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New and Old Challenges in Analyzing ECDA Indirect Inspections Data

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ABSTRACT

The analysis of indirect inspection data is a critical factor in conducting a successful ECDA process.

This paper covers two lessons learned recently when dealing with bonded pipelines along common rights-of-way and also with equalization currents. The “old” challenge of differentiating between “threat” related versus “tool” related indications will be also discussed.

Topics like attributing a coating holiday to the “right” pipeline in a common right-of-way, differentiating a magnesium anode profile from an equalization current signature and “double dipping” in a DCVG indication are reviewed in detail in this paper.

Keywords: External Corrosion Direct Assessment (ECDA), Close Interval Potential Survey (CIPS), Direct Current Voltage Gradient (DCVG), reverse gradient, equalization currents.

INTRODUCTION

The quality of the indirect inspection data and the accuracy of the data interpretation are critical factors in conducting a successful ECDA program. Decisions made based on false indications can result in high cost excavations at the wrong locations, while missed severe indications can result in an immediate threat to pipeline integrity.

Conducting close interval potential surveys on bonded pipelines along common rights-of-way makes assessing the protection level of each pipeline extremely difficult. Furthermore, a coating holiday indication on one of the bonded pipelines would also be sensed when surveying on the other lines. As such, improved survey procedures and new data processing methods must be developed to maintain the accuracy of the indirect inspection tools under these conditions.

This paper covers two lessons learned recently when dealing with bonded pipelines along common rights-of-way and also with equalization currents. The “old” challenge of differentiating between “threat” related versus “tool” related indications will be also discussed.

Each challenge lesson will be presented based on the original survey case, complete with recommendations for avoiding possible errors.

IDENTIFYING COATING HOLIDAYS ON BONDED PIPELINES

An ECDA process was conducted on a pipeline in Alberta (i.e., NPS 30 Mainline Loop) along a common right-of-way with an older pipeline (i.e., NPS 30 Mainline).

The presence of two parallel and electrically interconnected lines was expected to affect both the protection level assessment (CIPS) and coating condition assessment (DCVG). The result of the error affecting the CIPS would be a more conservative assessment, which was acceptable under the project. However, the DCVG survey in a multiple pipeline ROW could inadvertently detect a holiday on an adjacent pipeline and attribute it to the well coated pipeline under assessment. As such, every effort was made to attribute each possible DCVG indication to the appropriate pipeline.

The first survey was conducted along the NPS 30 Mainline Loop (pipeline under assessment) using the integrated CIPS/DCVG technique[1]. The pipe-to-soil potential and the lateral gradient at 3m were measured simultaneously using a two-channel data logger. The lateral gradients were measured on the east side, far from the NPS 30 Mainline. A sample of the results, as recorded from Ch. 13000 m to Ch. 14500 m is shown in Figure 1. The lateral gradients indicate four possible DCVG indications at Ch. 13149 m, Ch. 13808 m, Ch. 13892 m and Ch. 14377 m.

