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A Method for Assessing Facility Pipe Integrity

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ABSTRACT

In recent years, effective techniques have been developed for conducting integrity assessments along cross-country pipelines. In order to provide similar confidence in facility integrity, it was proposed to apply a modified external corrosion direct assessment process to a small station. Until now, congested facility environments have not generally been considered suitable for this approach because of the added complexity associated with electrically-continuous grounding and the large number of pipes and structures in close proximity.

This paper describes the technical approach which was developed in order to overcome the expected challenges. The conventional close-interval potential and direct current voltage gradient surveys were also enhanced to allow effective application in a facility. These enhancements are described as they relate to a variety of common conditions, and guidelines for properly interpreting survey results in a station are given.

Key words: external corrosion direct assessment, ECDA, CIPS, DCVG, congested piping, unpiggable, facility, station

INTRODUCTION

Effective assessment of facility piping has lagged behind assessments of cross-country pipelines. The reasons for this are varied, but include different regulatory conditions and difficulties in applying conventional, proven integrity assessment methodologies. As the age of facilities increases and industry's risk tolerance decreases, the need for a method to effectively assess facility integrity has grown.

The limitations with existing methodologies are generally known: In-Line Inspection (ILI) is limited by small diameter piping, short runs, and unsuitable mechanical layout; pressure testing is complicated and limited by multiple tie-ins; and External Corrosion Direct Assessment (ECDA) is perceived to be limited by the complex environment and tool limitations.[1] The authors are aware of at least one company that has resorted to 100% excavation and examination of entire stations as a result of these difficulties.

To address these needs, a pilot program was initiated with a goal of increasing the reliability and reducing the cost of validating facility integrity. ECDA was chosen as the most promising integrity assessment methodology due to the lower technical barriers. In addition, case studies of ECDA in station environments have previously been reported as successful.[1,2]

The present work will build on known ECDA techniques with a goal of enhancing industry's ability to effectively evaluate system integrity and is based on the authors' experience applying ECDA and related methodologies in facilities ranging in size from small meter stations to large compressor stations.

TECHNICAL APPROACH

ECDA is defined by NACE Standard SP0502-2010[3] as a four-step process consisting of pre-assessment, indirect inspections, direct examinations, and post-assessment. The multi-step direct assessments, which includes the ECDA process, have been applied extensively since the inception of the ECDA in 2002, including on more than 20,000 kilometres of pipeline in the United States alone from 2010-2013.[4] As a result, techniques for the successful application of direct assessment, and particularly ECDA, have been discussed extensively within the NACE community. However, applying the ECDA process remains technically challenging in its own right.[5] This paper will attempt to highlight differences between cross-country pipelines and station piping, and address challenges which are particular to station ECDAs. It should also be noted that although U.S. regulations demand strict adherence to ECDA for cross-country pipelines, within stations and within other jurisdictions it may not be necessary to achieve 100% compliance with the ECDA standard in order to gain a high degree of confidence in facility integrity and satisfy regulators.

Benefits in a Facility

Although many of the differences between stations and cross-country pipelines increase the difficulty of applying ECDA, there are a number of advantages to applying ECDA within a facility environment. First and foremost, preparation for site work is typically simplified because the pipeline operator owns and/or has a good working relationship with the owner of the facility. Site access is also simplified because facilities are usually accessible by road and ground cover is normally well-maintained.

CHALLENGES

Identification of Challenges

The challenges associated with ECDA in a facility, however, have limited the use of facility ECDAs to date. In terms of installation, stations are more likely to have been installed and modified in a piecemeal fashion, which increases the difficulty of the preassessment and dig selection. Also, all of the iterations of drawings and other records relevant to the changes may not be available. Where isolating flanges have been installed, there may exist uncertainty regarding their effectiveness or the date of failure, and the precise location of buried isolating flanges may not be known – features which are less common along cross-country pipelines.

