Paper No.
10061

NACE INTERNATIONAL CORROSION 2010 CONFERENCE & EXPO

ENSURING THE ACCURACY OF INDIRECT INSPECTIONS DATA IN THE ECDA PROCESS

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ABSTRACT

The quality of the indirect inspection data is a critical factor in conducting a successful ECDA program. New NACE standards (SP0207-2007[1] and TM 0109-09[2]), improved instrumentation, experience sharing, and extensive training during the last several years, has resulted in a significant improvement in the accuracy of the survey data.

This paper covers a number of lessons learned by dealing with less-known sources of measurement error, during six years of ECDA application on more than 50 gas pipelines in Ontario.

Topics addressed include a discussion of errors;

- generated by rectifying elements in current interrupters,
- caused by the influence of remote rectifiers,
- introduced by local changes in soil resistivity during the DC Voltage Gradient Survey, and
- produced by transient currents during the Close Interval Potential Survey.

Keywords: ECDA, CIPS, DCVG, HVAC powerlines, influence survey, transient currents.

INTRODUCTION

The quality of the indirect inspection data is a critical factor 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. A huge effort has been invested by the NACE community during the last few years to improve the process. New NACE standards (SP0207- 2007[1] and TM 0109-09[2]) were issued and large scale experience sharing has occurred via NACE symposia, seminars and technical exchange groups.

This paper covers a number of lessons learned, by Union Gas Limited (UGL)[(1)] and Corrosion Service Company Limited (CSCL)[(2)], in dealing with less-known sources of measurement error during six years of ECDA application on more than 50 gas pipelines in Ontario. One other source of error from an unrelated project is included, as it could impact on future ECDA work.

Each source of error is presented as a specific survey case, complete with recommendations for minimizing or even nullifying the error.

ERRORS DUE TO RECTIFYING ELEMENTS IN CURRENT INTERRUPTERS

A close interval survey was conducted in 2005 on a 219 mm (8") dia. natural gas lateral running in parallel with an HVAC powerline in eastern Ontario. The pipeline was protected by groups of magnesium anodes, which were also being used to mitigate the AC induced voltages on the pipeline. The survey was coordinated with the annual CIPS on the transmission pipeline which fed the lateral and which was owned and operated by a different company. An interrupter was installed at each magnesium anode group and synchronized with those installed on the foreign influencing rectifiers on the transmission pipeline. For future reference, the DC current at each anode group was measured before installing the interrupters. Data loggers were installed at remote test posts to collect data for use in compensating for any telluric activity. The interrupter in the first anode group was activated and an electropositive shift of 600 mV was measured, as shown in Figure 1.

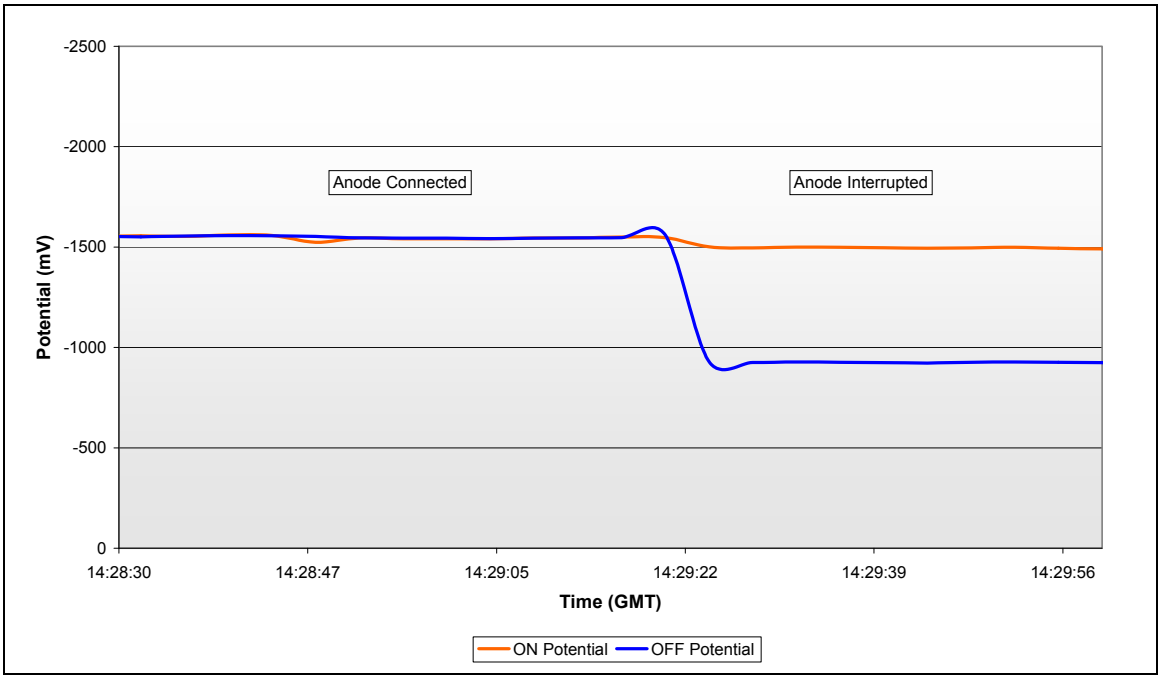

FIGURE 1 • 219 mm (8") Dia Line. Recorded ON/OFF Shift with Mg Anodes Interrupted

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The anode current measured before activating the interrupter was only 5 mA, but was 600mA with the interrupter connected. The interrupter was then disconnected and reconnected with the lead wires reversed. The OFF potential shifted to -2000 mV_{CSE} (see Figure 2) and the current remained at 600mA, but with reversed direction.

