rate. Systematic data collection and analysis of monitoring data is carried in HPCL (India). Specific formats are developed to collect data and incorporated in ISO quality system to ensure the same is followed. **HPCL (India)** follows OISD STANDARD-188: Corrosion Monitoring of Offshore & Onshore Pipelines. Ascertaining the CI efficacy is carried out as per NACE standard TM 0172-93 and internal corrosion monitoring techniques are ensured by the standard Oil Industry Safety Directorate (OISD) 141 (Clause 14.4.3).

EXTERNAL CORROSION

Model

No corrosion takes place on the external surface of the infrastructure as long as the mitigation strategies (e.g. coating and cathodic protection) work properly. Similar to internal corrosion, the external corrosion issues are seriously considered in the design stage to ensure that the pipelines are fully protected by coatings and cathodic protection.

Operating pipelines are always in process of collecting the data for variables affecting external corrosion and modelling the corrosion rate in an iteration process. Whenever required information is collected in spite of high of soil types and climate in India (HPCL).

Mitigation

All underground cross country pipelines are adequately protected with coatings and cathodic protection. Testing of coatings is performed in all aggressive soil conditions. Instant off potential readings are ensured and mitigation measures are implemented on immediate basis.

Monitoring

Above- ground monitoring techniques are carried out as per OISD 141 and NACE standard practice(SP) 0207(Performing close interval potential surveys and DC surface potential gradient surveys on buried or submerged metallic pipelines) and NACE SP TM0109 .These survey/tests are carried out every 5 years as per OISD-STANDARD-188: Corrosion Monitoring of Offshore & Onshore Pipelines. The frequency of survey may change depending on the condition of the pipeline. Additionally, Coating Conductance technique is applied to measure the potential drop across the coating and data is collected for further evaluation and collection of soil samples is performed for soil resistivity and any pH value.

MEASUREMENT

The measurements are collected not for corrosion control, but are obtained for effective corrosion control practice. In HPCL (India) proper procedures have been established to measure, collect and store data. The measured data is very useful for reviewing the corrosion control system and further action can be taken. Based on these measurement data, HPCL (India) carried out many remedial measures to correct the breakdown of the system.

MAINTENANCE

Maintenance is the key activity of pipeline network and is routinely carried out. HPCL (India) implemented and follows a good control corrosion program by ensuring that maintenance is not associated with equipment or pipeline alone. Preventative schedules are developed under International Organisation of Standards (ISO) 9001 SYSTEM to determine the maintenance requirement of the pipeline w.r.t corrosion (cathodic protection). Pigging is carried out every six months for internal corrosion. For external corrosion, the cathodic protection systems are inspected every fortnightly/monthly to ensure that they are in good condition to apply adequate current to protect the external surface. Corrective actions are taken as and when required on pipelines on priority basis and systematic manner. In HPCL (India), the average years of experience of technical

engineers is between 8 years to 15 years. A new personnel is always learnt from experienced person in In HPCL (India) by various orientation sessions /programs. In HPCL (India), attrition rate is reduced and work force is with an average 5 to 6 years of experience are associated for further contribution.

MANAGEMENT

Corrective and preventative (CAPA) actions are taken HPCL (India) for any incident or accident. HPCL (India) conducts a yearly safety audit as a mandate by internal team and external agency to evaluate the corrosion control system w.r.t monitoring and maintenance.

Table 1: Summary of status of KPIs in HPCL (India) transmission pipelines.

KPI No.	KPI description	Status of KPI	Description of Status
1	Segmentation of the infrastructure	**3**	Segment area varies
2	Corrosion risks	**1**	For no or low corrosion risk
3	Location of the infrastructure	**2**	Consequence of failure is relatively medium.
4	Quantification of risk	**2**	Overall risk from corrosion is relatively low – the system should be monitored to ensure that the risk remains low.
5	Life of infrastructure	**2**	The design life of the pipeline is around 35 years and it's in service for about 25 years.
6	Materials of construction	**1**	Material selected based on corrosion consideration.
7	Corrosion allowance (wall thickness)	**2**	Corrosion allowance more than mitigated corrosion rate times anticipated life.
8	Normal operating conditions	**1**	Operating conditions within the range established for the entire duration of the project.
9	Upset conditions or operation excursions in the upstream segment	**2**	Potential influence of upset conditions in the upstream segment on corrosion strategies of the segment under consideration is understood and communication plan is established with upstream team to obtain information in case if there is an upset or operating excursions.
10	Upset conditions in this sector affecting downstream sector.	**1**	Potential influence of upset conditions and operation excursions understood and plan established to avoid or minimize the effect of such upset conditions.
11	Mechanisms of corrosion	**1**	All corrosion mechanisms are considered and most prominent ones determined.
12	Maximum corrosion rate (internal	**1**	Maximum corrosion rate is based on

