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BUSINESS AS USUAL?
CORROSION IN A CIRCULAR ECONOMY

The Lost Art of Telluric Compensation

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ABSTRACT

Techniques for telluric compensation of close-interval potential survey (CIPS) data have been known and used in the pipeline industry for many years. However, the effectiveness of telluric compensation performed during periods of significant geomagnetic activity has resulted in data validity being questioned. In particular cases, survey crews have refrained from data collection during periods of high telluric activity at operators' request. This paper reviews the theory and basic techniques for telluric compensation.

The value of telluric compensation is discussed with reference to the results of a recent survey in Northern Alberta that was subject to significant telluric effects. The practical benefits are described, including reduced field exposure time, reduced time to complete surveys, and increased data reliability. Challenges of using telluric compensation are also described, and recommendations are made for applying effective telluric compensation to future surveys.

Key words: close-interval potential survey (CIPS), data integrity, stray current compensation, telluric compensation.

INTRODUCTION & HISTORY

Geomagnetic activity in the form of telluric currents can result in significant fluctuations in structure-to-electrolyte potential measurements. The mechanism of interaction between telluric currents and pipelines is similar to the interaction between high-voltage AC powerlines and pipelines.[1,2] However, because the frequencies involved are much lower, the measured DC potentials are directly affected.[3]

The need to compensate potentials for telluric effects has been known in the industry for many years, with practical compensation being attempted as early as 1979 in Alaska.[4] In Canada, telluric compensation techniques have been in use since at least 2000 by TransCanada Pipelines[5], and Enbridge was involved with a project to better understand telluric effects on pipelines in 2001 or earlier.[1] Both Place & Sneath and Nicholson have published practical techniques for telluric compensation.[5,6] The latest versions of relevant NACE standards recognize the existence of telluric compensation techniques, but do not provide details.[7,3]

Despite this long history, there is not currently widespread use of these techniques in the corrosion industry in Canada. Anecdotally, there are operators which specify that surveys must not be performed when telluric activity exceeds some thresholds, and contractors have generally not pushed-back on these requirements. This paper lays out clearly the mathematical principles and basic compensation technique and weighs the advantages and disadvantages of making use of telluric compensation.

COMPENSATION APPROACH

A close-interval potential survey (CIPS) consists of measured potentials that are inherently a function of position along the pipeline. In the presence of telluric effects, the potentials are also a function of time. The desired outcome, however, is a representative potential which is a function of position but not time. If the time-dependent component cannot be eliminated, then at any given position, the potential will include an unknown, time-varying error. Depending on the magnitude of this time-varying error and the rate of change of this factor, determining both general protection levels and the presence/absence of localized lows may not be possible.

Although the mechanism which results in fluctuating pipe-to-soil potentials is complex and modelling these effects would be difficult even if all the parameters were known, the local effect on potentials along the pipeline can be effectively estimated using measurements at fixed locations.

CALCULATION METHODOLOGY

This situation can be expressed more formally as follows. The actual measured potential $V(x,t)$ can be expressed as:

$$V(x,t) = V(x) + v(x,t) \quad \text{Eq. 1}$$

Where:

$V(x)$ = non time-varying true (or representative) pipe-to-soil potential at position *x*

$v(x,t)$ = time-varying component, in this case resulting from telluric fluctuations

x = position/chainage along the pipeline

t = time

$V(x)$ is assumed to be the potential which would exist in the absence of short-term telluric effects. Although in general $V(x)$ may also vary with seasonal conditions, on a short time scale it is assumed that a true potential exists. Note that this formulation is applicable to both the ON and OFF potentials, so the following derivation applies to both $V_{\mathrm{ON}}(x,t)$ and $V_{\mathrm{OFF}}(x,t)$.

For the analysis, it is assumed that telluric currents affect short segments of pipeline in similar ways; this assumption is true for many practical cases. That is, for a section of pipeline with similar characteristics, particularly geometry (e.g. running north-south without bends) and coating/loss characteristics (e.g. line pipe vs. stations), $v(x,t)$ along that section can be assumed to vary in similar ways. Thus, for an upstream location X_U and a downstream location X_D along the short section with $X_U \le x \le X_D$:

$$v(x,t) = k_1(x) \cdot v(X_D,t) + k_2(x) \cdot v(X_U,t) \qquad \text{Eq. 2}$$

with $k_1(x)$ and $k_2(x)$ varying along the section. Assuming a simple linear variation along the section between X_U and X_D, this relationship becomes:

$$v(x,t) = \frac{(x-X_U)}{X_D-X_U} v(X_D,t) + \frac{(X_D-x)}{X_D-X_U} v(X_U,t) \qquad \text{Eq. 3}$$

This formulation is expected to be given in an appendix of the forthcoming NACE TM0497 and implicitly relies on the stated assumptions; these are generally valid for straight sections of pipeline without appurtenances and closely-spaced test posts. The upstream and downstream locations X_U and X_D should not be at valve sites and should be chosen along the same straight section of pipe as the survey, if possible.