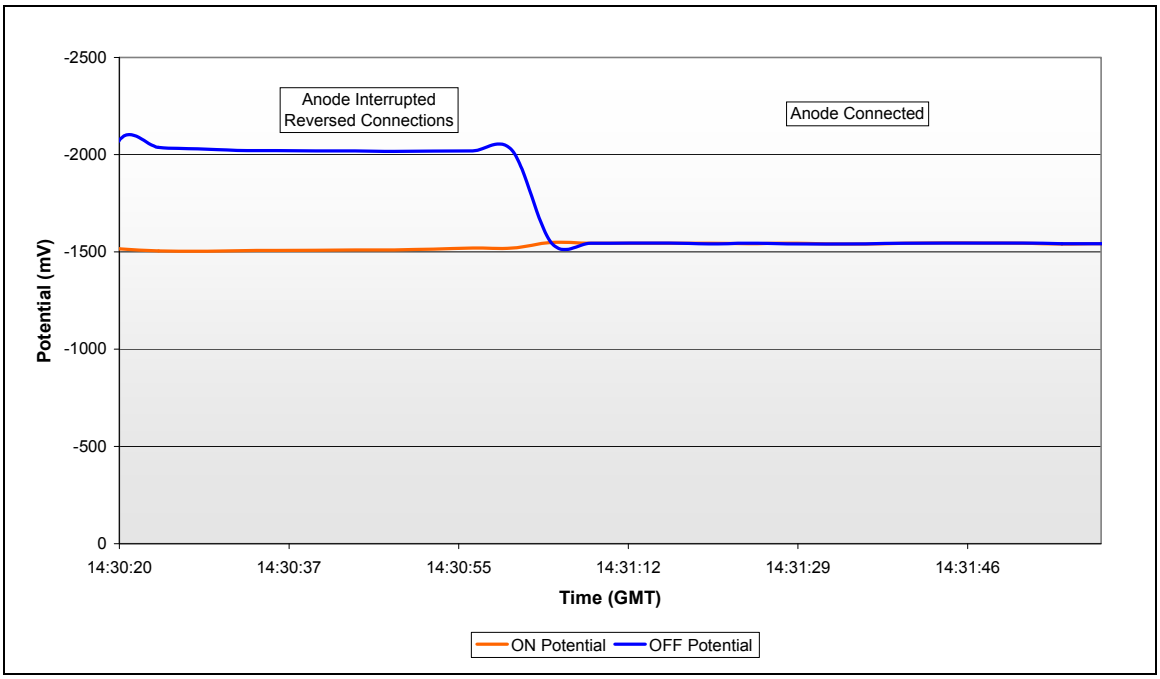

FIGURE 2 • 219 mm (8") Dia Line. Recorded ON/OFF Shift with Mg Anodes Interrupted and Wiring Reversed

It was then decided to remove the interrupters and to use a different identification criterion for CIPS indications (i.e. -1000 mV_{CSE}, with influencing rectifiers OFF and magnesium anodes connected).

A subsequent in-depth analysis of the phenomenon indicated that the protection diodes in the interrupter were rectifying the AC induced voltages, which reached values around 14V. The rectified AC voltage added or subtracted 600 mV from the actual pipe-to-soil potentials, depending on how the interrupter leads were connected inside the test post.

Therefore, when interrupting groups of anodes on pipelines subject to high induced voltages, it is recommended that the anode currents be measured to ascertain whether or not there is any variation when the interrupter is inserted into the circuit. If the current varies significantly, the survey must be conducted with the anodes connected and the identification and classification criteria modified accordingly.

ERRORS DUE TO INFLUENCE OF REMOTE RECTIFIERS

An ECDA procedure was conducted on a section of a 168 mm (6") dia. pipeline in southern Ontario. According to the pre-assessment data, the ECDA segment was cathodically protected by a dedicated rectifier (i.e. R#1) installed approximately two km east of a Transmission Station (see Figure 3).

