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New Concepts in the Prioritization of Multiple ECDA Indications

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ABSTRACT

This paper describes the challenge of integrating specific types of ECDA indications, such as AC-enhanced corrosion (ACEC) and DC interference (DCI), under the prioritization criteria recommended by NACE RP0502-2002.

Starting from the observation that the risk of corrosion does not always increase with the size of the holiday, the paper analyzes the interaction of up to four complementary ECDA indications (i.e. CIPS, DCVG, ACEC and DCI), with and without prior history of corrosion, as a function of their severity.

New concepts, such as "***distributed indication***" and "***relevant indication***", are introduced in order to establish the location of the direct examinations, where the indication affects entire sections of line (i.e. 10 km of line subject to severe ACEC).

Simple rules are proposed for integrating these multiple ECDA indications in matrix type prioritization tables. The paper also includes an example of using these tables to prioritize a combination of three indications without prior history of corrosion (i.e. moderate DCVG in conjunction with a severe DCI and a severe CIPS indication).

INTRODUCTION

The External Corrosion Direct Assessment (ECDA) as described in NACE Standard RP0502-2002 is a continuous improvement process using existing data and the results of indirect inspection techniques, validated by a series of direct examinations, to identify and address locations where external "corrosion activity has occurred, is occurring, or may occur". Using guidelines and minimum requirements provided by the NACE Standard, the pipeline operator shall establish his own criteria to identify, classify and prioritize the various types of indications in order to determine which indications from the indirect inspections are the most severe and accordingly to prioritize the direct examinations.

The NACE Standard RP0502-2002 provides excellent guidelines for both the classification and the prioritization processes, as proven by the successful application of the ECDA program over the last few years.

As more experience is gathered in the field and as the operator faces more diversified sets of indications, the application of these guidelines to generate the actual prioritization criteria naturally becomes a more challenging task.

This paper describes how Union Gas Limited (UGL) and Corrosion Service Company Limited (CSCL) dealt with two of these challenges during an ECDA project that covered more than 20 pipelines in the Province of Ontario.

PRIORITIZATION OF LARGE (DISTRIBUTED) INDICATIONS

The first challenge was related to "extensive" indications. Figure 1 shows the results of an integrated Close Interval Potential Survey (CIPS)/DC Voltage Gradient (DCVG) conducted on a section of pipeline in Northern Ontario. The data are plotted with respect to the distance measured from the beginning of the ECDA segment (i.e. chainage). The pipe-to-soil potential and the 3m lateral gradient[1] were recorded at 1m spacing. The line was protected by magnesium anodes directly connected to the pipe and all foreign rectifiers were interrupted. The identification criterion for CIPS indications was set at -1000 mV_{CSE} measured with rectifiers off and anodes connected, to compensate for the IR drop produced in the earth by the magnesium anodes in low resistivity soils. For illustration purposes, both the pipe-to-soil potentials and the CIPS identification and classification criteria were adjusted by +150 mV, to match the -850 mV_{CSE} polarized off potential NACE protection criterion.