In most cases, the effectiveness of the compensation (and thereby the suitability of the upstream and downstream locations) can be confirmed through visual inspection of the compensated data, although quantitative techniques can also be applied.

Note that dynamic stray compensation required due to transit system interference can use the same approach, but the spatial variation in $v(x,t)$ may be much larger, in some cases reducing the effectiveness of the simple linear formulation and generally requiring that X_U and X_D be located closer together. NACE SP0207-2007 recommends maximum intervals of 5 km for telluric current activity and 2 km for dynamic stray currents from DC traction systems in Sections 10.3.3 and 10.3.4.

To collect $v(X_D,t)$ and $v(X_U,t)$, dataloggers are installed upstream and downstream of the section being surveyed for the duration of the survey. So as not to bias the compensation with the actual potentials at these locations, the time-varying component needs to be extracted from the datalogger recordings, because the actual recorded value is $V(X,t)$, from Eq. 1. If it is assumed that the average value over the survey duration represents the true potential, that is $V(X) = \overline{V(X,t)}$, then:

$$v(X,t) = V(X,t) - \overline{V(X,t)} \qquad \text{Eq. 4}$$

The calculation of the average should be done with care so as not to introduce DC bias (e.g. due to rectifiers being left continuously ON overnight changing the recorded potentials). Nevertheless, in many cases the simplistic approach of using the average during the survey duration is sufficiently accurate.

The potentials $V(x,t)$ collected during the CIPS are then corrected for each *x* using Eq. 1 and Eq. 3 to obtain the true potentials $V(x)$ along the survey route:

$$V(x) = V(x,t) - \left[\frac{(x-X_U)}{X_D-X_U} v(X_D,t) + \frac{(X_D-x)}{X_D-X_U} v(X_U,t)\right] \quad \text{Eq. 5}$$

The corrected potentials can then be compared to industry standards and any other required analysis can be performed.

COMPENSATION EXAMPLE

An example of the raw survey data and compensated survey data is shown in Figure 1 below.