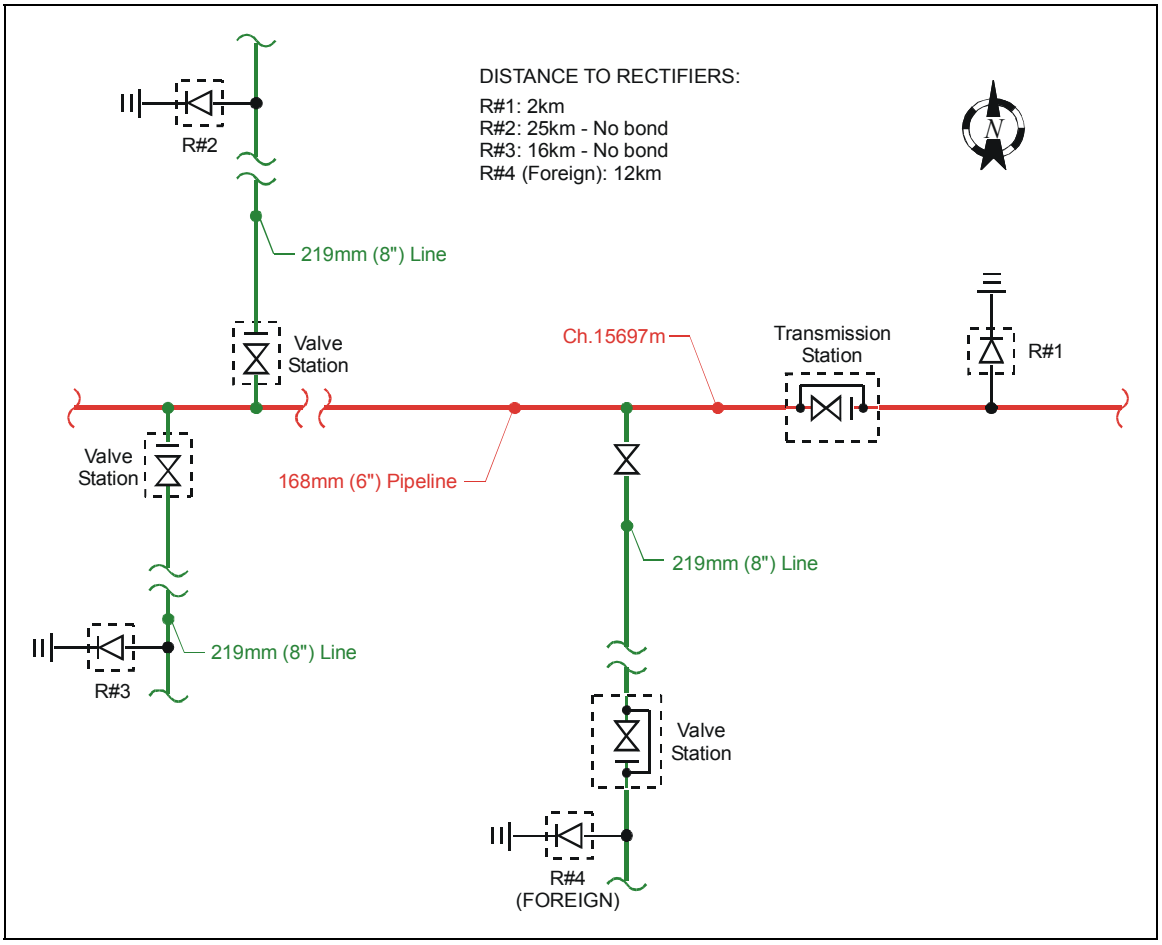

FIGURE 3 • 168 mm (6") Dia Gas Line. CP System Configuration

It was estimated that the pipe potentials might be influenced by several other rectifiers installed either remote from the segment or on other electrically isolated lines (i.e. R#2, R#3 and R#4).

The CIPS was conducted with all influencing rectifiers interrupted simultaneously and the results indicated diminishing shifts close to the transmission station (Figure 4).

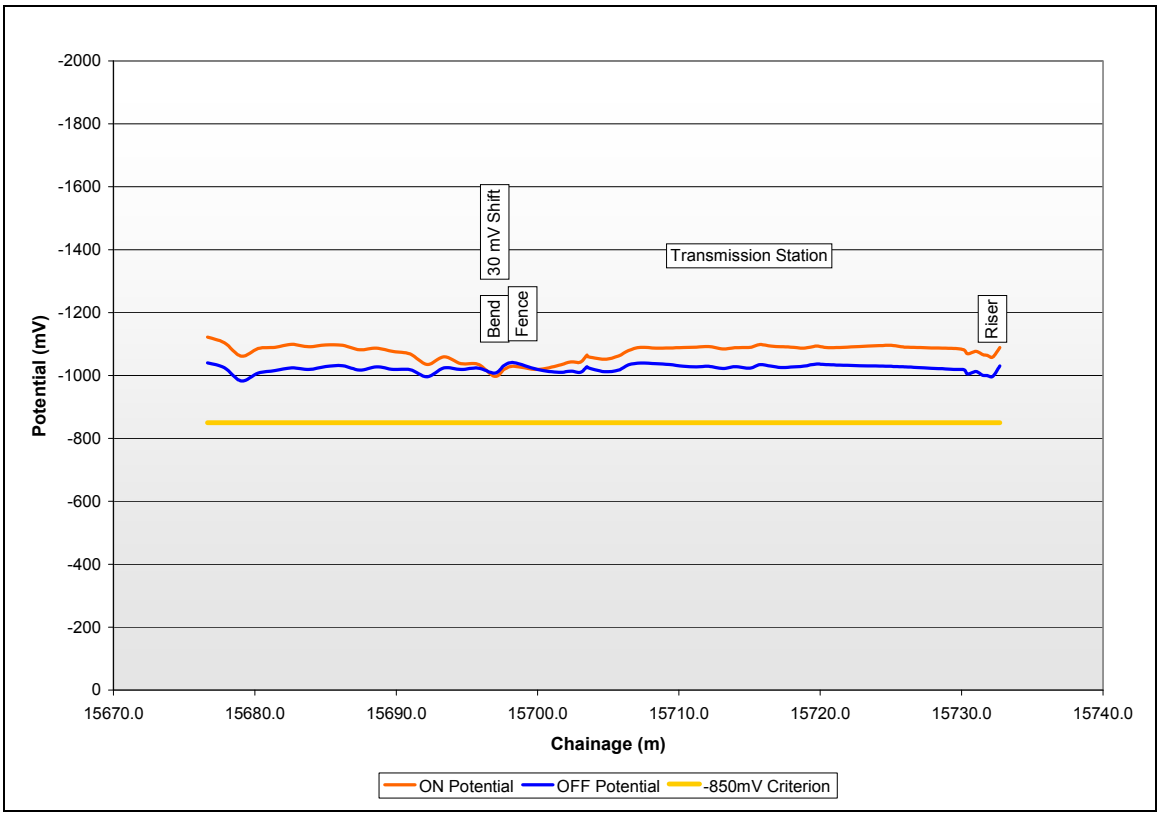

FIGURE 4 • 168 mm (6") Dia Gas Line. CIPS Data

To further evaluate this situation, a rectifier influence survey was conducted specifically at chainage 15697m by recording the ON/OFF pipe-to-soil potential shift. Initially, all influencing rectifiers were interrupted simultaneously. Then each rectifier was left ON for several minutes and turned OFF for several minutes, while the other rectifiers continued to be interrupted synchronously. The exact timing of each operation was recorded and then identified on the chart. The results are shown in Figure 5 and Figure 6.