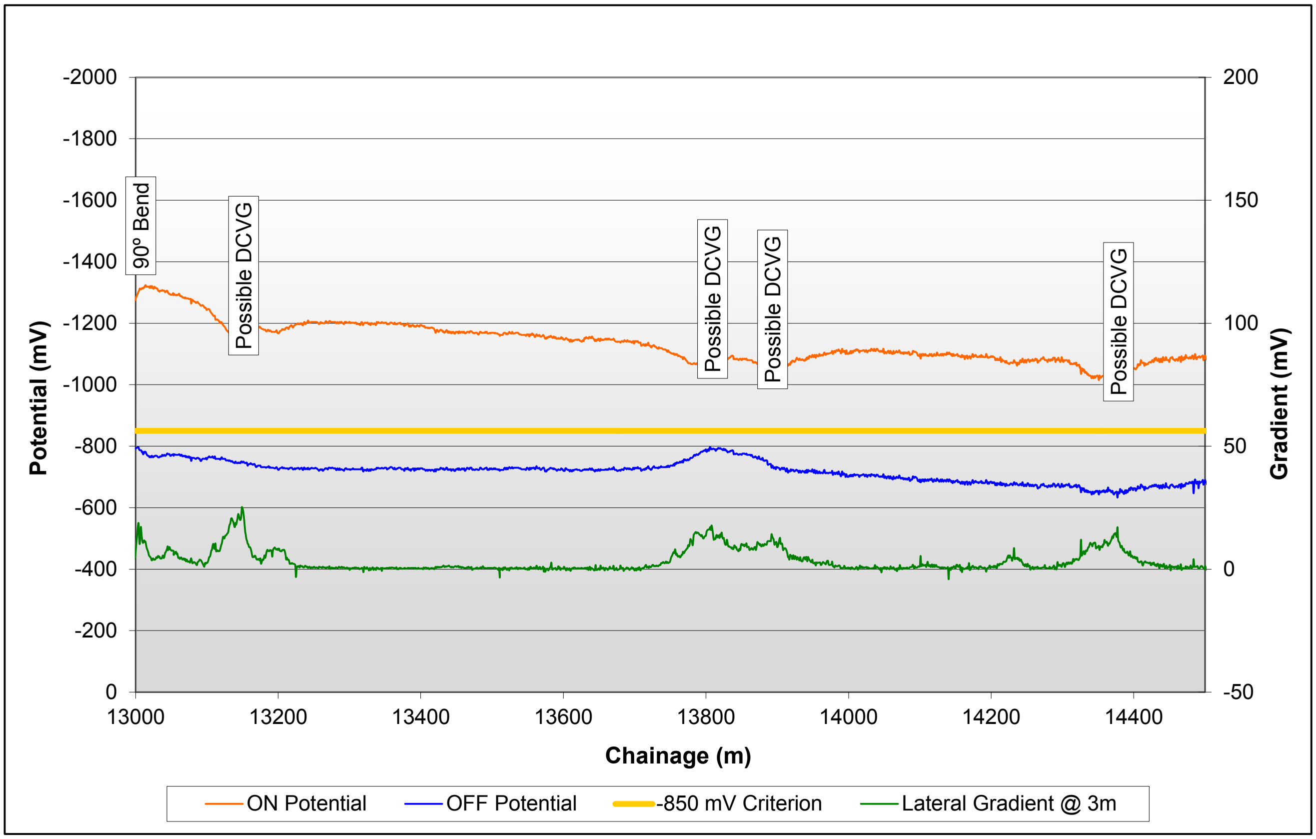

Figure 1: NPS 30 Mainline Loop. Integrated CIPS/DCVG Data. Preliminary Graph

Lateral gradient were then measured on both sides of the line at all possible DCVG indications. The results are shown in Table 1.

Table 1
NPS 30 Mainline Loop. Gradients at Possible DCVG Indications

Chainage (m)	Lateral Gradient (mV)			
	NPS30 Mainline Loop		NPS30 Mainline	
	East Side	West Side	East Side	West Side
13149.1	22	45	-	-
13807.9	16.9	-20.3	62	76
13892.0	13	17	-	-
14377.2	12.7	-18.1	26.1	33.7

Positive gradients indicate more electronegative soil potentials above the pipe (i.e., current flowing towards the pipe), while negative gradients indicate more electronegative lateral soil potentials (i.e., current flowing away from the pipe). Subsequently, positive gradients on one side of the line in conjunction with negative gradients on the other side indicate that the current just crosses the pipeline and are defined as "cross gradients". For additional confidence that the "cross gradients" indicate coating holidays on the adjacent lines, the gradients on the two sides of the other line were recorded at the "cross gradients".

The data indicates that only two holidays may be attributed to the line under assessment (i.e., at Ch. 13149 m and Ch.13892 m), as shown in the final graph of the survey – see Figure 2. The other two locations are marked on the graph as “cross gradient”.

