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Findings from ECDA performed on SPM lines- A CP related perspective

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ABSTRACT

Reliance India Limited's (RIL) Jamnagar Marine Terminal has nine (9) numbers of subsea pipelines catering to three Crude SPMs and two Product SPMs. SPM 1&2 were constructed in year 1999 whereas SPM 3, 4 and 5 were constructed in 2006. All SPM lines have underground portions from Marine Tank Farm (MTF) to Land Fall Point (LFP) except for SPM 05 and one (1) line of SPM-04

which is completely above ground and subsea. The underground sections are protected with coal tar enamel wrapping coating and cathodically protected with ICCP. To check the integrity of the wrapping coating, periodic indirect assessment surveys like DCVG (Direct Current Voltage gradient / CIPL (Closed Interval Potential Survey) is generally carried out. Intelligent pigging was also carried out in 2013 and in 2015 for SPM-1 & 2 revealing external corrosion of the underground sections of these lines.

As these SPM lines are lifeline for RIL refinery and any loss of containment may lead to serious environment damage and impact the business continuity, a decision was taken:

1. To review the effectiveness of current CP systems and indirect assessment surveys,
2. To find out the root cause of external corrosion and
3. To locate & predict susceptible areas where external corrosion have occurred or will initiate in the future

Hence it was proposed to carry out ECDA (External Corrosion Direct Assessment) of the underground segments of the SPM lines. The ECDA methodology as specified in NACE standard SP-0502-2010 & OISD-GDN-233 is a four-step procedure that requires the integration of historical data, multiple indirect field inspection surveys and direct pipe surface examinations with the pipe's physical characteristics to provide a more comprehensive integrity evaluation with respect to external corrosion. Allied Engineers was assigned to carryout turnkey ECDA.

The scope included five (5) underground portion of the SPM lines (SPM 1&2, SPM 3-01 & 3-02, and SPM 04 line 01 from MTF to Land Fall Point (LFP).

Keywords: ECDA, root cause, external corrosion

INTRODUCTION

ECDA is usually the preferred integrity validation technique for non-piggable lines but in this case, RIL chose ECDA for the piggable lines where, historically multiple intelligent pigging has also been carried out. This was the decision as RIL wanted to investigate further into the external corrosion anomalies found through intelligent pigging. The primary difference between both the integrity validation tools is that intelligent pigging is excellent in quantifying the location and extent of metal loss though reactively- as the metal loss has already occurred. Whereas, ECDA due to it's scientific approach of targeting susceptibility for external corrosion is the preferred integrity tool for investigating into root cause and subsequently coming up with a mitigation plan. The pipeline owner, as expected from a true asset manager, decided to take advantage of both techniques for solving the unknowns regarding the subject pipelines and control the integrity of the asset.

ECDA as per the existing NACE SP0502 standards is performed in four (4) inter-dependent sequential steps, wherein the learning's from the preceding step provide the framework for the subsequent step. The mandatory four steps are:

01. Pre-assessment (PrA)
02. Indirect Inspection (IDi)
03. Direct Examination (DEx)
04. Post Assessment (PoA)

The primary step of PrA is very critical, as this forms the foundation of the ECDA program. PrA entails a detailed review, more like an investigation and integration of all historic and current pipeline records related to the threat of external corrosion. The typical deliverables for a PrA step include:

- Assessing the feasibility of performing ECDA for each pipeline
- Selecting the preliminary ECDA regions
- Selecting a minimum of two (2) IDi survey tools (above ground surveys) for each region, which are usually the CP related surveys

In addition to the above, as per best practices of ECDA, while performing a detailed PrA investigation several times:

- Immediate modifications may be required to the existing CP system or pipeline
- Suggestions are made for deeper analysis for certain concerns found during PrA
- Procedures for the CP surveys are customized to suit the respective region and the overall asset
- Assumptions are concluded based on the missing data

All of the above are possible, based on the ECDA team (including the respective Subject Matter Expert's) visit to site and investigation on and offsite along with the pipeline owner team. As the second step of ECDA i.e. Indirect Inspection, comprises of CP surveys such as Close Interval Potential Survey (CIPS), Direct Current Voltage Gradient (DCVG), Current Attenuation Technique (CAT) etc. that use the existing CP system to a varying degree, hence it is required to study the compatibility of the CP system during the PrA step. Also, as these CP surveys would form a critical part of the integrity validation, therefore, all CP related data, equipment, connections and procedures are questioned and reviewed during this step. This may require additional site time and pre-survey field investigation, which may not have been originally planned at the start of the ECDA program. In addition, such a CP related pre-survey becomes an important reference for the pipeline owner for future maintenance, repair and revamp of the existing CP system. Thus, such a detailed study within the PrA step has its own standalone value.