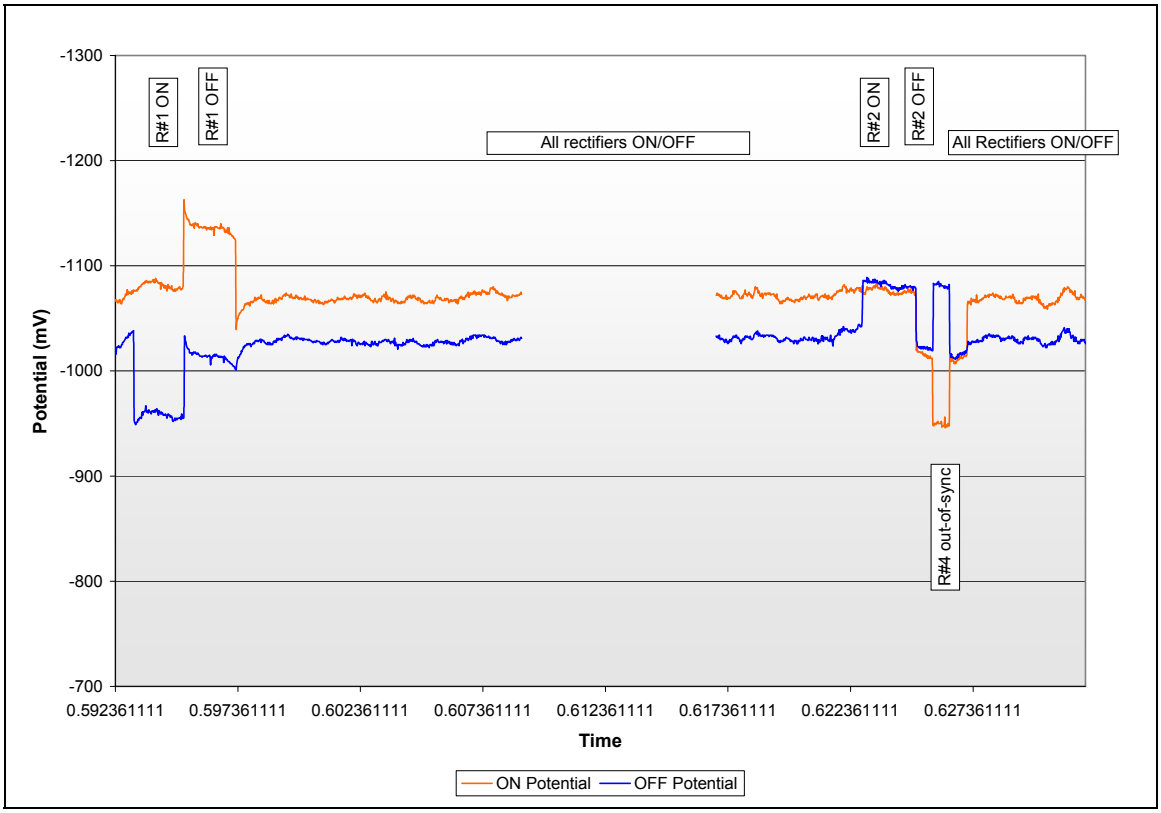

FIGURE 5 • 168 mm (6") Dia Gas Line. Chainage 15697. Influence of R#1 and R#2

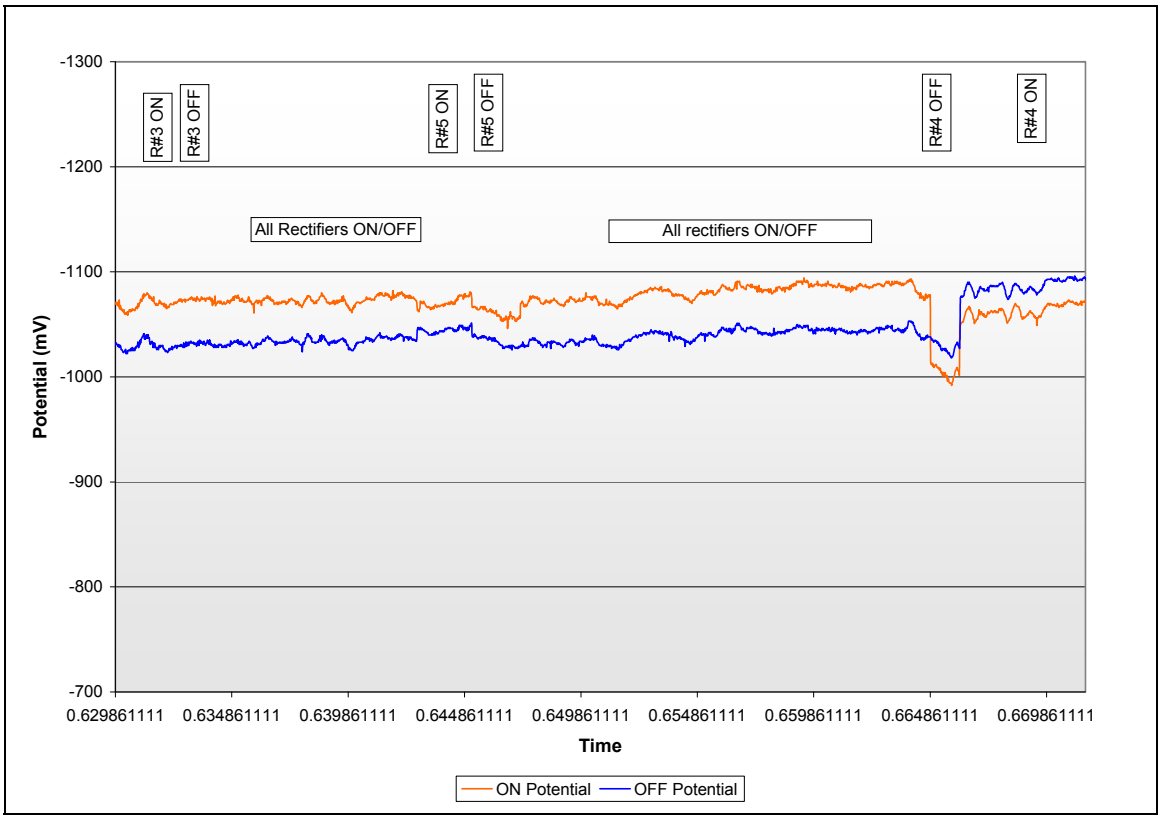

FIGURE 6 • 168 mm (6") Dia Gas Line. Chainage 15697. Influence of R#3, R#4 and R#5

The results (see Figure 7) indicated that the dedicated rectifier R#1 actually produced a 90 mV electropositive shift caused by a failed bond. This reverse shift was being compensated by electronegative shifts produced by three remote rectifiers (i.e. 40 mV by R#2, 10 mV by R#3 and 70 mV by the foreign rectifier R#4), resulting in an apparently normal ON/OFF shift of approximately 30 mV.