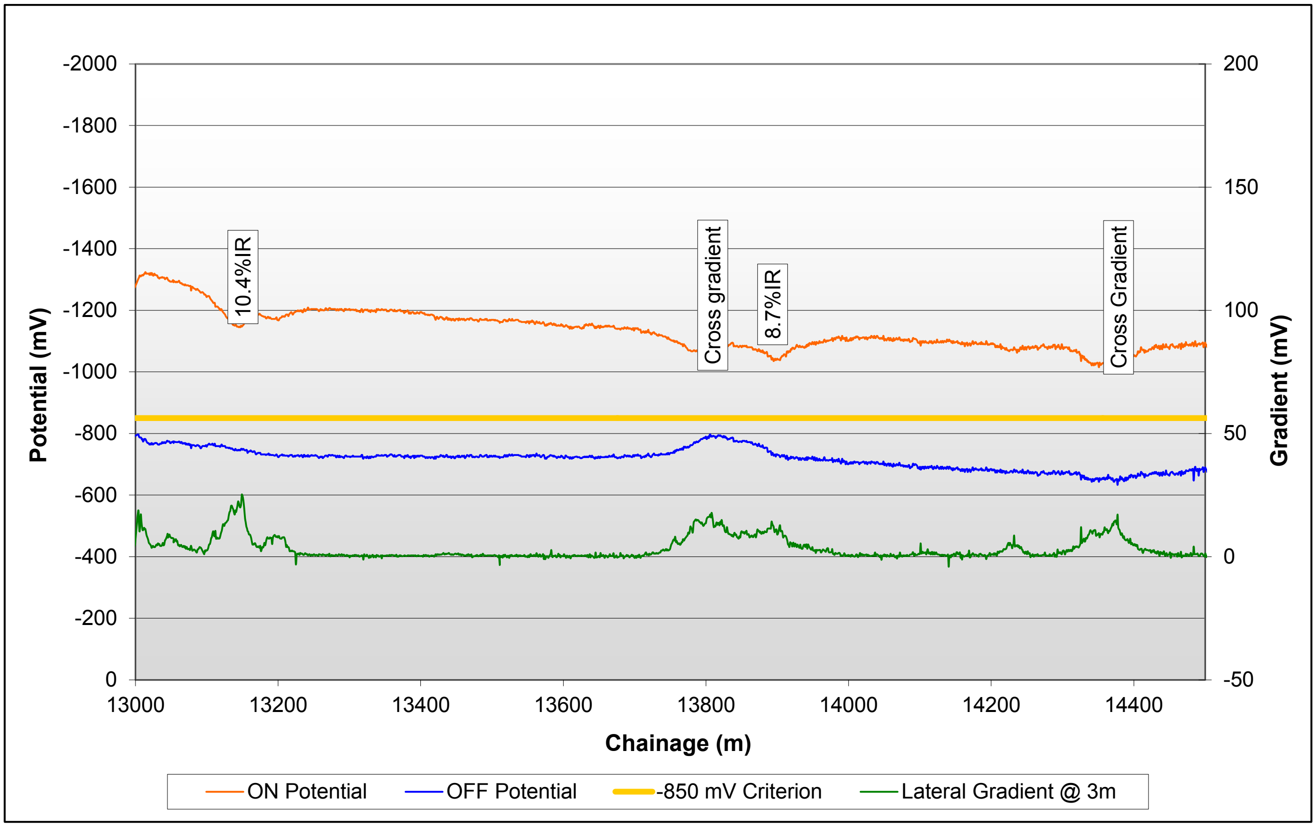

Figure 2: NPS 30 Mainline Loop. Integrated CIPS/DCVG Data. Final Graph

Measuring the lateral gradient on the two sides of the line at all possible DCVG indications proved to be an effective way to attribute DCVG indications to the appropriate pipeline along common rights-of-way.

However, it should be mentioned that severe DCVG indications on an adjacent line may “hide” small holidays on the line under assessment.

MAGNESIUM ANODES OR COATING HOLIDAYS?

The typical profile of a magnesium anode in a CIPS/DCVG graph shows an increase in the OFF potential in conjunction with a significant lateral gradient, as shown in Figure 3.