The facility environment typically has many pipelines in close proximity, with pipelines running in parallel and crossing each other. Smaller diameter pipelines such as those for power gas, domestic gas, and water may not appear on most drawings. To protect all of these structures, distributed cathodic protection (CP) may have been installed at many different times and using a variety of anode types, further complicating the survey. These features complicate the field surveys and data interpretation.

Considerations related to grounding are probably the most commonly cited reason for being unable to conduct ECDA within a facility. Electrical ground may or may not be continuous with the facility piping, and ground rods and distributed grounding may be intermingled with the piping itself. Although most buildings and piles are continuous with electrical ground, other structures within the facility such as the fence, pipe supports, etc. may or may not be continuous with either the piping or electrical ground. Continuous bare structures have a significant impact on the voltage gradients and the recorded potentials. Even discontinuous structures such as fences may impact the survey results if they are subject to DC interference, for example. In addition, if thermal insulation with a metallic sheath has been installed on above-grade piping, it may be electrically continuous with the piping and any contact with the soil will result in holiday indications and distorted potentials.

A number of these features, as might be encountered in a typical compressor station, are shown in Figure 1. This paper will present both field and data analysis techniques which can be used to increase the reliability of conventional ECDA in a facility.

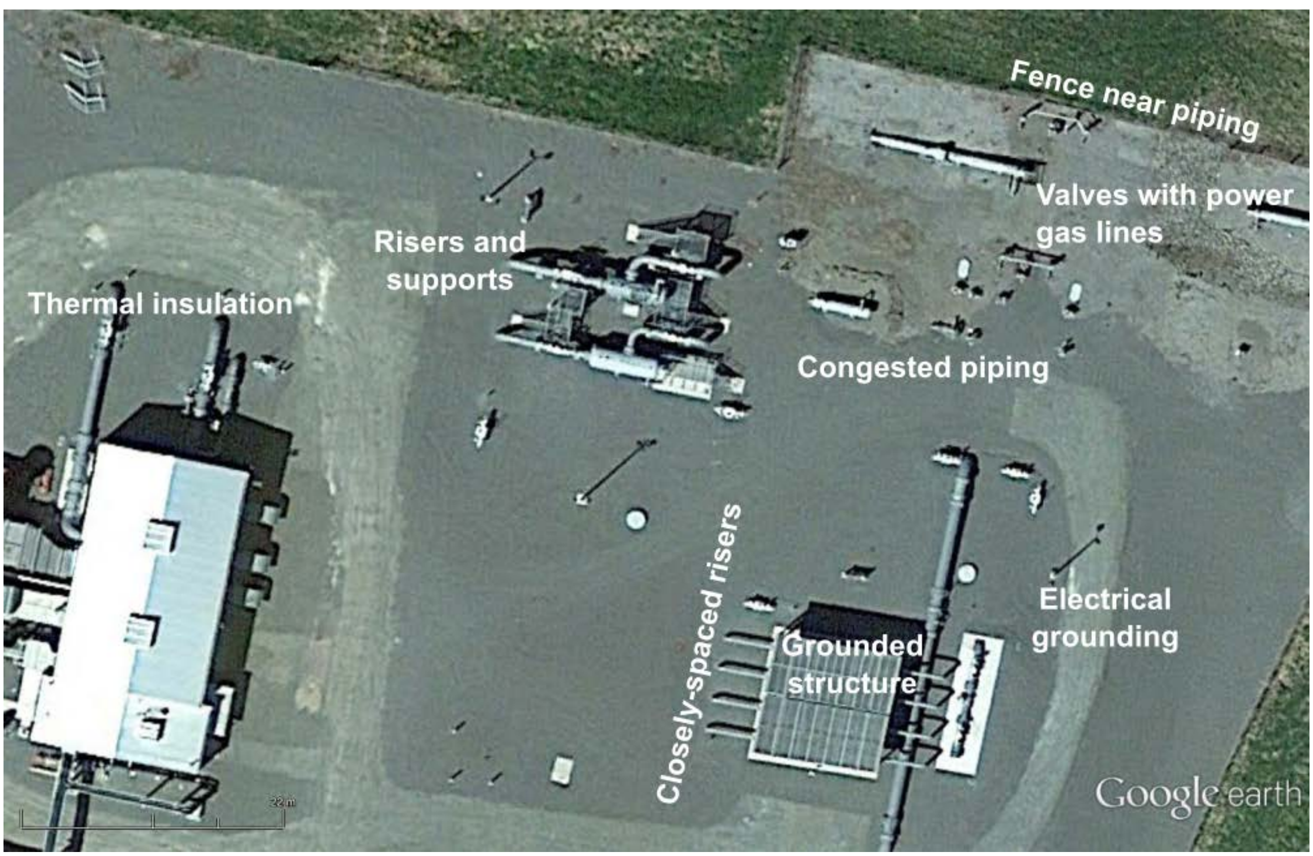

Figure 1: Satellite image showing challenges typical to a compressor station.

Conducting Surveys

The indirect inspection tools are selected as part of the preassessment portion of an ECDA. However, in many cases the primary tools selected are the close-interval potential survey (CIPS) and DC voltage gradient (DCVG) survey. Note that the implications for other coating defect identification tools will be similar. The CIPS is used because it is the most appropriate tool for judging protection levels on the pipeline. The DCVG is normally selected because it is a sensitive coating inspection tool which also provides coating defect severity information.

In addition to regular survey considerations, it is critical that the field technicians have an excellent understanding of the data analysis in addition to maintaining a high degree of awareness of the data collection process. As in all surveys, there are many issues which can only be identified on-site. To assist in the data collection, it is strongly recommended that all buried structures within close proximity of all the piping within scope be pre-located. Continuity between the facility piping and all adjacent structures should also be recorded. Photographs should be taken of all valves, risers, and other relevant features.