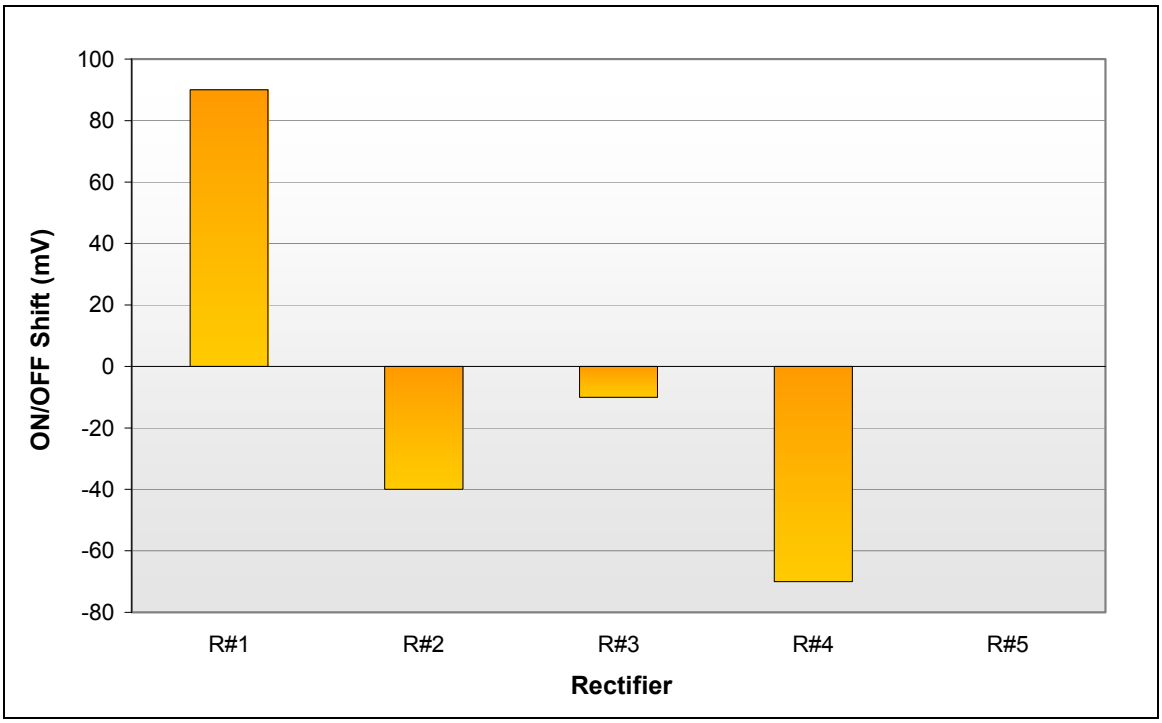

FIGURE 7 • 168 mm (6") Dia Gas Line. Chainage 15697. Contribution of Various Rectifiers

When the bond was repaired, the line was re-surveyed and it displayed normal shifts along the entire length.

The lesson to be learned again and again is that influencing rectifiers can be located tens of kilometers from the surveyed area and all efforts must be made to ensure that the line is “clean” by recording wave-forms during the OFF cycle, identifying rectifier fingerprints by frequency analysis, measuring lateral gradients, and finally using common sense.

ERRORS DUE TO LOCAL SOIL RESISTIVITY CHANGES

The relevant survey situation occurred on a 219 mm (8") dia. pipeline in Northern Ontario. An integrated CIPS/DCVG survey was conducted along the line and the %IR was calculated using the method described in a previous paper[3], which was based on a lateral gradient measured at 3 m distance and the pipe-to-soil potentials measured above the pipe.

As the survey progressed in a rocky area, the pipe-to-soil potential ON/OFF shifts dropped below 20 mV and the calculated %IR reached values close to 90% (see chainage 1100m on Figure 8).