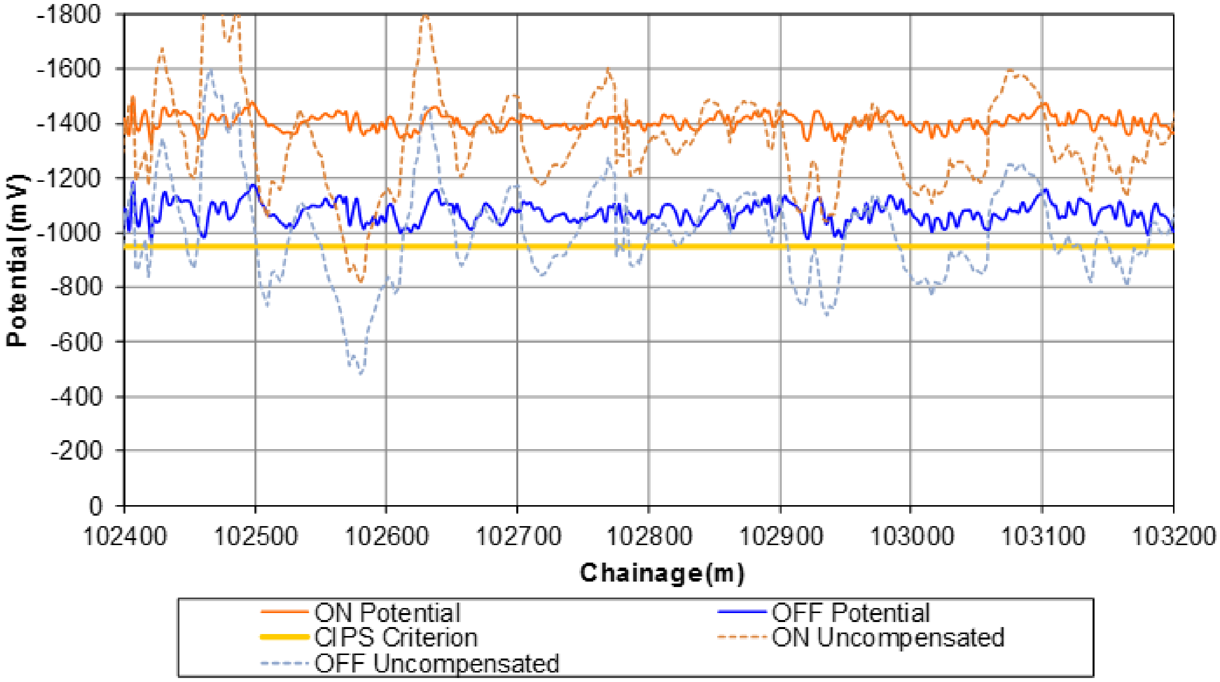

Figure 1: Uncompensated & Compensated Data During a Period of Telluric Activity

The telluric activity resulted in multiple sub-criterion excursions in the uncompensated data, with -501 mV_{CSE} being the most electropositive reading at chainage 102580 m. The profiles at several of the sub-criterion excursions could also conceivably be attributed to coating defects. Therefore, without compensation, the data is potentially very misleading and should not be used for pipeline integrity management efforts.

A sample of the upstream and downstream OFF potential data for the 5-minute period corresponding to chainages 102906 m to 103062 m is shown in Figure 2. The upstream potential variations exceeded 400 mV, with somewhat smaller potential variations observed at the downstream location.

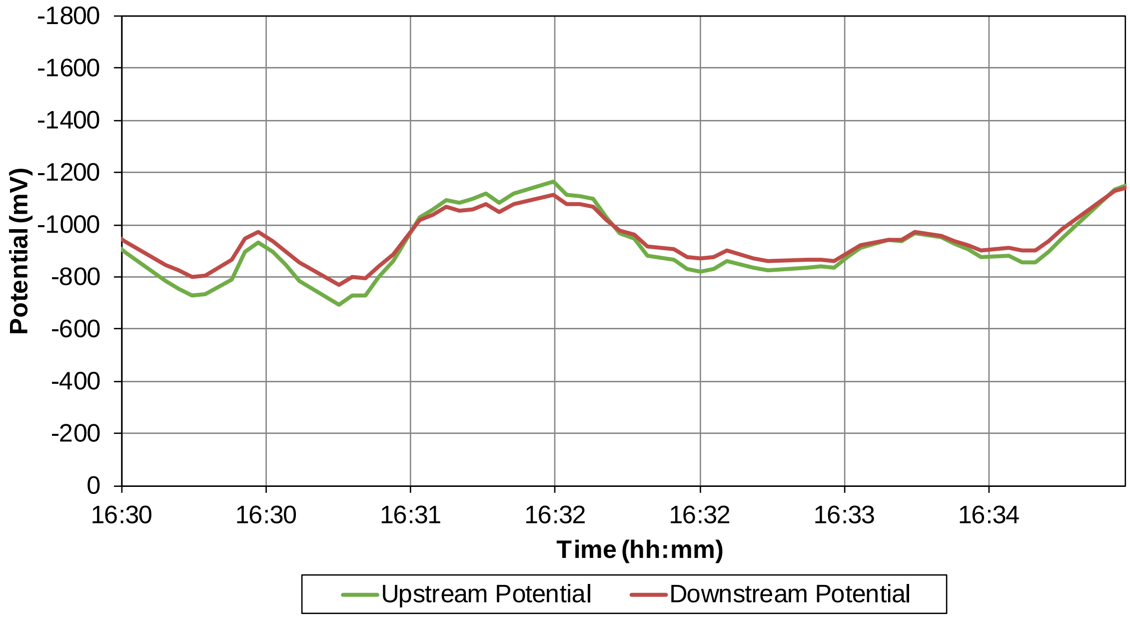

Figure 2: Potentials Recorded Upstream & Downstream of the Surveyed Section

The shape of the waveforms is quite similar, but the magnitude of variation differs, as does the absolute potential. The absolute potential, however, has minimal effect due to the subtraction of the local DC average.

These measurements were recorded during an “Active” period for the Sub-Auroral zone (see Figure 3 for the ranges) based on magnetic data from the Meanook observatory in central Alberta.