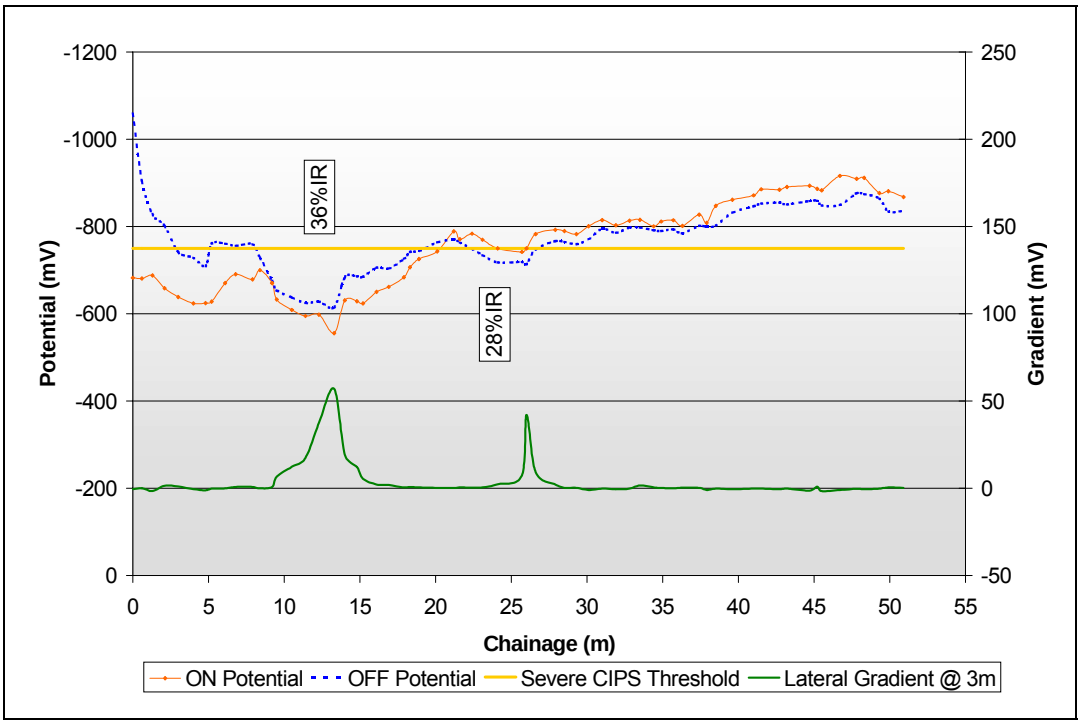

FIGURE 1 – Distributed Severe CIPS Indication

[1] Measured with one reference located above the pipe and the second reference located at 3m distance, perpendicular on the pipeline.

The pipe-to-soil instant-off potentials were more electropositive than the threshold for CIPS severe indications (i.e. -750 mV_{CSE}) at 23 locations (i.e. from chainage 3 m to chainage 5 m and from chainage 8 m to chainage 27 m). Should these indications be considered as "Multiple severe indications in close proximity" as per paragraph 5.2.2.1.1 of NACE Standard RP0502-2002, and require immediate action? And if so, should the entire 3 m and 20 m long sections be excavated?

In order to answer these questions, we introduced several new concepts, such as "***distributed***" indications, "***localized***" indications and "***relevant***" indications.

A "***localized indication***" is an indication affecting a specific but isolated location on the line, identified by GPS coordinates or marked on site. Examples of "***localized***" indications are the DCVG indications and DC interference (DCI) indications at the crossing of two pipelines. Two DCVG "***localized***" indications appear in Figure 1 (i.e. a 36%IR moderate indication at chainage 13.3 m and a 28%IR minor DCVG indication at chainage 26 m).

A "***distributed indication***" is a continuous indication affecting an entire section of line. The section starting at chainage 8 m and ending at chainage 27 m displays a severe "***distributed***" CIPS indication, assuming that the threshold for a severe indication is set at -750 mV_{CSE}.

The section of line shown in Figure 1 also displays DC interference (DCI) indications, ranging from minor to severe, from chainage 0 m to chainage 20.1 m (i.e. electropositive potential shifts when the interfering rectifier is turned on).

"***Distributed***" indications can vary in extent from several meters to several kilometers. For example, an 8" dia. pipeline in Eastern Ontario displayed moderate AC-enhanced corrosion indications over a length of 1200 m of pipe, with calculated AC current densities exceeding 50 A/m^2 at 1 cm^2 holidays. Prioritizing an indication covering 1200m of line for direct examination would obviously be unrealistic, due to the amount of excavation required.

In order to evaluate the best way to prioritize this type of extensive "***distributed***" indication, we considered a "theoretical direct examination" along such a lengthy section of pipeline.

Assuming that the entire 20 m long section from chainage 8 m to chainage 27 m would be excavated, the inspector is expected to observe a well coated pipe without any exposure to corrosion from chainage 8 m to chainage 13.3 m and from chainage 13.3 m to chainage 26 m. The only locations where corrosion could be expected would be at coating holidays recorded as DCVG indications (i.e. at chainage 13.3 m and at chainage 26 m).

In other words the "***distributed***" CIPS, DCI and ACEC indications define the risk of external corrosion in a particular section of the line, however the actual corrosion attack would occur only at a coating holiday, where the pipe surface is exposed to the soil. As such, it makes sense to prioritize "***distributed***" indications in conjunction with DCVG indications.

We have defined "***localized***" indications and "***distributed***" indications in conjunction with DCVG indications as "***relevant indications***". As a general rule, only the "***relevant***" indications would be prioritized for direct examination under paragraph 5.2.2 of NACE Standard RP0502-2002.

As an exception, short "***distributed***" severe indications related to accelerated corrosion, such as AC and DC interference, could be considered for direct examination even if no coating holidays were identified, due to the high risk of pipe failure.

Using these concepts, the indications identified in Figure 1, would be classified[2] as shown in Table 1, but would be selected for prioritization as shown in Table 2.