Implications for CIPS

In terms of survey considerations, the changes to the CIPS are relatively minor. It is important to ensure a relatively tight spacing between measurements is maintained (typically 1 metre) and that the field technicians are extremely careful while measuring chainage/position at starting points and bends. The spacing should also be adjusted as required to capture any sharp changes in potentials and physical features identified in the field. Note that positioning based on sub-metre GPS is not recommended without validating the repeated accuracy of the points.

The protection levels measured by the CIPS will be influenced by the nearby bare structures and each measurement recorded during the CIPS will be a mixed potential representing all of the nearby continuous metallic paths. Although this may have a significant impact on the data analysis, it is not usually possible to modify the survey procedure to eliminate this influence.

Implications for DCVG Surveys

The DCVG will be heavily influenced by the presence of nearby electrically continuous metallic structures. In order to interpret the results of the DCVG survey, it is necessary to record additional gradient measurements at suspected holidays. This generally allows the measured gradients to be properly attributed to the pipeline or to other structures. In the simplest case, the additional measurement takes the form of a gradient reading on the other side of the pipeline. At some locations, it will be necessary to map the soil gradients with additional measurements to differentiate their source. Both papers cited earlier make use of grid-based voltage gradient measurements[1,2], but it is important to maintain focus on the piping in scope rather than drawing conclusions about the big picture voltage gradients in the facility.

Another significant challenge which may be encountered during DCVG survey in facilities is distributed cathodic protection groundbeds. This type of groundbed is most commonly found in larger facilities such as compressor stations with poor coating quality and very congested piping. Under these circumstances, the DCVG survey cannot be conducted with these close anodes interrupted because the gradients produced by the anodes completely dominate the measurements. Therefore, these anodes need to be de-energized. Disabling one circuit of a rectifier, however, has resulted in negligible potential shift on certain sections of piping. To mitigate this phenomenon, it may be necessary for the field crew to connect and disconnect only the closest anode string while increasing the output of other nearby anode strings to generate sufficient shift. Note that it is very difficult to install effective temporary groundbeds under these circumstances if even nearby permanent installations do not provide shift. The authors have also had acceptable results under very low potential shift (e.g. less than 50 mV).