Short Term Hourly Range Activity Levels (nT)

Zone	Quiet	Unsettled	Active	Stormy	Major Storm
Polar Cap	0 - 50	50 - 100	100 - 180	180 - 600	600+
Auroral Zone	0 - 90	90 - 170	170 - 300	300 - 1000	1000+
Sub-Auroral Zone	0 - 30	30 - 50	50 - 90	90 - 300	300+

Figure 3: Activity Classifications for Polar Cap, Auroral and Sub-Auroral Zones[8]

FIELD EXPERIENCE

The compensation techniques described in the previous sections were applied to a CIPS performed on a 107 km-long pipeline segment running generally north-south in Northern Alberta. Telluric effects were a significant consideration because of the pipeline’s location and because the subject survey was a continuation (going north) of a previous survey which did not make use of telluric compensation techniques; portions of that survey were basically unusable.

The results shown in Figure 1 are an excerpt from this survey. As can be seen, even after compensation there were fluctuations of ±50 mV, but the compensated data was able to demonstrate conformance to the CIPS criterion at most locations along the survey. To meet this goal for the whole pipeline segment, initial data processing and compensation was performed daily. Whenever there was uncertainty regarding the effectiveness of the compensation or validity of sub-criterion readings, resurveys were performed. Re-mobilization was not required because the field technicians were still on-site and actively surveying. Only1.7% of the line was required to be resurveyed as a result of heavy telluric activity.

Another approach to avoiding fluctuations in the data is to avoid surveying whenever telluric activity levels are forecast to be at or above a certain level (e.g. “Stormy” per Figure 3). However, this approach suffers due to downtime and has significant budget and scheduling implications. In addition, during the subject survey it was observed that data collected on some “Stormy” days was of acceptable quality, while on other days with lower telluric activity levels, the uncompensated potential fluctuations resulted in unacceptable data. In addition, a day may start with major fluctuations but end with very few fluctuations. A crew sitting in a hotel would not collect any of useable data.

During this survey, there was only one day when the survey was actually cancelled. This was a “Major Stormy” day where fluctuations of 1400 mV were observed in a span of 4 seconds. However, on another “Major Stormy” day, the crew was able to survey successfully, so even this metric has limited applicability.

Therefore, the use of telluric compensation resulted in far better data quality and increased productivity compared with relying on arbitrary telluric activity limits. Using the basic telluric compensation method described in this paper, a high-degree of confidence in the protection levels on the subject pipeline was established, despite the presence of significant telluric activity.

BENEFITS & PRODUCTIVITY

The benefits of telluric compensation may be overshadowed by the need to perform additional survey data post processing. Post processing data after crews have demobilized from the field automatically produces a requirement for remobilization when suspect data is identified. To mitigate this, daily initial data processing is a key activity step in ensuring the true value of telluric compensation is identified and utilized at the correct time in the survey project process. Without executing initial data processing daily, re-survey areas or deficiencies are merely left to be flushed-out at the final report stage. For example, equipment synchronization is critical and discrepancies can be minimized by utilizing time dependent equipment incorporating global position satellite (GPS) receivers.[5] Utilizing visual representation software to compare GPS coordinates against pipeline data in the initial data processing step helps depict areas of inaccurate data. It is important to note that most commonly, initial data processing and compensation should be performed by survey office support staff, which limits the workload placed on field survey technicians.

When the true value of telluric compensation is utilized during the data collection process it leads way to a reduction in time required to execute a CIPS. One could be at the mercy of geomagnetic activity forecasts to perform data collection, which in some cases could be more than a 48-hour period. Simply refraining from data collection during periods of impactful geomagnetic activity does not add value to a survey’s productivity. It could be perceived that performing telluric compensation during times of impactful geomagnetic activity adds a layer of unnecessary complexity. However, there is significant value for the contractor in the form of reduced time spent. Ensuring data meets established technical requirements is more easily performed when the subject data is fresh, versus having to verified against historical data in some cases months later. Similarly, an operator obtains financial added value by reducing the survey duration.

Performing telluric compensation is also beneficial in terms of increasing data validity itself. Without effective compensation, CIPS data can be misleading with respect to criteria conformance, and should not be used as an input for integrity management efforts. CIPS data sets are an input into a pipeline operators' larger comprehensive framework to manage pipeline system integrity activities. This places an emphasis on having a high-degree of data quality.