TABLE 1
CLASSIFICATION OF ECDA INDICATIONS

Chainage (m)	ECDA Region	Classification	Notes
From 1 to 3	1	Minor CIPS Severe DCI	-802 mV_{CSE} @ Ch. 2.1 143 mV shift
From 3 to 5	1	Severe CIPS Severe DCI	-710 mV_{CSE} @ Ch. 4.8 105 mV shift
From 5 to 8	1	Moderate CIPS Severe DCI	-756 mV_{CSE} @ Ch. 6.8 65 mV shift
From 8 to 13.2	1	Severe CIPS Minor DCI	-625 mV_{CSE} @ Ch. 11 29 mV shift
13.3	1	Severe CIPS Severe DCI Moderate DCVG	-615 mV_{CSE} 59 mV shift 36%IR
From 13.4 to 16	1	Severe CIPS Severe DCI	-624 mV_{CSE} @ Ch. 15 61 mV shift
From 16 to 18	1	Severe CIPS Moderate DCI	-704 mV_{CSE} @ Ch. 17 42 mV shift
From 18 to 20.1	1	Severe CIPS Minor DCI	-726 mV_{CSE} @ Ch. 19 18 mV shift
From 20.1 to 25.9	1	Severe CIPS	-718 mV_{CSE} @ Ch. 24
26	1	Severe CIPS Minor DCVG	-714 mV_{CSE} 28%IR
From 26.1 to 27	1	Severe CIPS	-748 mV_{CSE} @ Ch. 27
From 27 to 37	1	Moderate CIPS	-765 mV_{CSE} @ Ch. 28
From 37 to 41	1	Minor CIPS	-800 mV_{CSE} @ Ch. 38

TABLE 2
SELECTED ECDA INDICATIONS

Chainage (m)	Classification	Prioritization
4*	Severe CIPS Severe DCI	To be determined
13.3	Severe CIPS Severe DCI Moderate DCVG	To be determined
26	Severe CIPS Minor DCVG	To be determined

* chainage refers to the center of excavation

[2] The classification criteria are summarized in Appendix A.

Prioritizing only the "***relevant***" and the high risk short "***distributed***" indications allowed us to deal efficiently with extensive indications.

In summary, the answers to the two hypothetical questions asked at the beginning of this paper would be:

Q1: Should the "***distributed***" severe indications shown in Figure 1 be considered as "Multiple severe indications in close proximity" as per paragraph 5.2.2.1.1 of NACE Standard RP0502-2002, and require immediate action?

A1: In our opinion the answer is no, because paragraph 5.2.2.1.1 applies only to "***relevant***" indications. Some "***relevant***" severe indications may require immediate action when in close proximity, or when in conjunction with other severe indications at the same location, or when in conjunction with a severe prior history of corrosion, but the prioritization would not be related to the extent of the "***distributed***" indications.

Q2: Assuming that the "***distributed***" indications, shown in Figure 1 and classified as severe, were considered as "Multiple severe indications in close proximity" as per paragraph 5.2.2.1.1 of NACE Standard RP0502-2002, and prioritized as Immediate Action Required", then should the entire section be excavated?

A2: In our opinion the assumption is false, since only "***relevant***" indications are prioritized. Typically the pipe would not be excavated at a location where the coating is expected to be in perfect condition, as recorded by the DCVG survey. Also, if a severe ACEC indication covers 1200 m of line, excavation of the entire 1200 m long section should not be required. The only exceptions are the short isolated sections of line under severe risk of accelerated corrosion at any undetected holiday.

PRIORITIZATION OF MULTIPLE INDICATIONS

The second challenge was related to dealing with multiple types of indications and specifically with the fact that the severity of indications from different inspection techniques at the same locations is not necessarily additive and should be analyzed for each specific combination of indications.

For example, the risk of accelerated corrosion due to AC and DC interference increases with the current density, and consequently decreases with an increase in the surface area of the holiday. Therefore, a minor DCVG indication in conjunction with an AC or DC interference indication is more serious than a severe DCVG indication in conjunction with the same type of indication and should be prioritized accordingly.

Tables were prepared to cover the various combinations of interactive indications. An example of such a table covering DCVG, CIPS, DCI and ACEC indications, with and without prior history of corrosion is shown in Table 3.