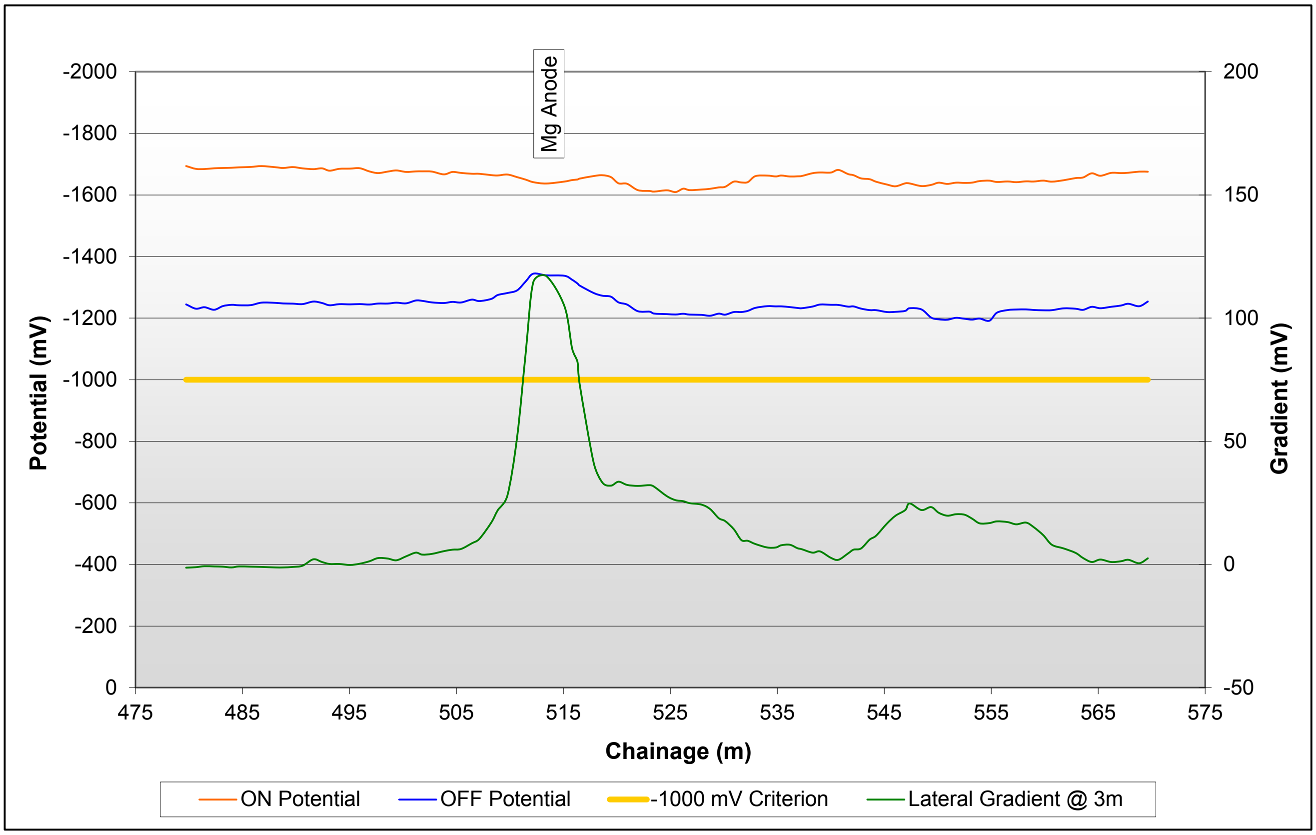

Figure 3: Typical Profile of an Active Magnesium Anode

Sometimes, the increase in the OFF potential is barely detectable (i.e. several millivolts) and the gradient produced by an old magnesium could be incorrectly attributed to a coating holiday.

An ECDA process was conducted in 2006 on a NPS 4 pipeline in Ontario and the results of the CIPS and DCVG surveys conducted from Ch. 10 m to Ch. 110 m are shown in Figure 4.

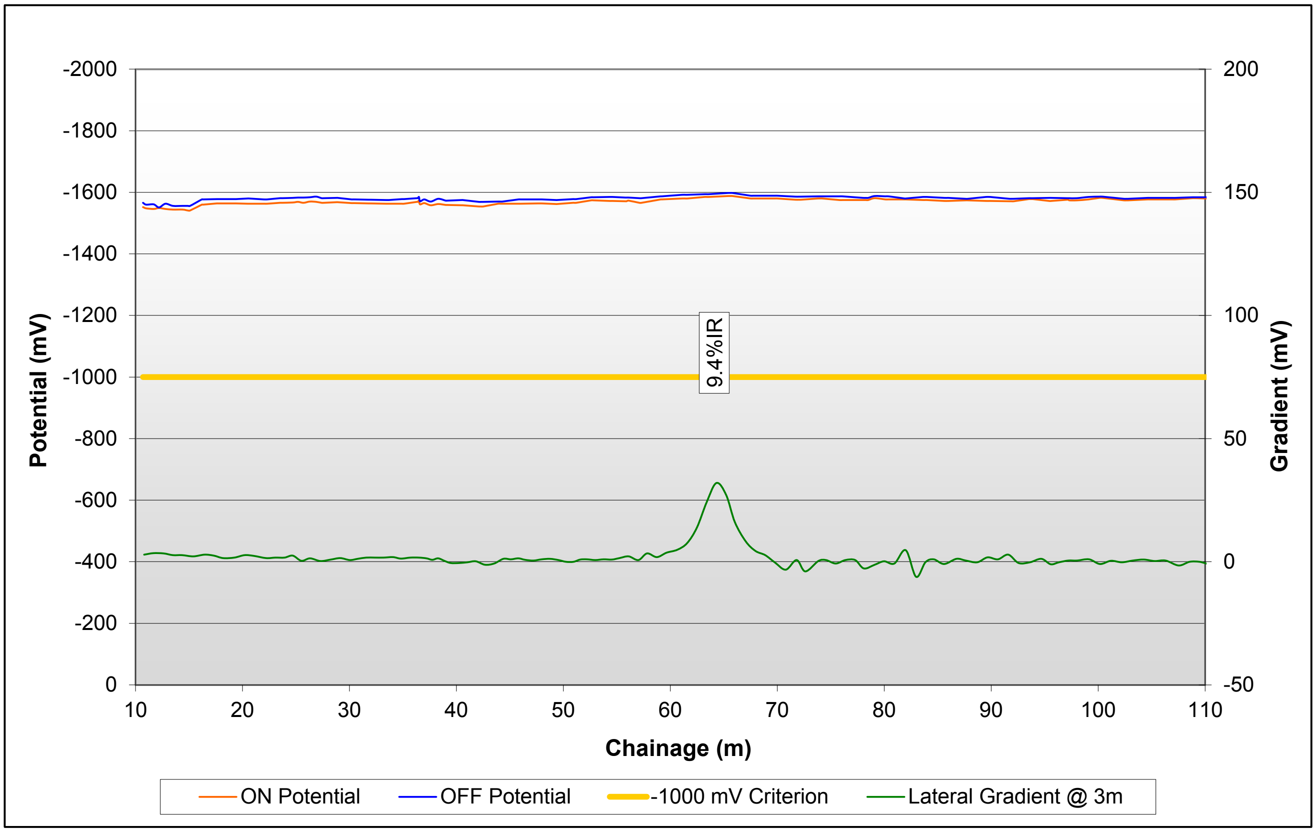

Figure 4: NPS 4 Pipeline. Ch. 10 m to Ch. 110 m. CIPS/DCVG Aligned Data

The increase in the lateral gradient at Ch. 64.30 m was identified as a “below threshold” DCVG indication[1] and with no more severe indications, it was selected for direct examination.