In addition to these changes, it is not possible to compute the %IR based on the conventional method of interpolating potentials and taking measurements to remote earth due to the presence of nearby anodes. Instead, the %IR must be computed based on an integrated survey methodology[6], which depends on the potential shift measured at the location of the gradient.

The pogo-to-pogo spacing must also be adjusted and regulated based on proximity to other pipelines (e.g. tighten a typical 3 m spacing to 2 m in order to focus attention on a particular pipeline). The choice of spacing must be made in the field, but the decisions must also be communicated effectively to the office for proper data analysis. During the office analysis, it is also important to know the spacing and to properly correlate the gradient data collected on adjacent/parallel lines so that gradients on multiple lines can be attributed to a single source when necessary and holidays can be classified accurately.

Analysis in the Presence of Station Grounding

In many cases the electrical grounding is electrically continuous with the facility piping even if provision was originally included for electrical isolation by the use of insulating flanges. There are two main concerns with this shorted condition: 1) mixed potentials and 2) spurious gradients. Figure 2 shows simulated data for a survey conducted past a building which is grounded on the pipeline side via two grounding rods. The lateral gradient pogo is situated on the side of the pipeline away from the building.

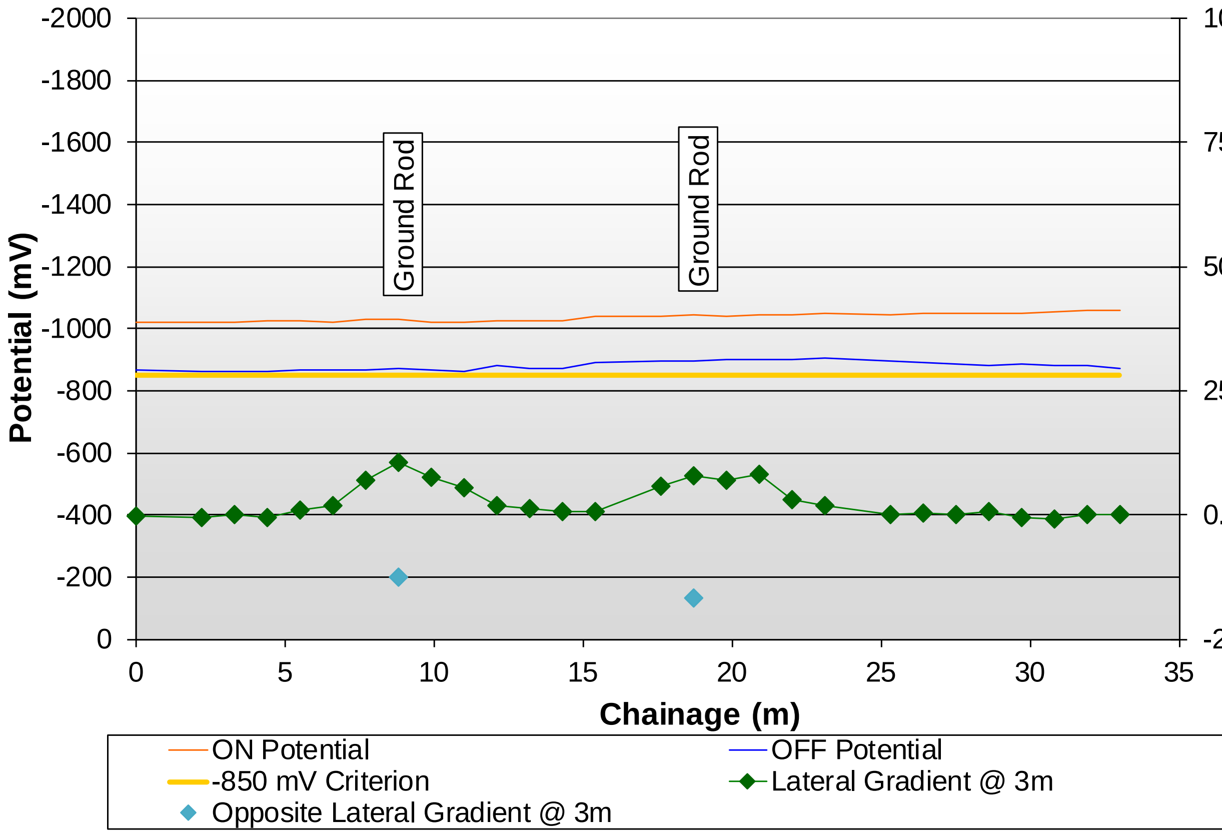

Figure 2: Plot of simulated data in vicinity of a building.