TABLE 3
SUMMARY OF PRIORITIZATION CRITERIA

DC Voltage Gradient Indication	Close Interval Potential Survey Indication		Prioritization											
			Prior History of Corrosion (PHC)				DC Interference (DCI)				AC Induced Corrosion (ACC)			
			SV	MD	MN	Nil	SV	MD	MN	NI	SV	MD	MN	NI
			1	2	3	4	5	6	7	8	9	10	11	12
DCVG-SV	CIPS-SV	1	I	I	I	I	I	I	I	I	N/A	N/A	N/A	I
	CIPS-MD	2	I	I	S	S	I	S	S	S	N/A	N/A	N/A	S
	CIPS-MN	3	I	I	S	S	I	S	S	S	N/A	N/A	N/A	S
DCVG-MD	CIPS-SV	4	I	I	I	S	I	I	I	S	N/A	N/A	N/A	S
	CIPS-MD	5	I	I	S	S	I	S	S	S	N/A	N/A	N/A	S
	CIPS-MN	6	I	S	M	M	I	S	M	M	N/A	N/A	N/A	M
DCVG-MN	CIPS-SV	7	I	I	S	S	I	S	S	S	I	S	S	S
	CIPS-MD	8	I	S	S	S	I	S	M	M	I	S	M	M
	CIPS-MN	9	S	M	M	M	I	S	M	M	I	S	M	M
DCVG-BT	CIPS-SV	10	I	I	S	S	I	S	S	S	I	S	S	S
	CIPS-MD	11	S	S	M	M	I	S	M	M	I	S	M	M
	CIPS-MN	12	M	M	N	N	I	S	M	N	I	S	M	N
DCVG-NI	CIPS-SV	13	I*	N	N	N	I*	N	N	N	I*	N	N	N
	CIPS-MD	14	I*	N	N	N	I*	N	N	N	I*	N	N	N
	CIPS-MN	15	N	N	N	N	I*	N	N	N	I*	N	N	N

***Consider excavating short sections of line under severe risk of external corrosion, even if DCVG indications were not found.

Legend:

SV	=	Severe indication	**I**	=	Immediate action required
MD	=	Moderate indication	**S**	=	Scheduled action required
MN	=	Minor indication	**M**	=	Suitable for monitoring
BT	=	Below threshold	N	=	No action required
NI	=	No indication	N/A	=	Not Applicable

The prioritization status is obtained by intersecting the relevant line and column in the matrix shown in Table 3.

For example, the intersecting cell between the 4th row (DCVG-MD & CIPS-SV) with the 5th column (DCI-SV) stipulates that a moderate DCVG indication in conjunction with a severe CIPS indication and a severe DC interference indication requires immediate action (I).

Note that short lengths of pipeline under severe DC interference are considered for immediate action, even if no DCVG indications were found (see intersection between rows 13, 14, or 15 and column 5).

Using the prioritization matrix shown in Table 3, the indications identified in Figure 1 would be prioritized as shown in Table 4.

TABLE 4
PRIORITIZATION OF ECDA INDICATIONS

Chainage (m)	Classification	Prioritization
4*	Severe CIPS Severe DCI	To be considered for immediate action
13.3	Severe CIPS Severe DCI Moderate DCVG	Immediate Action Required
26	Severe CIPS Minor DCVG	Scheduled Action Required

* chainage refers to the center of excavation

CONCLUSIONS

The introduction of concepts such as "***distributed***", "***localized***" and "***relevant***" indications allowed for the prioritization of indications covering long lengths of pipeline in accordance with the general guidelines of NACE standard RP0502-2002.

The use of classification criteria in a matrix form facilitates the evaluation of multiple types of interactive indications at the same location and simultaneously ensures consistency in the assessment process.

APPENDIX A
CLASSIFICATION CRITERIA FOR INDICATIONS

Protection Level (Close Interval Potential Survey)

- Minor: V_{OFF} between -800 mV_{CSE} and -850 mV_{CSE}
- Moderate: V_{OFF} between -750 mV_{CSE} and -799 mV_{CSE}
- Severe: V_{OFF} more electropositive than -749 mV_{CSE}

Coating Damage (DCVG Survey)

- Minor: % I-R less than or equal to 35% and C-C (cathodic-cathodic) behaviour. (Categories 1 or 2, no direct examination recommended)
- Moderate: % I-R higher than 35% and less than or equal to 60% and C-C or C-N (cathodic-neutral) behaviour (Category 3, major consumer of CP current)
- Severe: % I-R more than 60% or C-A (cathodic-anodic) or A-A (anodic-anodic) behaviour (Category 4, recommended for immediate repair)

AC Induced Corrosion (AC Voltage and Resistivity Survey)

- Minor: AC current density less than or equal to 50 A/m^2
- Moderate: AC current density higher than 50 A/m^2 and less than 100 A/m^2
- Severe: AC current density more than 100 A/m^2

DC Interference with No CIPS Indication (DC Interference & CIPS Surveys)

- Minor: Electropositive shift greater than 30 mV, when the interfering rectifier is turned ON
- Moderate: N/A (no moderate or severe indications on fully protected lines)
- Severe: N/A (no moderate or severe indications on fully protected lines)

DC Interference with CIPS Indication (DC Interference & CIPS Surveys)

- Minor: Electropositive shift less than 30 mV, when the offending rectifier is turned ON
- Moderate: Electropositive shift from 30 mV to 60 mV, when the offending rectifier is turned ON
- Severe: Electropositive shift higher than 60 mV, when the offending rectifier is turned ON