The key observations related to the CP system, which were highlighted during the PrA step of the subject pipelines are discussed in the following text. Further, during IDi, the CIPS data provided more insight into the challenges being faced for these lines.

Generic Information about the five (5) lines in the ECDA program

The subject pipelines and their respective CP system can be categorized into Group-1 and Group-2.

Group 1: Contains SPM 1 and SPM 2. Both are parallel running underground pipelines from SAIPEM to LFP and then go aboveground and continue to offshore forming a loop at the SPM end. Therefore, SPM 1 and 2 lines are considered a single electrically continuous utility. This ECDA program focuses on the buried section of the pipeline only that is from SAIPEM to LFP.

Group 2: The remaining SPM 3 Line 01, SPM 3 Line 02 and SPM 4 Line 01 form Group 2. These lines originate at SAIPEM and remain above ground up to LFP, thereafter they go underground and run parallel until the Lolo jetty.

The ECDA program focuses on this buried section of the pipeline. These three (3) lines further continue to offshore and SPM 3 Line 01 and Line 02 form a loop at the SPM end. Therefore, SPM 3 Line 01 and Line 02 are considered a single electrically continuous utility.

Table-1 provides pipeline information and Figure-1 provides the geographic layout.

Both the groups are provided with three (3) CP stations each and with close bed anodes due to their geographic limitation. Group 1 pipelines anode system is categorized as "Continuous Horizontal Anode Bed" constructed close to the pipeline having a parallel length to the pipeline axis as 115 m. For Group 2, the CP system can be categorized as "Distributed Anode ICCP System."

A few of the critical concerns pertaining to Reliance's ECDA program are discussed in this paper.

<u>Concern 1:</u> Group 2 pipelines anode output not being given due weightage historically

In case of Group 2, that is the Distributed Anode ICCP system, rather than relying on the total current output of the T/R unit, a more effective and critical mean is to focus on the individual anode output. The individual anode is responsible to ensure protection of the corresponding pipeline span within the field of that particular anode. It was a bit surprising; that the importance of this individual anode output parameter was not emphasized in the original design documents. As a result, the historic monitoring reports had no monitoring data related to the individual anode outputs. Hence, collection of this data was prioritized during the PrA stage of ECDA program, so that due importance can be given to this parameter for planning subsequent exercises.

Table-2 provides the measurements obtained while performing the pre-survey during the PrA step of the ECDA program for Group 2 lines.

Each T/R unit has a positive current control box. Through this box, positive current is distributed to the four (4) anode junction boxes (AJB's) and each AJB feeds current to eight (8) anodes. In total, there are ninety-six (96) anode circuits, though, in the original design documents it was mentioned as ninety-two (92) anodes. Based on the results of the field survey during PrA for this exercise, 55% of these anodes were found to be in an inoperative condition. This is a dangerously large figure.

Moreover, when such large number of anodes are inoperative the remaining anodes take extra load and in turn their deterioration cycle accelerates.

<u>Concern 2:</u> Group 2 Pre-mature failure of anodes

It is interesting to note that there were more than 50% of the anodes left inoperative. One of the reasons possible for this is explained here. CP current from individual anodes is fed to the pipelines. Now, that current is returned back to the T/R unit via only one drain point per pipeline. This implies that CP current from sixteen (16) anodes is flowing through the pipelines upto the drain point. The additional cumulative voltage drop in the pipeline longitudinal resistance, causes a steeper attenuation in the pipeline. Associated to this attenuation is an additional current requirement over and above the normal CP current requirement. This requirement is catered to by the anodes near the drain points. This can be the reason for accelerated consumption of the selected anodes near the drain point.

This could have been avoided by devising a negative distribution as meticulously as the positive distribution network. In that scheme, associated to each AJB there could have been one negative junction box (NJB). This would have allowed for the current from a group of anodes from an AJB to have preferably returned via the local drain cable to the NJB, thereby transferring voltage drop in longitudinal resistance over a large span of pipeline (typically 400 m) to the drain cable. Four (4) drain cables could pass on the collected current to negative header cable. Two (2) such cables could return the accumulated CP current of the CP station to the T/R unit. This way the current passage through pipeline longitudinal resistance, additional attenuation and associated unwanted current discharge from anodes, near the present single drain location could have been avoided. Thus, the premature consumption of large number of anodes could have been partially controlled.