In line with the two ground rods, at Ch. 8.8 m and Ch. 18.7 m, peaks in the lateral gradient are visible, indicating a current toward the pipeline at these locations. This is the same profile which would be measured in the presence of holidays on the subject pipeline. However, by also measuring the gradient on the opposite side, i.e. towards the building, the lateral gradient peaks are shown to be cross gradients and can be correctly attributed to the ground rods rather than to holidays on the pipeline.

In this case, there is also no evidence of depressed potentials attributable to these copper ground rods. If the soil is not aerated, this result is expected because copper will readily polarize.[7] Under these circumstances, where there is sufficient current supplied to the station to polarize all of the buried metallic structures, mixed potentials are less of a concern and would generally result in only a slightly conservative assessment of the protection levels.

Under aerated conditions, mixed potentials could be much more problematic. Coupons might be the only viable option for determining the true protection levels of the piping under assessment. This condition is also more likely to result in a detrimental galvanic couple between the steel and copper. Note that copper, under aerated conditions, requires very high current densities to polarize.[7,8]

Analysis for Holidays Hidden by Gradients

Another situation which has arisen is the ability to detect holidays in the vicinity of gradients produced by other, larger holidays or by station grounding. The issue appears to be most acute near valves, which are often poorly coated and have a large surface area, but also applies to areas of congested piping.

Data simulated by super-imposing a 65%IR holiday on a parallel line 3 metres away from a 15%IR holiday on the surveyed line is shown in Figure 3. In the super-imposed case, the smaller holiday, which would normally be classified as a minor indication, has very little impact on the measurement and could not be reliably identified.