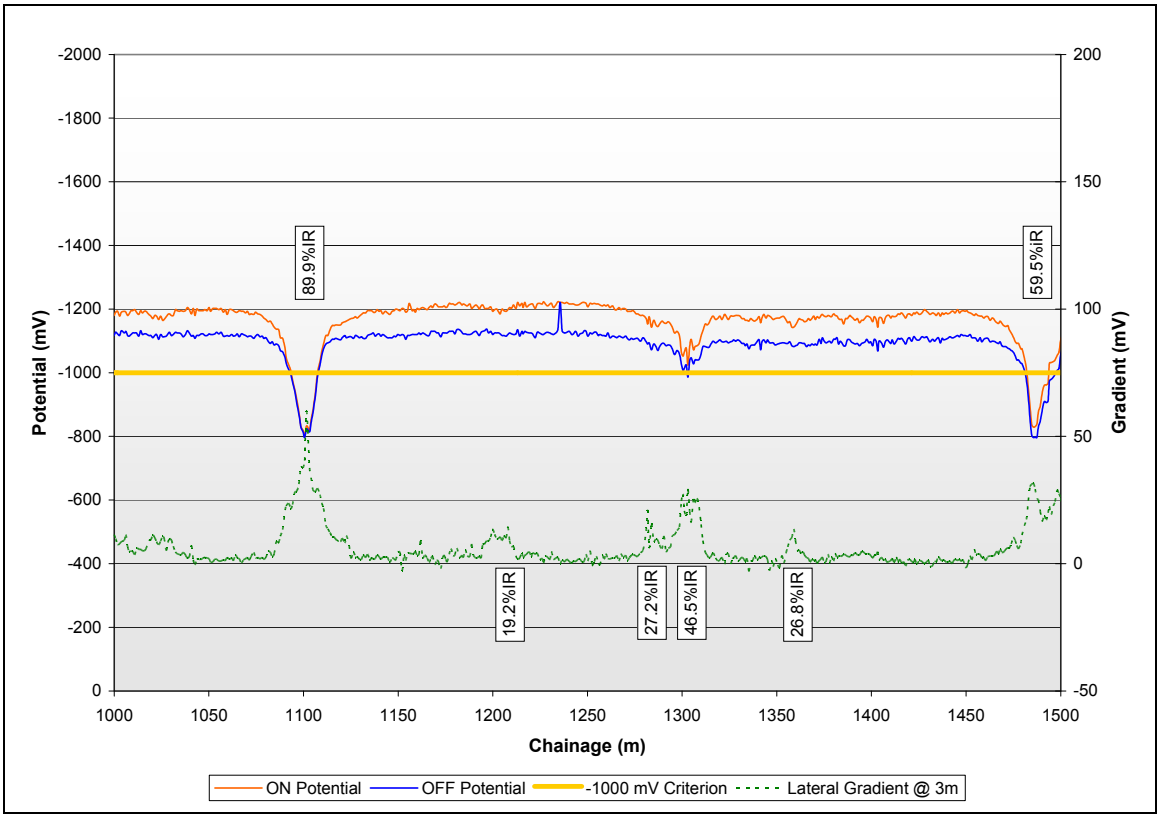

FIGURE 8 • CIPS/DCVG Profile in High Resistivity Area

Although the calculation method had previously been tested in the field during six years of ECDA applications and had been found to give excellent results, it was never used where such small potential shifts were encountered. Installing a temporary groundbed to increase the shifts was not an option, since the high anodic gradients would have obscured the detection of the smaller gradients produced by the coating holidays.

Subsequently, it was decided to validate the calculation method by actually measuring the lateral gradient and the total potential shift with respect to remote earth at two DCVG indications (i.e. chainage 1101.6 m and chainage 1485.7 m). The exact value of the %IR was then calculated using the fundamental equation:

$$\%IR = \frac{\Delta G_{OL-RE}}{\Delta V_{RE}} \tag{1}$$

where:

ΔG_{OL-RE} = Lateral gradient shift measured to remote earth

ΔV_{RE} = Pipe-to-soil potential shift measured to remote earth

The results, shown in Table 1, confirmed the validity of the %IR calculations with small potential shifts in high resistivity soil conditions.

TABLE 1 • Validation of %IR Calculations in High Resistivity Soil

Chainage (m)	ΔV_{RE} (mV)	ΔG_{RE} (mV)	%IR	
			Measured	Calculated
1101.6	123	117	95%	89.9%
1485.7	103	65	63%	59.5%

Using the regular practice of interpolating pipe-to-soil potentials measured to remote earth at adjacent test posts would have resulted in completely erroneous values, since the closest test posts were located in relatively low resistivity areas where the pipe-to-soil potential shifts were 230 mV up-stream and 136 mV down-stream.

A direct examination conducted at chainage 1101.6 m confirmed the extended damage to the coating, as shown in the coating inspection map of Figure 9 and the site photo (Figure 10).

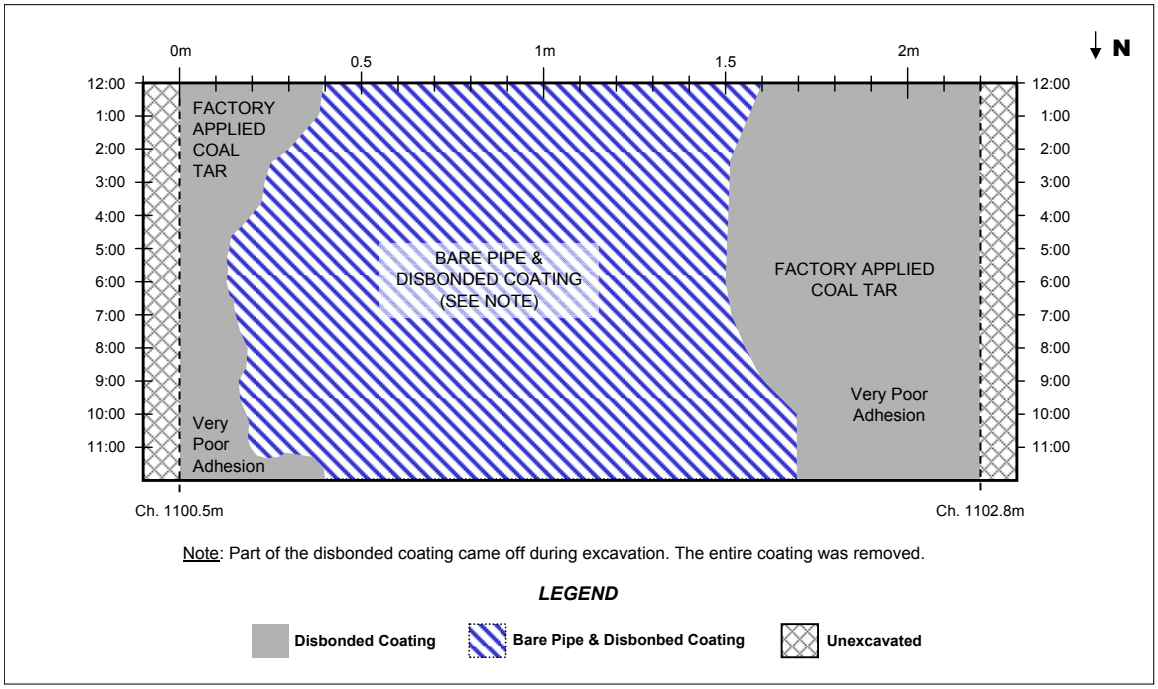

FIGURE 9 • Ch. 1101.6 m. Coating Inspection Map

FIGURE 10 • Ch. 1101.6. Coating Damage

To avoid errors in interpolating pipe-to-soil potentials measured to remote earth at test posts installed in areas with different soil conditions, it is recommended to either measure the value locally or use a calculation method which accounts for the local conditions.