A section of questionable ON CIPS data[a] collected during the previous survey on the adjacent section of pipeline (i.e. located to the south) is shown in **Figure 4**. Although the data was compensated for telluric activity and the data quality improved significantly as a result, there was still uncertainty regarding the actual protection levels, with the most electropositive ON potential -709 mV_{CSE} at Ch. 17817 m and several other locations more electropositive than -850 mV_{CSE}. In addition, the potentials along the section between Ch. 17350 m and Ch. 17900 m are depressed compared with the upstream and downstream sections. This type of questionable data cannot be relied on to adequately assess pipeline threats. Furthermore, there is a possibility that CIPS data could become the focus of a regulatory review. These concerns strongly support the use of effective telluric compensation supported by daily quality reviews and resurveys to improve data quality.

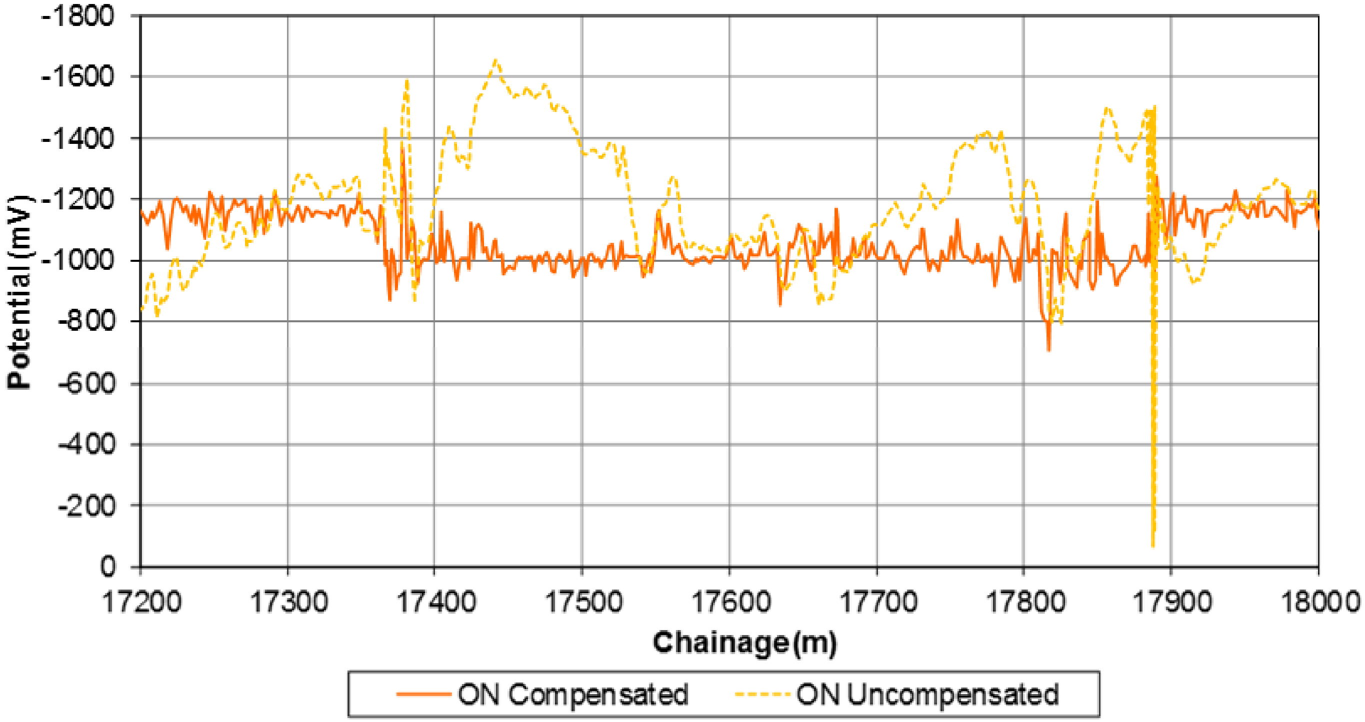

Figure 4: Questionable Data From Previous Survey

Due to the nature of the survey environment, there are inherently many health and safety concerns. These are commonly mitigated by adopting a hierarchy of controls. However, physically removing the hazard via elimination is the most effective technique for reducing hazards.[9] By employing effective telluric compensation during the data collection process, a supplementary benefit is obtained via reduced field exposure time for survey crews through the elimination of the need for additional re-surveys. Reducing the time spent by workers in a complex survey environment is advantageous for both the company and contractor.