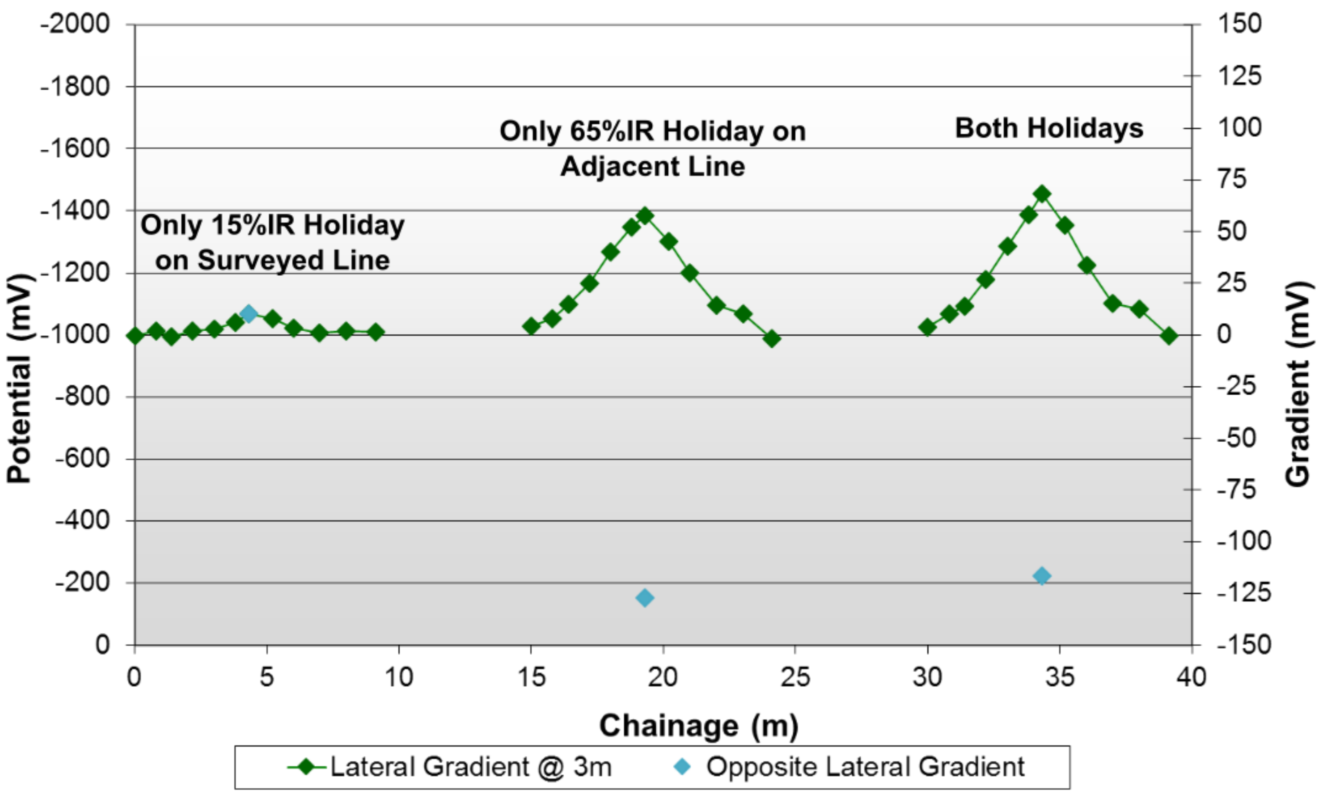

Figure 3: Plot of simulated DCVG data for a holiday masked by another holiday.

In the absence of sufficient cathodic protection (i.e. subcriterion areas), there could be corrosion at such a location, but the survey would not have detected a holiday at this location. To understand the impact on the assessment and risk, however, consideration must be given to section 5.6.2.1 of SP0502-2010 which states that, "The ECDA process helps find representative corrosion defects on a pipeline segment, but it may not find all corrosion defects on the segment." The premise on which the ECDA methodology is built is that (section 5.6.2.2), "If corrosion defects that exceed allowable limits are found, it should be assumed that other similar defects may be present elsewhere in the ECDA region."

Two cases exist, therefore (see Figure 4): (a) the gradient is caused by a coating defect on piping under scope and (b) the gradient is caused by another structure (such as grounding rods or piles). If the larger gradient is caused by the piping itself, then the ECDA process will process this larger holiday and conduct an excavation if necessary. If the larger gradient is caused by another structure, then the holiday – and the corrosion condition at this location – could be masked.