	surface)		model, laboratory experiment, simulation, or documented similar field experience.
KPI No.	**KPI description**	**Status of KPI**	**Description of Status**
13	Maximum corrosion rate (external surface)	**2**	No basis for the selection of maximum corrosion rate.
14	Installation of proper accessories	**1**	Corrosion professional is involved during construction to ensure installation of accessories for implementing, mitigation, monitoring, and maintenance activities.
15	Commissioning	**1**	Infrastructure is properly hydro tested and the water used in the hydro test properly removed, baseline conditions established to ensure that the corrosion rate is and will remain at the predicted rate, and all data from the design stage is collected and properly stored in the database for future use.
16	Mitigation to control internal corrosion: Is it necessary?	**2**	Yes, based on the analysis performed at the conceptual and design stages.
17	Mitigation strategies to control internal corrosion.	**2**	Mitigation strategy is established and aligned by trial and error method under the operating conditions and is proven to be effective.
18	Mitigated internal corrosion rate, target.	**1**	Mitigated corrosion rate is based on baseline corrosion rate and efficiency of mitigation strategy.
19	Effectiveness of internal corrosion mitigation strategies	**1**	Mitigation practices are implemented more than 99% of the time.
20	Selection of mitigation to control external corrosion.	**1**	The most appropriate strategies selected based on current standards and industry best practices at the conceptual and design stages.
21	Implementation of mitigation strategies to control external corrosion	**1**	Corrosion control strategies implemented and baseline data collected within the first year of operation of the infrastructure.
22	Mitigated external corrosion rate, target.	**1**	Mitigated corrosion rate is based on baseline corrosion rate and efficiency of mitigation strategy.
23	Effectiveness of external corrosion mitigation strategy	**1**	Mitigation practices are implemented more than 99% of the time.
24	Internal corrosion monitoring techniques	**1**	Two or more complimentary techniques that are proven to be effective in monitoring the corrosion type occurring in the segment are

			used.
25	Number of probes per unit area to monitor internal corrosion	**2**	Number of working probes enough to cover most critical areas.
KPI No.	**KPI description**	**Status of KPI**	**Description of Status**
26	Internal corrosion rates, from monitoring technique.	**1**	The corrosion rates from two or more different types of monitoring probes agree with one another within 10%.
27	Accuracy of internal corrosion monitoring techniques	**1**	The corrosion rate from two or more different types of monitoring probes agree with one another within 10% and they agree with mitigated corrosion rate within 10%.
28	External corrosion monitoring techniques	**1**	Two or more complimentary techniques that are proven to be effective in monitoring the corrosion type occurring in the segment are used.
29	Number of probes per unit area to monitor external corrosion	**1**	Working probes or measurements by above-ground measurement cover all critical areas and non-critical areas.
30	External corrosion rates, from monitoring technique.	**2**	The corrosion rates from two or more different types of monitoring probes agree with one another within 11 to 25%.
31	Accuracy of external corrosion monitoring techniques.	**2**	The corrosion rates from two or more different types of monitoring probes agree with one another within 11 to 25% and they agree within mitigated corrosion rate within 25%.
32	Frequency of inspection	**1**	Frequency established based on sound engineering and documented process.
33	Percentage difference between targeted mitigated internal corrosion rate or corrosion rate from monitoring techniques and corrosion rate from inspection technique.	**1**	The corrosion rates from inspection technique and from the monitoring probes agree within10%.
34	Percentage difference between targeted mitigated external corrosion rate or corrosion rate from monitoring techniques and corrosion rate from inspection technique.	**2**	The corrosion rates from inspection technique and from the monitoring probes agree within 11 to 25%.
35	Measurement data availability	**1**	All measurement data required for deciding corrosion conditions of the segment are available in readily usable format.
36	Validity and utilization of measured	**1**	The validity of the measured data is

	data.		established using a documented procedure and the measured data is properly integrated to establish the corrosion rate.
KPI No.	**KPI description**	**Status of KPI**	**Description of Status**
37	Procedures for establishing the maintenance schedule.	**1**	Preventive type established based on experience, when the risk moves from low to ALARP stage, and scheduled on time.
38	Maintenance activities	**1**	The maintenance work is carried out as planned with all teams delivering their services as per schedule.
39	Internal corrosion rate, after maintenance activities	**1**	Corrosion rate after the maintenance activities is lower than the corrosion rate before maintenance activities.
40	Percentage difference between internal corrosion rates and after maintenance activities.	**1**	Corrosion rate before the maintenance activities is within 10% of corrosion rate established in activity 33.
41	External corrosion rate, after maintenance activities	**1**	Corrosion rate after the maintenance activities is lower than the corrosion rate before maintenance activities..
42	Percentage difference between external corrosion rates and after maintenance activities.	**2**	Corrosion rate before the maintenance activities is lower by more than 10% the corrosion rate established in activity 34 indicating the maintenance activity is not necessary at this time.
43	Workforce- capacity, skills, education, and training.	**1**	The number of workers is enough to carry out the work and all personnel involved have proper education and formal training to carry out the task.
44	Workforce- experience, knowledge, and quality.	**2**	Key personnel have at least five years of experience and knowledge in similar work and others are gaining experience and knowledge under the key personnel.
45	Data management – Data to database.	**2**	Date form different activities measurements are manually and systematically transferred to the database.
46	Data management – Data from database.	**1**	Data is properly verified, systematically stored, and proactively passed onto appropriate persons can retrieve the data in the format required.
47	Internal Communication Strategy	**1**	Internal communication strategy between all parties is established,

			practiced and documented.
KPI No.	**KPI description**	**Status of KPI**	**Description of Status**
48	External Communication Strategy	**2**	External communication strategy and communication person(s) with only some entities are established, communication with others is only on adhoc basis.
49	Corrosion Management review	**1**	The corrosion control activities i.e all 50 steps discussed in this table, are reviewed annually and lessons learned are implemented to improve the corrosion control practice.
50	Failure Frequency	**1**	Zero failure or incidence due to corrosion during the review period for the segment.

CONCLUSIONS

Almost all KPIs are adequately and appropriately implemented. 49 of the KPIs are in the **Good and Fair** status. This level of good corrosion control practices was possible because of appropriate proactive steps in the capital expenditure (CAPEX). Consequently, the operating expenditure (OPEX) is anticipated to be low, without increasing the risk. Green colour – successful implementation of the KPI, yellow colour –adequate implementation and red colour- inadequate implementation of the KPI.

On KPI that requires further refinement is 1, i.e., Segmentation of the infrastructure. Steps are being taken to adequately segment the infrastructure to implement corrosion control strategies.

REFERENCES

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