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[a] No OFF data was reported.

RECOMMENDATIONS

Requiring telluric compensation as part of a CIPS often can be perceived to be increasing the survey complexity through these specific additional technical requirements. Optimizing the technical requirements identified at the pre-job meeting phase is key to minimizing scope creep. In addition, during this stage in the survey project, it is imperative to view all technical requirements from a macro view. This fosters an environment of revisiting the larger objective when deviations from specific technical requirements are encountered.

The up-front added cost for telluric compensation is minimal if upstream and downstream dataloggers are already installed; this is an existing requirement of some operators for other data integrity purposes. In this case, telluric compensation can be performed whenever the data indicates it is required, meaning it is a minor incremental cost. If there is no existing requirement to install upstream and downstream dataloggers, then collecting the data required to allow for telluric compensation adds cost to the survey. This cost should be evaluated against the downtimes and lower data quality which would otherwise result. For very short surveys or for surveys with low risk of impact from telluric activity, this cost may not be justified. For longer surveys where telluric activity is expected, telluric compensation is expected to be a net benefit to the operator. In extreme cases, such as on the Alyeska Pipeline in Alaska, it is not realistic to survey without telluric compensation.

When key CIPS data governance principles are established in advance of data collection it allows for a framework to ensure effective data integration. In this survey's case, one principle applied was standardization. For example: establish during the pre-job meeting what are the expectations for deviations from 'typical' survey data (i.e. resurvey, note in report, etc.). If resurveys are only identified at the end of the survey cycle, additional re-work such as re-installing interrupters and re-acquiring permits may result. Thus, applying the data governance principle of standardization ensures that the minimum effort would be expended to maintain the survey objectives.

Typically, evaluating CIPS schedule performance can sometimes be viewed as a non-value-added task to the performance of project. However, understanding how a survey is progressing based on established optimized specific technical requirements can flush out stepwise improvements during survey execution. For example, it was perceived, due to a technical requirement, that data collection could not proceed during classified periods of stormy short term hourly range activity. During the early stages of this project, based on technical observations from the data, this was judged to be an arbitrary assumption. Thus, the technical requirement was not supporting the project objectives, and ultimately supported a stepwise improvement.

CONCLUSIONS

The mechanics of telluric compensation were explained in detail to help overcome resistance in the industry to using these techniques. A specific example was provided showing survey data on a recent line in northern Alberta. By compensating data for telluric effects and incorporating a daily data review, significant benefits were realized in the areas of scheduling and costing, which result from reduced time in the field, and data quality. Higher quality data allows operators to satisfy the specific survey and broader pipeline integrity objectives with confidence. Although there are costs associated with more detailed survey data collection and data analysis, the benefits of telluric compensation will in many cases exceed the costs of resurveys and low data integrity.

REFERENCES

1. D.H. Boteler, L. Trichtchenko, "Observations of Telluric Currents in Canadian Pipelines," CORROSION/2001, paper no. 01316 (Houston, TX: NACE International, 2001).

2. P. Fernberg, L. Trichtchenko, D.H. Boteler, L. McKee, "Telluric Hazard Assessment for Northern Pipelines," CORROSION/2007, paper no. 07654 (Houston, TX: NACE International).

3. NACE SP0207-2007, "Performing CIPS and DCVG on Buried or Submerged Metallic Pipelines" (Houston, TX: NACE International).

4. A.L. Smart, "Early CIS – From the Backpack to the Slurpy Cell," CORROSION/2009, paper no. 09131 (Houston, TX: NACE International, 2009).

5. T.D. Place, T.O. Sneath, "Practical Telluric Compensation for Pipeline Close Interval Survey," CORROSION/2000, paper no. 00741 (Houston, TX: NACE International, 2000).

6. P. Nicholson, "Correcting CIPS Surveys for Stray and Telluric Current Interference," CORROSION/2007, paper no. 07182 (Houston, TX: NACE International, 2007).

7. TM0497-2012, "Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems" (Houston, TX: NACE International).

8. Natural Resources Canada, Short Term Magnetic Review and Forecast, June 6, 2015, http://www.spaceweather.gc.ca/forecast-prevision/short-court/sfst-en.php.

9. Centers for Disease Control and Prevention – NIOSH, Hierarchy of Controls, May 11, 2018, https://www.cdc.gov/niosh/topics/hierarchy/default.html

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