However, an interesting question is: “Does avoiding an error in estimating the %IR under such unusual conditions justify the extra effort of taking direct potential measurements to remote earth at each suspect location or using a different survey method, such as that proposed by the authors?”.

Although it is difficult to estimate the possible consequences of such error, the findings of a recent ECDA survey on a 114 mm (4") dia. pipeline in Northern Ontario cannot be ignored.

This survey displayed a severe DCVG indication at chainage 2382.2 m (i.e. 61.4%IR) recorded with a relatively low potential shift (i.e. 89 mV) in conjunction with a severe CIPS indication (-577 mV_{CSE}), as shown in Figure 11. This location was selected for direct examination.

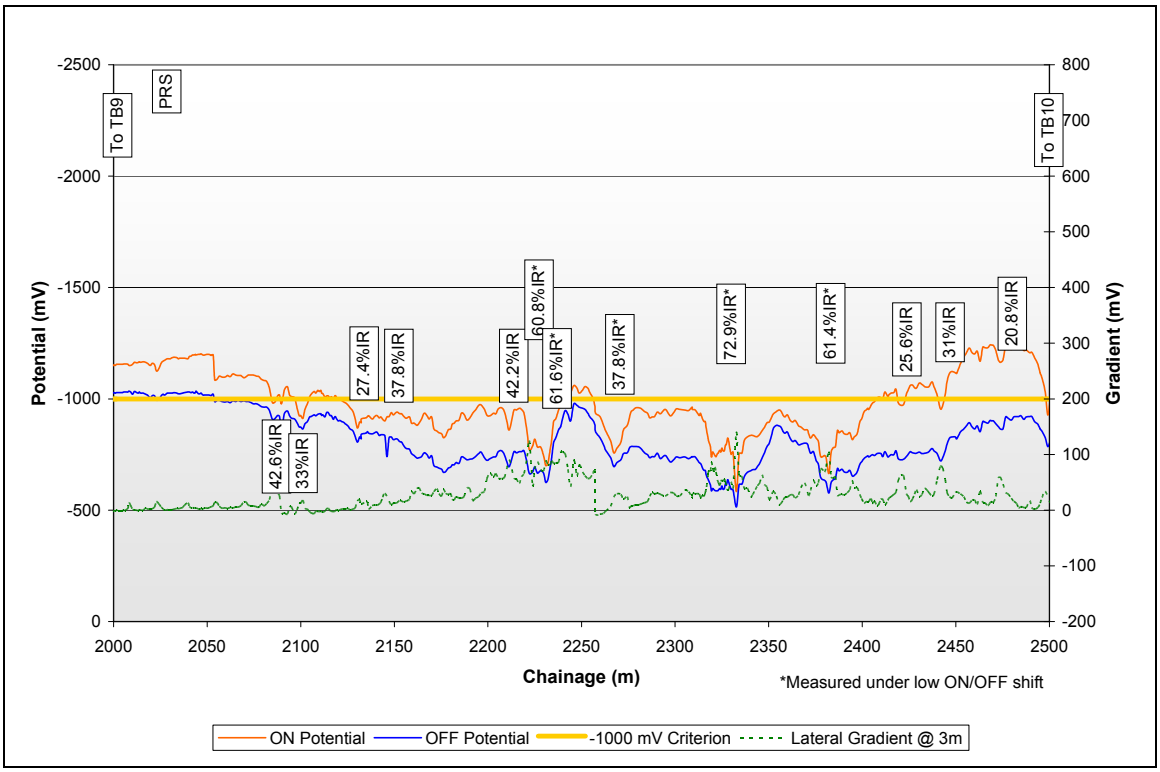

FIGURE 11 • 114 mm (4") Lateral. Ch. 2000 to 2500m. CIPS/DCVG Profile

Less than 100 m down-stream, the potential shift increased from 89 mV to 299 mV and interpolation of the data may have downgraded the indication to moderate or even minor. The 12.3 km long pipeline displayed more than 250 DCVG indications with extended areas having very low protection levels. Twenty-one indications were prioritized as “Immediate Action Required” and seventy-nine indications were prioritized as “Scheduled Action Required”. If this indication had been classified as moderate or minor, it almost certainly would not have been included in the list of direct examinations.

The direct examination was performed on July 24, 2009. The pipe condition after coating removal is shown in Figure 12.

FIGURE 12 • 114 mm (4") Lateral. Direct Examination. Pipe Condition

The deepest pit was 71% through wall.

This project is still underway, with more direct examinations to be performed and probably more lessons to be learned. The authors hope to discuss in detail the complete findings of this project in a future paper. The preliminary results (i.e. severe pitting on a large poorly coated area of unprotected pipe in a high resistivity rocky area) appear to reinforce the very conservative approach of NACE standard[4] SP0502-2008, which requires prioritizing severe CIPS indications in conjunction with severe DCVG indications as “Immediate Action Required”, even in high resistivity, aerated soil conditions.

ERRORS DUE TO TRANSIENT CURRENTS

This situation is unrelated to an actual ECDA project, but could occur on pipelines that have been selected for the ECDA program. Several companies expressed concern regarding highly electronegative instant OFF potentials measured on pipelines running in parallel with high voltage powerlines and equipped with DC decouplers. The authors would like to thank Dairyland Electrical Industries Inc.([3]) for granting permission to publish the preliminary results of the study conducted to analyze this topic.