Concern 3: Group 1 Excessive polarization along with lack of protection

As the anode beds are closely placed near the pipeline and driving potentials are high, pipe to soil potentials (PSP) values on the pipeline sections in the vicinity of the anode beds are expected to be very high. This effect was evident during the CP pre-survey exercise for Test Station no. 3 on SPM 1 and 2 pipelines, which is in the vicinity of anode bed for T/R 2. The ON potential measured was -3.7V wrt Cu-CuSO4 reference electrode. Similar effects were revealed on both pipelines throughout the length, as per the results of CIPS readings obtained during the IDi step. The relevant potential patterns on the pipeline segments as logged in CIPS for chainage 1 to 1.5 km for the parallel loop line is shown in below Figure-2.

Based on the results of the CIPS during the IDi step following was observed:

i. Anodic hills are obtained at all of the three anode bed proximity locations. The ON PSP's are locally rising to very high levels of -2.5 to -3V in the proximity of the anode beds which can be detrimental for the pipeline
ii. Upon traversing along the pipeline away from the adjacent anode bed location, the potentials drop steeply. In fact, based on the thresholds for instant OFF potentials as per NACE criteria, the pipelines would be classified as under protected for majority of the length
iii. To achieve this kind of partial protection, the three (3) T/R units together were feeding approximately 90 Amperes in the earth during the CIPS data collection.

Further, having such a high potential in the vicinity of anode beds can be a bigger problem for RIL. This can lead to cathodic disbondment and would need to be further validated during the 3rd step of ECDA, that is Direct Examination (DEx). If this is confirmed then that would be a self-driven irreversible coating damage which will cause bigger challenges in the future for integrity assessment. There can also be a possibility of hydrogen embrittlement cracking in certain environments which would need to be addressed. As the ECDA program concludes, in the upcoming steps, in case these high potentials are found to be detrimental to pipeline, the CP system may have to be redesigned.

Concern 4: Group 1 and 2 Limitation of DCVG during IDi

i) Due to parallel loop lines:

It may be noted that Group 1 lines and SPM 3 lines from Group 2 are in pair as piggable loop lines. Hence, are having a mechanical and metallic continuity in the offshore section. As a result, practically for DCVG and CAT surveys, when test current is given to one pipeline it is bound to be carried to the other pipeline in the loop system. Therefore, any of these loop lines cannot be isolated which is a mandatory requirement while conducting DCVG and CAT surveys. Due to this fact, there could be a shielding effect from a major indication on one side of the loop line for a smaller indication compared to the other side of the loop line. As a result, detecting smaller indications might be more difficult. This constraint has to be kept in mind while conducting DCVG survey.

ii) Due to topographical constraints:

DCVG indication categorization is based upon % IR drop that is derived from field data component namely “On-Line Remote Earth Potential” (OLRE).

Here, it may be noted that the for the underground sections of Group 1 and 2 pipelines, approximately 3 to 5 m away from pipeline axis, there is a paved (tar) road and immediately after that a compound wall. OLRE is measured in the leapfrog manner traversing perpendicular to the axis of the pipeline in steps of approximately 2 m each. There can be several such steps till no marginal change is found in subsequent steps, which signifies remote earth. In such a situation, achievement of full OLRE extent cannot be guaranteed. This is yet another constraint to be borne in mind, while performing DCVG on these parallel pipelines on a tight right of way.

iii) Due to closed bed anode system:

In case of Group 1, each of the existing anode beds of 115 m in length, act as a secondary anode.
As the existing anodes are close to pipeline, they will need to be disconnected from the respective T/R units. In positive circuits of T/R units, instead of existing permanent anode beds, temporary anode beds for DCVG test current are installed and connected that are relatively away from the pipeline. Current passing through earth takes the least resistance path. As a result, test current for DCVG will preferably take path via existing permanent anode bed, which is a long metallic member, underground, having length approximately of 115 m. Large part of DCVG test current will, thus, in fact concentrate on existing anodebed and will selectively get discharged to pipeline from this existing anodebed. This results in the existing anode beds of 115 m in length to act as secondary anodes.

There will be relatively lesser test current concentration at places other than existing anode proximity. As a result, weak test signal can pose a problem in detecting smaller indications.

