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Application of Direct Assessment Methods in Arid and “Sabkha” Environments

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ABSTRACT

Based on Federal laws, pipeline operators in USA were required to develop a proactive Pipeline Integrity Management Plan to manage risk and protect public areas near pipelines. NACE initially published RP0502-02 for ECDA (External Corrosion Direct Assessment), and standard practices for other methodologies followed. Since many techniques used for ECDA rely on electrochemical tools, soil contact is an important consideration from an applicability standpoint. Contact resistance can cause increase in signal-to-noise ratio and the concern is how this may bias the recorded data or mask anomalies. DA was recently applied to pipelines of various design & operating conditions that traverse desert conditions like arid soil, and “Sabkha” (salt flat). This was an ideal opportunity to determine the effectiveness of the methods in extremely arid and high saline conditions with consideration of electrical and geological shielding. Results are presented and a comparison is made between predicted & actual findings.

Key words: Direct Assessment, ECDA, coating defects, arid soil, Sabkha (salt flat), sand dunes, coating disbondment, shielding, Direct Examination.

INTRODUCTION

Inline inspection (ILI) was the preferred methodology to inspect pipelines, and hydrostatic testing was the alternative, but based on federal laws signed in 2001, the Interstate Gas Association of America, together with the Gas Technology Institute, assembled an expert team to develop an

alternate inspection methodology, called Direct Assessment (DA), which made use of a combination of proven techniques.

NACE International, as the industry representative initially published RP0502 for ECDA in 2002, and standard practices for the other methodologies followed. As living documents, these standard practices are subjected to peer review every 4-6 years and improvement are made based on experience in use.

ECDA is a structured methodology to enhance safety of pipelines by assessing and managing external corrosion defects. This is achieved by identifying the external corrosion locations, then prioritizing remedial action that prevents them from growing to a size that affects the structural integrity of the inspected pipeline section. ECDA is a proactive and continuous process by which if applied successively the pipeline operator would be able to have a better outlook not only where the corrosion has happened but on where it would happen in future. Based on the ECDA results the operator would be able to streamline maintenance works in a cost effective and timely manner.¹

The ECDA process relies on the integration of historical data along with the results of additional inspection tools and physical and operational parameters of the pipeline, validation of the results, root cause, and future mitigation plan. Therefore, the process was split into four consecutive steps, Pre-assessment, Indirect Inspection, Direct Examination, and Post Assessment.¹

The purpose of pre-assessment step is to determine the feasibility of Direct Assessment process for the subject pipeline, identify ECDA regions and identify the most appropriate Indirect Examination tools to be applied in the second step for each region, taking into consideration all design, operational, and environmental aspects of the pipeline. The pre-assessment includes collecting pipeline's physical and mechanical characteristics, and historical and current operational parameters. The data collection might also include site survey for route features and interviewing the operators for operation and maintenance track record.¹

Second step is the Indirect Inspection, where above ground inspection techniques are used to locate corrosion related features such as coating defects, low CP, high corrosive areas and identify their severity. A minimum of two techniques shall be conducted over the entire length of pipeline, additional tools can be used for more solid and reliable results. Indirect Inspection tools include but not limited to AC or DC Voltage Gradient (ACVG/DCVG), Close Interval Survey (CIS), AC Current Attenuation Survey, Soil Resistivity Survey.¹

Direct Examination is the third step that includes correlation and interpretation of Indirect Inspection data and identifying quantity and locations of dig sites. The pipe surface and surrounding soil shall be examined, including soil, coating, CP and corrosion products (if found), the extent of corrosion shall be determined using appropriate NDT, the remaining strength shall be calculated, and suitable repair measures shall be taken.¹

In the last step a post-assessment is carried out to analyze the data of the previous three steps and evaluate the success of the entire ECDA process. This step includes, root cause analysis, determining the remaining life the re-assessment intervals.¹

Although it's a proven methodology, Direct Assessment process is not widely adopted by Middle East pipeline operators, a few in UAE, Oman, and a little more in Kuwait. However, some Indirect Inspection tools are broadly used in all Arabian Gulf states but on an individual mode not through a complete DA process. This paper addresses a pilot ECDA process applied on two different

sections of pipelines in Saudi Arabia with different physical and operational conditions that traverse the most usual soil forms in the Middle East like arid soils, Sabkha, sand dunes, rocky areas etc.

The main data input for ECDA process is through the indirect inspection tools, and since most of these tools rely on direct contact with earth to collect specific electrical signals, it must be ensured that the contact between soil and the sensing element is at its best performance. Contact resistance can cause increase in signal-to-noise ratio and the concern is how this may bias the recorded data or mask anomalies. Having said that, the top challenges that disturb an ECDA process are related to soil conditions, but that shouldn't lead to failure of the process rather to correct it with certain factors or considerations when encountering these challenges. Another challenge is the disbonded high di-electric shielding coating such as coal tar and PE tape wraps which make the indirect inspection techniques inefficient and unreliable at these locations. Depending on the age and expected condition of these coatings, the corrosion engineer can make the decision of it's feasibility.