The coating was found in good condition, with no identifiable holidays. An old magnesium anode connection was found at this location as shown in Figure 5.

Figure 5: Magnesium Anode Connection

Such errors are increasingly rare, as the data are scrutinized for increases in OFF potential within the few millivolts range but won't identify a consumed magnesium anode that leaves a steel core behind.

However, a new challenge appears to be the opposite situation, when a typical profile of a magnesium anode could in fact be a coating holiday.

An integrated CIPS/DCVG survey was conducted in 2014 on an NPS 36 pipeline in Western Canada, as part of the ECDA program. The CIPS/DCVG profile is shown in Figure 6 and the survey data around Ch. 3851.7 m is shown in Table 2.

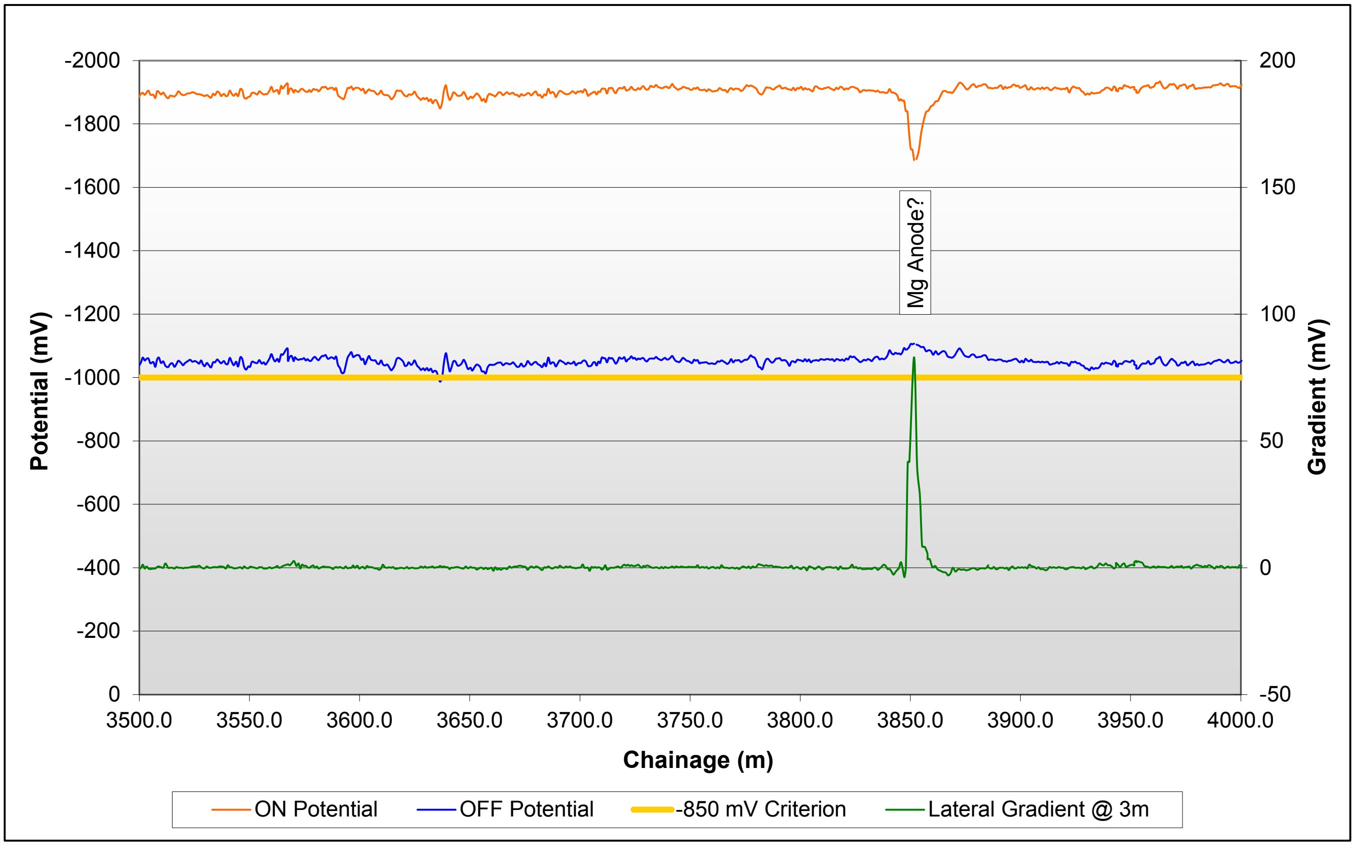

Figure 6: NPS 36 Pipeline. Ch. 3500 m to Ch. 4000 m. Integrated CIPS/DCVG Data

Table 2
NPS 36 Pipeline. Excerpt of CIPS/DCVG Data

Chainage (m)	ON Potential (mV)	OFF Potential (mV)	Lateral Gradient (G) @ 3m (mV)		
			ON	OFF	ΔΓ
3846.4	-1873	-1093	-0.8	-3	2.2
3847.9	-1841	-1088	-7.6	-7.6	0
3848.7	-1839	-1090	-6.7	-3	-3.7
3849.4	-1772	-1096	6.3	5.5	0.8
3850.2	1721	-1106	26.5	-15.2	41.7
3850.9	-1719	-1105	25.6	-16.2	41.8
3851.7	-1686	-1107	66.1	-16.9	83
3852.8	-1689	-1104	29.5	-10.6	40.1
3853.9	-1717	-1101	28.3	-0.3	28.6
3854.9	-1773	-1096	11.4	2.9	8.5
3856	-1810	-1096	11.6	3.3	8.3
3857.1	-1837	-1083	7.7	2.1	5.6
3858.2	-1842	-1086	-5.2	-8.6	3.4
3859.3	-1855	-1084	-0.1	-3.5	3.4
3860.4	-1860	-1072	1.1	0.9	0.2

The lateral gradient shift ΔG in Table 2 increases, reaches a maximum at Ch. 3851.7 m (i.e., 83 mV), and then decreases. The calculated %IR is 23.2%, which would correspond to a minor DCVG indication, if the gradient shift is attributed to a coating holiday.

The OFF potential increases to -1107 mV, compared to -1070 to -1090 mV levels adjacent to the peak, pointing to a magnesium anode.

However, the relatively new (i.e. 1993), well coated pipeline is fully protected by the impressed current system and no magnesium anodes were ever reported to be installed along the line.

In order to reconcile this discrepancy between the pre-assessment data and the results of the indirect inspection, the data analysis was extended to include the actual recorded ON and OFF lateral gradients.

At Ch. 3851.7 m, the gradient ON is 66.1 mV, indicating significant current pick-up, while the gradient OFF is -16.9 mV indicating significantly lower current discharge.

Both, a magnesium anode and the pipe at a coating holiday may pick-up current during the ON cycle, but a magnesium anode would pick-up less current than a holiday, due to the potential barrier created by its high open circuit potential.

Similarly, both a magnesium anode and a well-protected pipe may discharge current during the OFF cycle, but the current generated by the anode will be higher than the equalization current discharged by the pipe, due to higher driving voltage.