DCVG technique for the subject pipelines would have a very limited validity and the output data should be classified and prioritized accordingly.

RESULTS

Table 1: Generic Pipeline Information

Group	Pipeline Name	Diameter (Inches)	Wall thickness (mm)	Commissioning Year	Total Length (Km's)	Below Ground Length as part of ECDA (Km's)	Loopline Status	No of T/R's	No of TLP's	Type of CP System
1	**SPM 01**	48	12.7	1999	17.5	2	Yes - One loop line	3 common	10 common	Continuous horizontal close bed anodes
	SPM 02				19	2				
2	**SPM 03 - 01**		14.9 / 20.6	2007	55	2.6	Yes - One loop line	3 common	3 common	Distributed close bed anodes
	SPM 03 - 02					2.6				
	SPM 04	30	14.27		60	2.6	No			

Table-2: Pre-survey measurements

AJB No	T/R unit	Reverse Chainage from LFP to SAIPEM (m)	Current (Amps)									Inoperative Anodes
			Incoming (Amps)	Output (Amps)								
				Anode 1	Anode 2	Anode 3	Anode 4	Anode 5	Anode 6	Anode 7	Anode 8	
8514/07	1	From 216.2 m To 864.4 m	6.2	0	0	1.3	0.9	0.5	1.1	1	1.2	**2**
8506/07			8.5	1.5	1.8	0	0	0	1.9	1.4	1.2	**3**
8516/07			7.7	2.2	1.4	0	0.7	0.9	0.7	0	0.7	**2**
8510/07			4.4	0	1.1	1.2	0	0.7	1	0	0.6	**3**
8507/07	2	From 864.4 m To 1728.30m	9.8	2.1	0	0	1.9	1.9	0.2	2.5	1.8	**2**
8511/07			8.9	0	0	1.8	0	2.2	1.6	0	3	**4**
8508/07			3.3	0	0	0	0	0	0	1	2.3	**6**
8509/07			4.9	0	0	0	2.4	2.4	0	0	0	**6**
Number not readable	3	From 1728.30 m To 2600 m (in LOLO Jetty)	0	0	0	0	0	0	0	0	0	**8**
8515/07			7.2	0	0	0	2.2	1.3	1.3	1.8	0	**4**
8517/07			2.3	0	0	1.2	0	1.5	0	0	0	**6**
Number not readable			2.3	2.3	0	0	0	0	0	0	0	**7**