SOIL CHALLENGES

The soil bed around the pipeline is the current path used by the indirect inspection tools to detect the flowing signal from/to a coating defect. The majority of Middle East soils are arid which reflect an extremely high soil resistivity that impact the most typically used and accurate survey tool, the DCVG. DCVG relies on relative sizing of coating defects throughout the calculation of percentage voltage drop (%IR) as a function of over-the-line to remote earth potential relative to pipe-to-soil potential of at-the-defect location. The severity of coating defect is then determined by categorizing the %IR as very minor (1%-15%), minor (16%-35%), moderate (36%-60%), and severe (61%-100%). Soil resistivity is a main contributor in the %IR results, and then the aforementioned categories cannot be valid at extremely high soil resistivity. Considering the absence of any stray current, two coating defects of the same size at different soil resistivity values can show different %IR values that mislead the interpretation of indirect inspection results and makes it relative.^{2,4}

A different type of soil called "Sabkha" exists near or at the coastal lines of all Gulf states.³ Sabkha is typically a salt-encrusted mudflat that is normally characterized by wetness and high level of salts which indicates a very low soil resistivity.³ Measured soil resistivity in Sabkha areas can reach to as-low-as 5 Ohm-Cm. The extreme low soil resistivity can have the same impact on %IR measurement as of high resistivity but in the opposite direction. A resulted %IR of low value can be considered minor in normal conditions, but in Sabkha it might be reflecting a higher defect surface area than what was calculated. This is a very critical factor while interpreting DCVG results, despite of corrosiveness level represented by chemical composition of the soil or presence of microbiological organisms, low resistivity areas are normally considered severely corrosive from a conductivity standpoint. The DCVG results are always preferred to be integrated with the Close Interval Survey (CIS) results, and soil type and corrosiveness (as in Sabkha). Cathodic Protection (CP) level shall be checked at every identified DCVG defect, a non-cathodically protected defect in Sabkha should be an alert even though the DCVG %IR was low indexed.²

Another critical factor to be considered throughout the Indirect Inspection stage is the pipeline depth. In normal conditions the pipelines are usually of a little variance in depth through the entire length except at road crossings, pipeline crossings, or at special conditions where the

pipeline goes deeper. During the operation of pipeline, the depth of cover rarely changes unless if sand dunes move over the pipe route and increase the depth. The deeper the pipeline the less %IR can be measured, e.g. a low %IR measured at a depth of 7 meters would be higher if the pipeline was at a depth 1.5 meters for the same coating defect. In addition, the sand dunes cover the features of pipeline and makes it more challenging to accurately locate the centerline of the pipe, due to higher depth and difficulty of walking over the dunes. In addition, during CIS survey as the soil cover gets higher the detection angle of reference cell becomes wider which leads to reading a mixed potential over a longer span of the pipe.^{2,4}

Therefore, in order to establish a realistic correlation between the %IR and defect size a correction factor can be plugged into the calculation that normalizes the results to a pre-defined soil resistivity and pipeline depth.

Some other manageable challenges exist on the pipeline and could be tackled during survey like paved surfaces where holes can be drilled to provide access into native soil. Oily sand cover on the pipeline berm can also disturb the data collection and shall be removed while inserting the probes into ground. During wind seasons the carried sand particles in the air can create a static charge on the earth surface which could fluctuate the DCVG needle and disturb the signal interpretation, surveyor shall be aware of this aspect and avoid collecting data in windstorm conditions.

Geological shielding can be caused by land formation such as rocks where the pipeline is bored in, this geological formation prevents CP current from reaching the embedded pipe section within, and makes some Indirect Inspection tools unfeasible, especially those which rely on transmitting the signal from a far distance, in this situation selecting the survey tool is crucial.¹

EXPERIMENTAL PROCEDURE

In order to examine and verify the above expected challenges an ECDA process was applied on two segments of buried pipelines in Saudi Arabia, the pipelines were selected in a way to cross three main conditions, arid soil, Sabkha, and sand dunes, with different types of coatings and a combination of scrapable (piggable) and un-scrapable (un-piggable) pipelines for validation. The pipeline details are listed in the below table:

Table 1
Pipeline Details

Pipe	Dia.	Length (m)	Environment	Indirect Inspection Survey Tools
A	42"	3,000	Arid Soil	DCVG, ACVG, CIPS, DoC, Continuous Soil Resistivity
B	46"	5,000	Sabkha	DCVG, ACVG, CIPS, DoC, Continuous Soil Resistivity

The following surveys were performed over the two sections of pipelines, a brief procedure for each survey is shown below:

Close-Interval Potential Survey (CIS), the CP power sources, typically transformer rectifiers, are synchronically interrupted at an interval cycle of 4 to 1 or 3 to 1 to avoid depolarization. While the technique is based on the normal method of recording pipe-to-soil potentials with the cathodic protection system operating, instantaneous-off or 'polarized' potentials were collected,⁴

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