Finally, significant pick-up current at a holiday will result in high polarization level and subsequently in OFF potential peaks, which could exceed the peaks created by partially depleted magnesium anodes and result in equalization current during the OFF cycle.

With a high ON gradient and a significantly lower OFF potential, and considering that no anodes were installed according to the pre-assessment data, the gradient shift at Ch. 3851.7 m was attributed to an "anode shaped" holiday.

As a final validation, the ON and OFF gradients were compared with those of a typical active magnesium anode (Figure 3) and of a depleted anode (Figure 4). The results are shown in Table 3.

Table 3
Comparison between ON and OFF Gradients of Holidays vs Mg Anodes

Feature	Lateral Gradient (G) @ 3m (mV)			%IR
	ON	OFF	ΔΓ	
Magnesium Anode	34.4	-82.7	117.1	41.50%
Old Magnesium Anode	19.9	-12.1	32	9.40%
Coating Holiday	66.1	-16.9	83	23.20%

The high positive ON gradient in conjunction with a low negative OFF gradient of the coating holiday are obvious versus the low positive ON gradient in conjunction with a high negative OFF gradient of an active magnesium anode; however, as expected, the difference is less evident for old magnesium anodes.

"THREAT RELATED" VERSUS "TOOL RELATED" ECDA INDICATIONS

Today, practice in the ECDA process is to identify "tool related" indications. A pipeline may display CIPS indications, DC voltage gradient (DCVG) indications, AC voltage gradient (ACVG) indications, etc. To avoid "double dipping" (i.e. having both indirect inspection tools pointing to the same indication), the NACE SP0502-2010[2] requires that indications must be provided by complementary tools. For example an ECDA process cannot rely only on DCVG and ACVG surveys, which are expected to provide the same data.

The problem is that some indirect inspection tools may provide several types of information. For example: the CIPS is the only tool allowing the protection level to be assessed, but it also may provide valuable data regarding the presence and size of a holiday and the risk of DC interference. As such, when using the term “CIPS” indication (a “tool related” indication), the operator should keep in mind that a low (i.e., electropositive) potential is a “protection level-threat related” indication, a drop in potential could be a “coating holiday - threat related” indication and a low or reversed ON-OFF potential shift is a “DC interference – threat related” indication.

The following example shown in a previous paper[3] demonstrates how a DCVG indication could be identified from CIPS data, which could result in a “double dipping” situation.

Figure 7 shows the results from an integrated CIPS/DCVG survey in southern Ontario.