Total Number of Inoperative Anodes	53 of 96

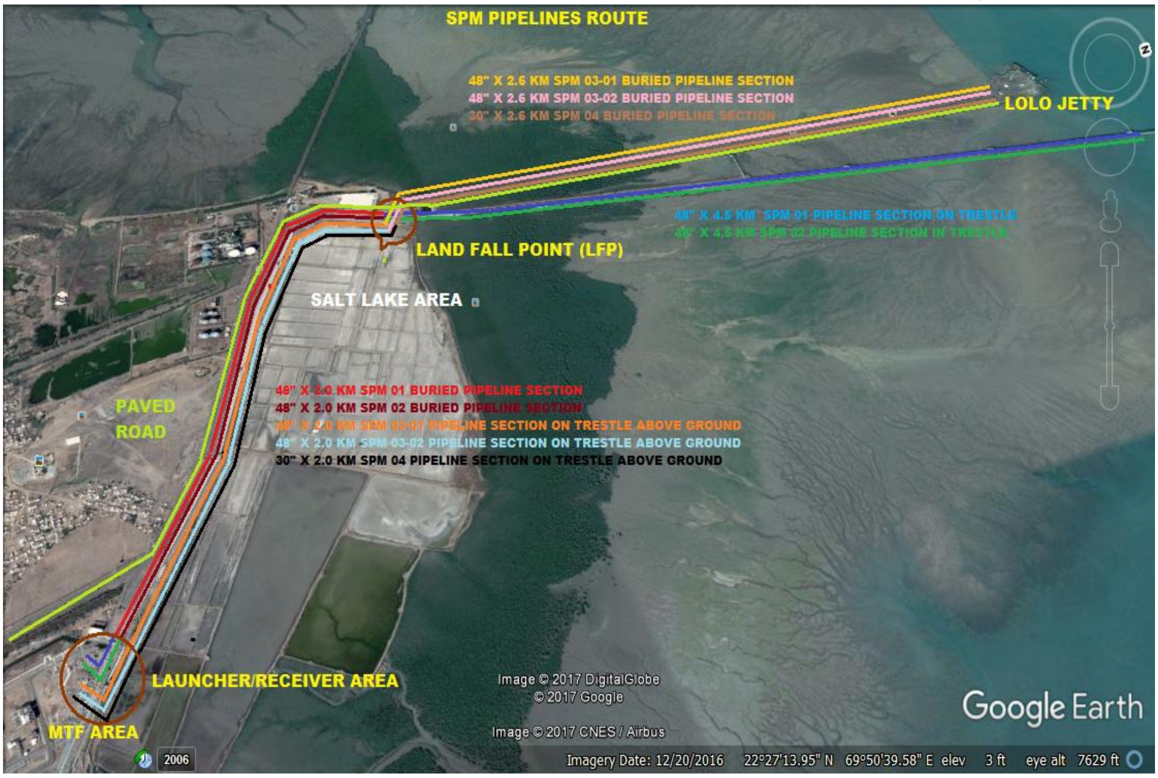

Figure-1: Geographical layout of the subject pipelines

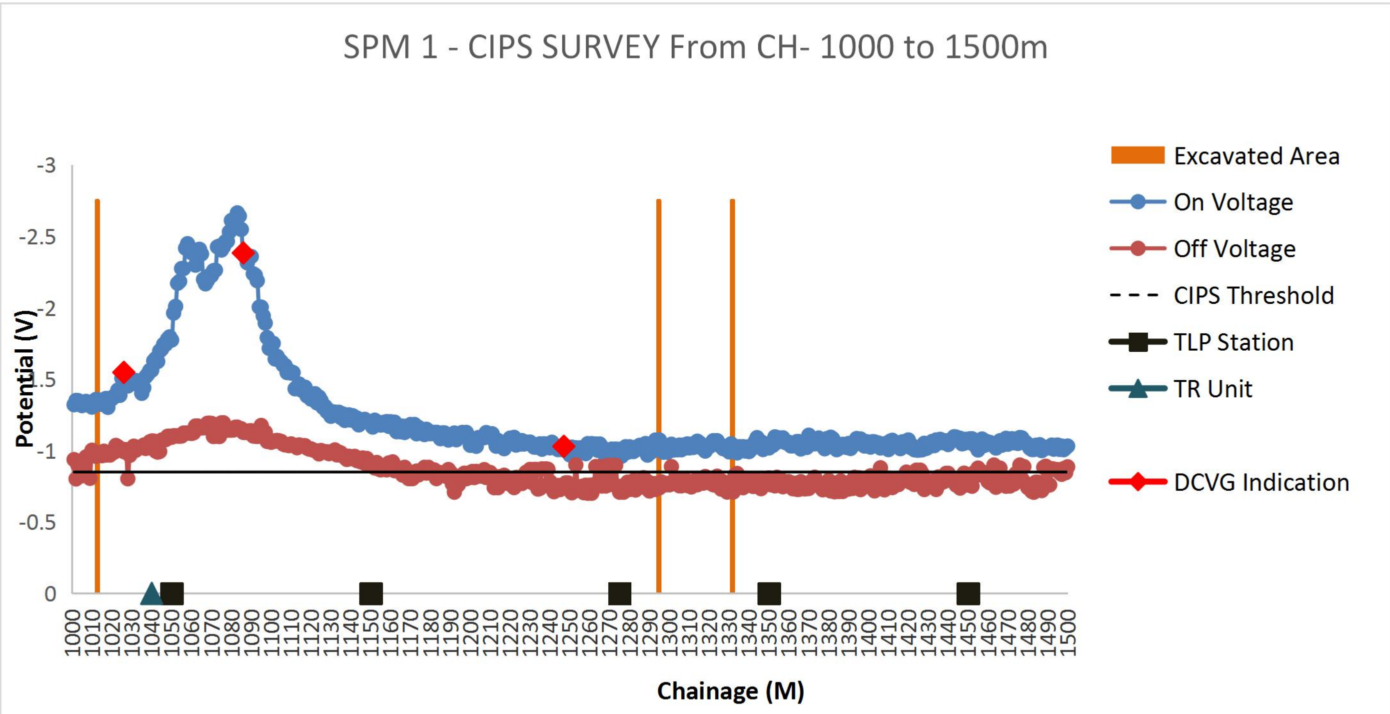

Figure-2 (a): CIPS survey data for SPM-1 (1 to 1.5 Km)