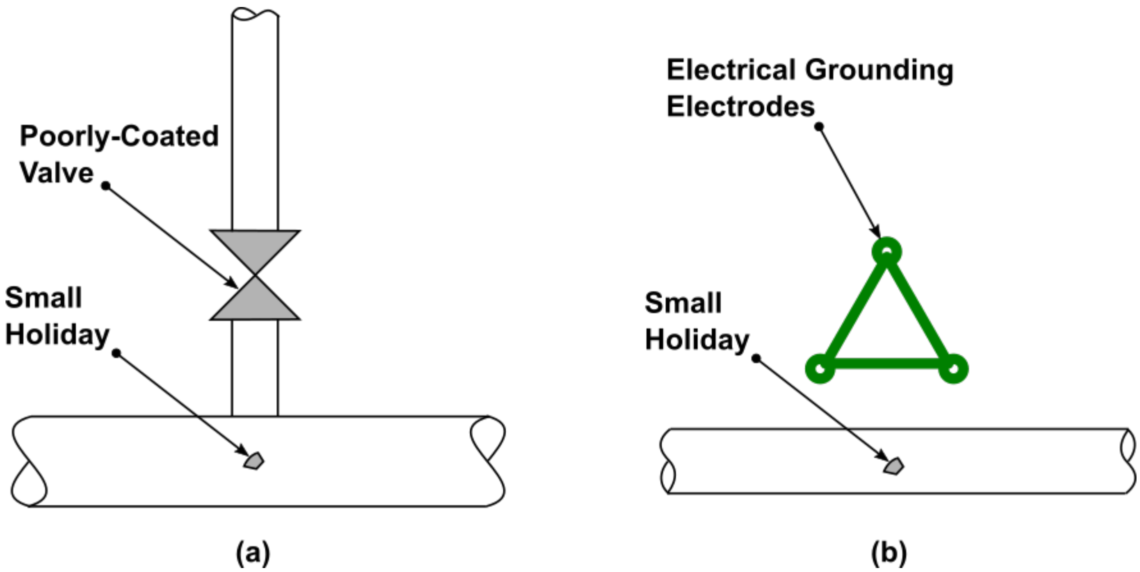

Figure 4: Diagram of two cases where small holidays could be hidden by gradients.

For condition (a), the most poorly coated structures in a facility are typically valves. This raises the question of which indication is more severe: a large DCVG indication at a valve; or a smaller indication at a tee, bend, or on a straight section of pipe? Valves typically have much greater wall thickness than other piping, so if a given pit depth were observed on the body of a valve then the corrosion, when considered as a percentage of the wall thickness, would be less severe. However, due to the presence of more bare steel, the protection levels would normally be lower at a valve than elsewhere, which would result in more corrosion. As the ECDA process is designed to "identify and address corrosion activity" (from the Foreword to SP0502-2010), a possible approach would be to select the location where corrosion is most likely to occur (in this case, valves would generally be good candidates with all else equal) while also considering the possibility that similar pit depths could be observed at locations with lesser wall thickness for the purposes of determining remaining life.

For condition (b), where the holiday is masked by a gradient external to the piping, the approach is less elegant. In this case, cross gradients may need to be classified as coating holidays, with the severity related to the magnitude of the cross gradient. If protection levels are sufficient based on the results of the CIPS, then active corrosion is not expected and the risk from these locations is minimal. If protection levels are not sufficient, then these locations may be prioritized more severely. This rare situation may necessitate the definition of additional ECDA regions and may result in extra direct examinations, so this approach should be used only as a last resort and may in some cases be avoided through the use of additional gradient mapping.

The situation is further complicated by the possibility that the hidden holiday is deeper underground than the source of the masking gradient. In this case, it would be possible for a larger holiday to be hidden.

These concepts are also applicable for understanding surveys of very congested facilities. In this case, a single CIPS pass would be used to represent multiple pipelines. Holidays which are detected would not necessarily be attributed to a particular pipeline. This results in some uncertainty regarding holiday sizing because the %IR depends on the actual pipe depth, but this can be mitigated to a large extent through thoughtful data analysis. Note that conservatively assuming such holiday(s) are on the deepest pipe at the location, which would result in the highest %IR, may not be appropriate because other indications could then have a lower likelihood of being excavated as a result.

CONCLUSIONS

The ECDA approach attempts to identify all the locations most susceptible to failure from external corrosion. If these locations can be successfully identified, and the worst of the locations are safe, then logically other locations on the pipeline will also be safe. Based on the authors' experience conducting surveys and data analysis in facilities, and based on the results direct examinations, it is possible to successfully identify the worst locations with a high degree of confidence. Therefore, it is possible to use the ECDA methodology within facility environments.

The over-arching implication of the additional complexities is increased difficulty in data collection and analysis. This results in higher cost per kilometre than on cross-country pipelines, and may also result in higher per-excavation costs because hydrovac is typically required. It must be remembered, however, that the cost should be compared with the available alternatives for facility assessment (such as 100% excavation and direct examination), not with cross-country ECDA. If the cost is properly framed and is shown not to be excessive, the primary considerations become the practicality and effectiveness of the ECDA techniques within a facility, which have been demonstrated.

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