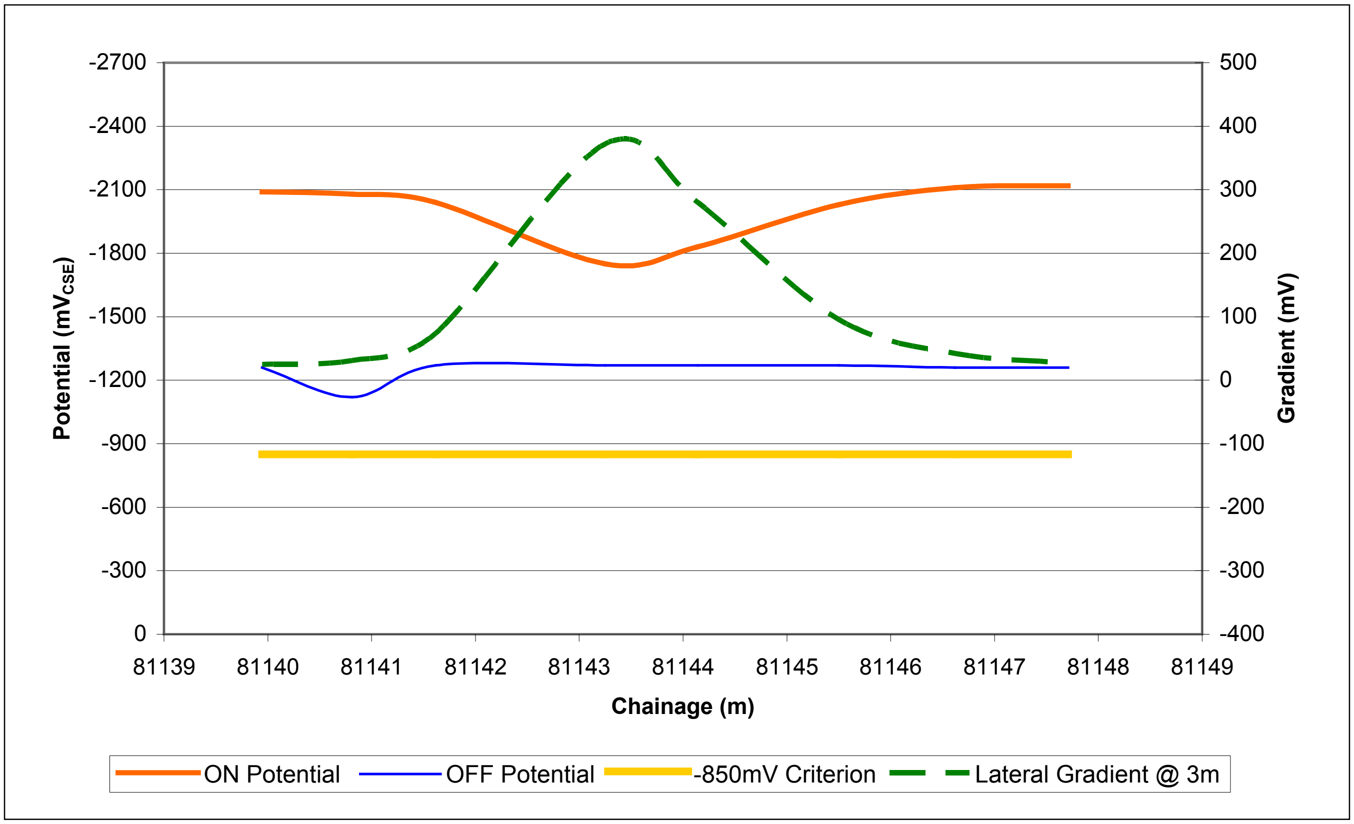

Figure 7: NPS 16 Pipeline. Ch. 81139 m to Ch. 81149 m. CIPS/DCVG Data

Figure 8 shows the same measured lateral DCVG profile versus the calculated DCVG longitudinal profile. The DCVG longitudinal profile was obtained from the pipe-to-soil potential data plotted in Figure 7, by assuming that the longitudinal gradient between two points on the pipeline equals the difference between the two pipe-to-soil potentials.