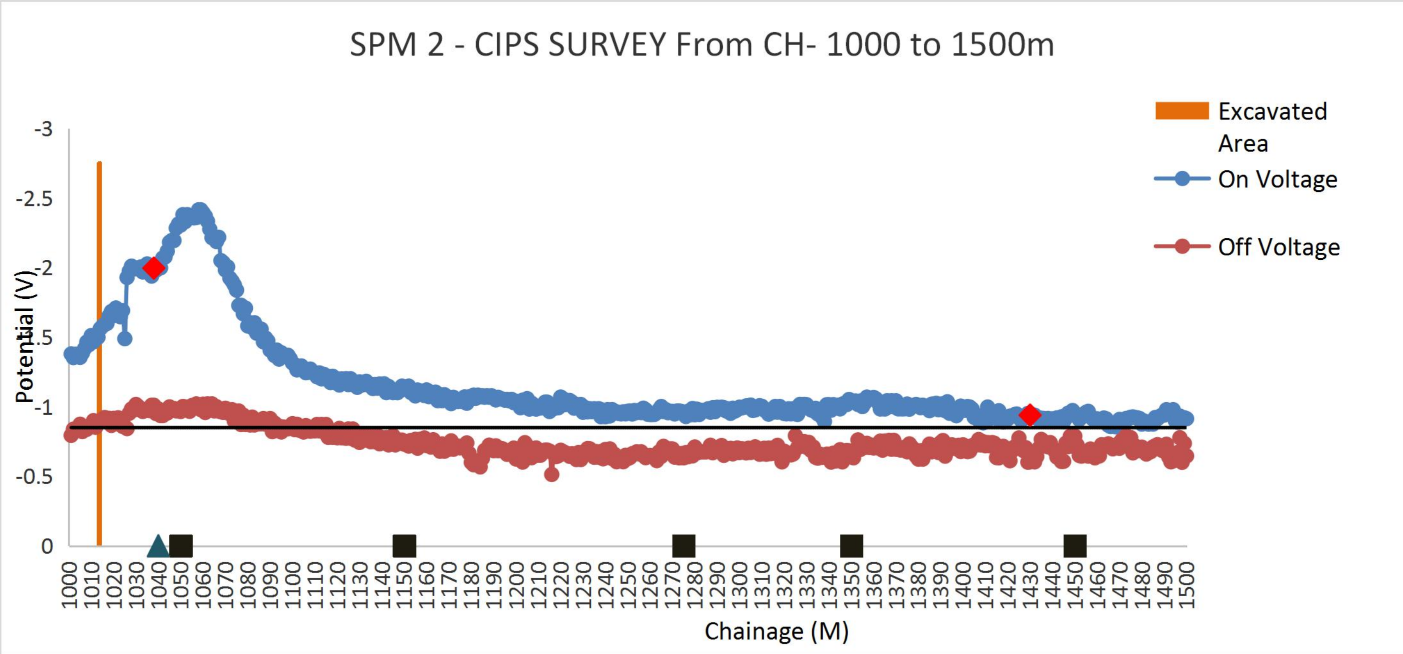

Figure-2 (b): CIPS survey data for SPM-2 (1 to 1.5 Km)

CONCLUSIONS

It may be noted that based on the existing terrain and configuration of the pipeline, constructing remote anode bed was not possible and that is the only reason why for such large diameter pipelines a closed distributed or a closed continuous anode were designed. Even achieving a remote anode bed temporarily is not possible. This qualifies for the reason why RIL opted for such a CP design. Though, such CP systems have their own challenges for CP maintenance, monitoring and assessment techniques as highlighted in this paper.

The learning's from the ongoing ECDA program has not only allowed RIL to validate the external integrity of the pipelines but more importantly gained insight into the root causes for the threat of external corrosion. As the ECDA program approaches completion, the final step of post assessment (PoA) will provide the remaining life along with a mitigation plan for the threat of external corrosion.

RIL’s Pipeline Integrity Toolbox

RIL’s decision to perform ECDA based on the results of the previously applied intelligent pigging and CP surveys has utilized the uniqueness and the optimum deliverables from the different integrity validation options available in RIL’s toolbox. This does confirm the statements mentioned in NACE SP0113-2013 standard for Pipeline Integrity Selection as “Each integrity assessment method complements the others. They do not have identical performance, but each has advantages over the others.”

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