A coated pipeline behaves as an R-C circuit and therefore transient currents can appear during the interruption cycle. The duration of the transient current is normally very short since the capacitance of the coated pipe is relatively low. Data loggers used today in CIPS surveys allow a sufficient measurement delay for the corresponding transient potential spike to dissipate.

When the capacitance and the resistance of the circuit increase significantly (i.e. when a DC decoupler and a grounding electrode are added into the pipeline-ground circuit), the time constant of the circuit (i.e. $\tau = RC$) and subsequently the duration of the transient potential increases accordingly.

(3) Dairyland Electrical Industries Inc., P.O. Box 187, Stoughton, WI 53589.

Figure 13 shows two waveforms recorded at a valve station during the interruption cycle; one with the decoupler disconnected (i.e. normal interruption) and the second with the decoupler connected.

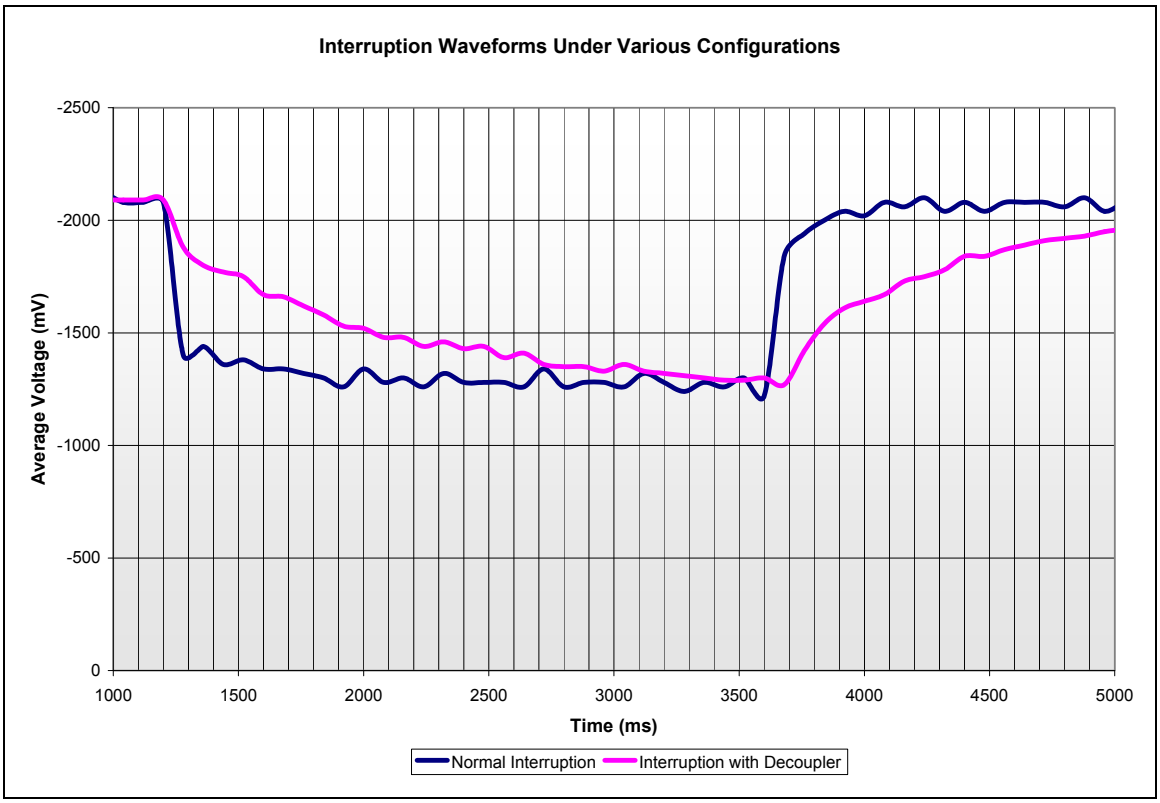

FIGURE 13 • Variation of Pipe-to-Soil Potential during the OFF Cycle

When the OFF potential is recorded 300 ms after interruption (i.e. at t = 1500 ms), the potential with the decoupler connected is approximately -1750 mV_{CSE}, while the "true" potential measured without decoupler connected is only around -1350 mV_{CSE}. When the pipe potential is measured after approximately 2 s (i.e. at t = 3200 ms), the error introduced by the transient current in the R-C circuit is negligible.

It is therefore recommended that the required delay time to minimize the transient error be determined prior to commencing with a CIPS survey and that the data loggers be adjusted accordingly. If the interruption cycle becomes unrealistically long, especially for a close interval survey, it is recommended that cathodic protection coupons be installed at the test stations.

Besides DC decouplers, electrolytic cells, and rectifier capacitors used to minimize the voltage ripple, are also expected to generate similar transient potential measurement errors.

CONCLUSIONS

The ECDA program is not only a continuously improving process, as required by paragraph 6.5 of NACE Standard SP0502-2008[4], but also a continuing learning process for the involved consultants and pipeline operators. The best survey procedures, such as those recommended in NACE standards SP0207-2007[1] and TM 0109-09[2] cannot address all the site specific issues.

Two cases were presented where extreme variations in soil resistivity were successfully addressed using an integrated CIPS/DCVG survey and the calculation method described by the authors in a previous paper[3]. Under the same conditions, the normal practice of interpolating pipe-to-soil potentials measured to remote earth at adjacent test posts would have resulted in significant errors. With one of

the two sites displaying a pit 71% through wall, it is important to address these specific situations with extra caution, either by directly measuring the pipe-to-soil potential to remote earth at the DCVG indication or using an integrated CIPS/DCVG survey and the associated calculations.

Other sources of error, such as influence of remote rectifiers, transient effects, and rectification of AC induced voltages, could affect the accuracy of the close interval surveys. Recommendations were made to identify and mitigate these sources of error.

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