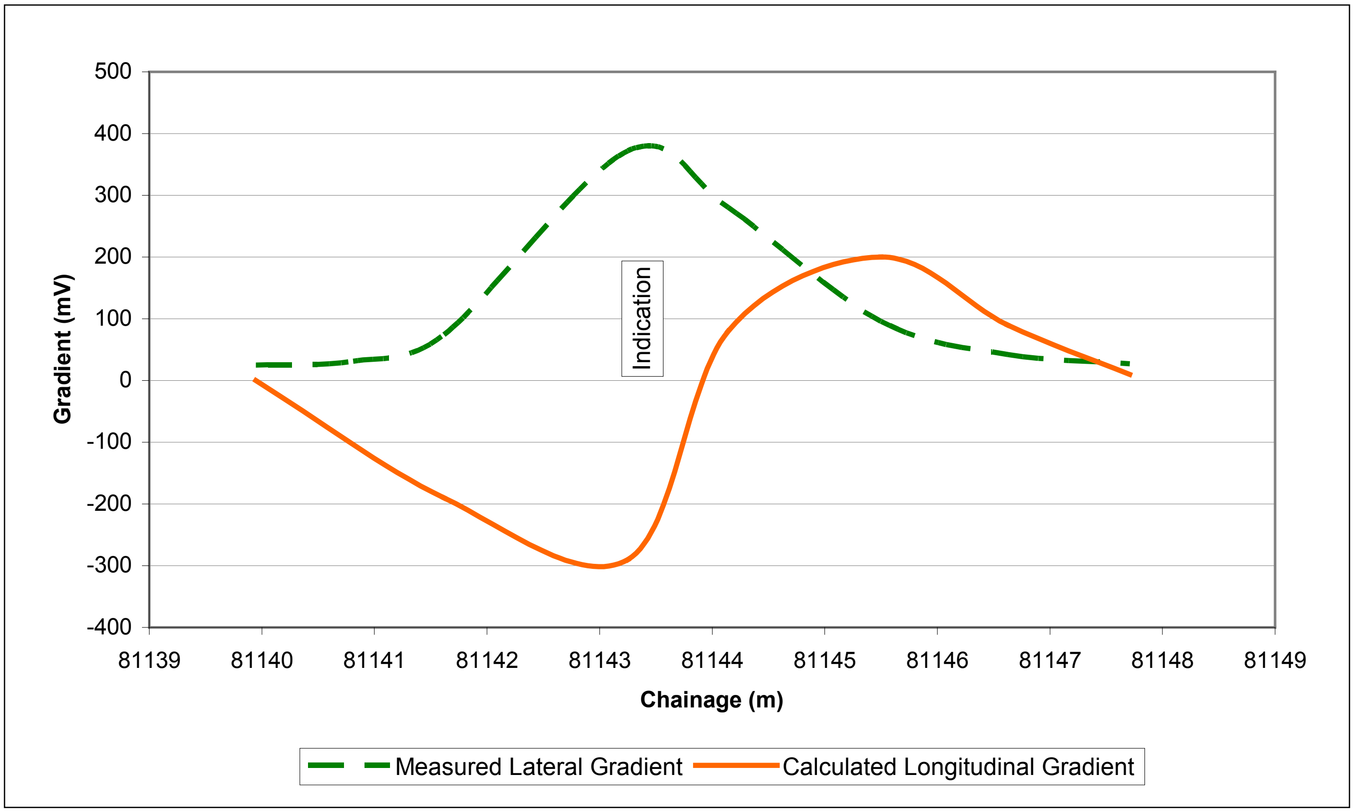

Figure 8: NPS 16 Pipeline. DCVG Indication Identified from CIPS Data

Both profiles identify the same holiday.

In a very possible scenario, a large holiday in a protected area would be classified as a “severe” CIPS indication based on the sharp drop in potential and also as a “severe” DCVG indication, based on the measured gradient. Subsequently, the two severe indications would have to be prioritized as “Immediate Action Required” requiring direct examination, although the line is fully protected and no corrosion is expected.

To avoid this type of “double dipping” only the DCVG indication should be prioritized. The drop in potential displayed in the CIPS profile should be seen as a confirmation of the presence of a holiday and not an independent CIPS indication.

CONCLUSIONS

Three cases were presented in this paper dealing with new and old challenges in the interpretation of the indirect data.

In the first case, measuring the lateral gradient on the two sides of the pipeline at all possible indications allowed attributing a coating holiday to the appropriate pipeline, when surveying bonded pipelines along a common right-of-way. Positive gradient shifts indicate more electronegative soil potentials above the pipe (i.e., current flowing towards the pipe), while negative gradient shifts indicate more electronegative lateral soil potentials (i.e., current flowing away from the pipe). Subsequently, positive gradients on one side of the line in conjunction with negative gradients on the other side indicate that the current just crosses the pipeline going to a holiday on the adjacent line.

In the second case, analyzing both the ON and OFF lateral gradients at possible indications allowed differentiating between active magnesium anodes and coating holidays. High positive ON gradients in conjunction with lower negative OFF gradients indicate a well-protected coating holiday, picking up significant current during the ON cycle and discharging relatively low equalization current during the OFF cycle. Low positive ON gradients in conjunction with high negative OFF gradients indicate an active magnesium anode, picking up low current during the ON cycle due to its high open circuit potential and discharging relatively high current during the OFF cycle, due to high driving voltage.

The third case, discussed in a previous presentation, developed a possible error scenario based on actual survey data. The common practice of identifying a sharp drop in potential as a CIPS indication may result in two indirect inspection tools (i.e., CIPS and DCVG) pointing to the same holiday defect indication. Subsequently, a severe coating defect in a well-protected area could be erroneously prioritized as "Immediate action required". To avoid this type of "double dipping" we recommend that only the DCVG indication should be prioritized. The drop in potential displayed in the CIPS profile should be seen as a confirmation of the presence of a holiday and not an independent CIPS indication.

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