QUALITY CONTROL OF CATHODIC PROTECTION FIELD RECORDS

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ABSTRACT

Field data is required to document the field tests and to support a conclusion as to the operation of the cathodic protection (CP) system, that is, to confirm if a criterion has been met. Later it can be used as historical data to support an External Corrosion Direct Assessment (ECDA) or in the event of an incident it may become evidence in court that is available to all parties.

The past method of documentation of cathodic protection tests often makes it very difficult if not impossible for a proper analysis as the field notes leave many unanswered questions. If used in court, poor record keeping provides an opportunity for the opposition in court to discredit the data.

Field personnel spend a great deal of time and effort in accessing a measurement location but then fail to spend the few minutes of extra time required to properly document the data. There is no acceptable reason for lack of documentation.

The CP industry needs to establish improved minimum detailed standards for field notes that later can be easily understood by those not exposed to the test and also will be solid court evidence. Technology is now available for improved and controlled data collection. This provides the opportunity to ensure that all necessary data is documented but to include provision for the analysis of this data.

Keywords: CP Data, documentation, ECDA, records, data quality, quality control, CP criterion

INTRODUCTION

Documentation of cathodic protection (CP) field tests is required to provide a historical record and to support a conclusion as to the operation of a CP system and if a criterion has been met. If the structure being protected is regulated, in Canada and the USA, this documentation must be made annually with bi-monthly monitoring of the system during the year. If it is not regulated, such practice is considered as best industry practice and should still be followed.

These records can later be used as historical data to support an External Corrosion Direct Assessment (ECDA) or in the unfortunate event of an incident they may become evidence in court and available to all parties.

CGA OCC-1-2005, Section 6[1] and NACE SP-0169-2007 Section 11[2] both describe records that are pertinent to design, installation, maintenance and effectiveness of external corrosion control measures in general terms and although these are a minimum requirement even these terms are not always met in our CP records. More detailed information that needs to be documented is provided with the intent that the CP industry will improve field data standards. Many of these points should be obvious but they are detailed as they are often not recorded.

There are rigid requirements for detailed requirements for CP records and as a result the information documented is often sparse with many assumptions left to the reader. This not only makes it very difficult or impossible for a proper analysis of the field notes but in the event that they become evidence in court, the lack of information also provides an opportunity for the opposition in court to discredit the data. Regulated companies must store information for the life of the structure therefore, at a later date this information must be easily understood by those that were not familiar with the test

Technological advances in data acquisition and storage are now available to this industry. These allow a more accurate recording and thorough analysis of more complete data.

PAST PRACTICES

There were a multitude of methods of recording CP data in use and a few methods are described.

Prior to computers all data was recorded on paper. This may be on loose pages in a binder, clip board or a hard bound note book. With loose pages, there is a risk of pages getting lost or damaged. In addition, recording data on loose pages may not be acceptable as a legal defense since pages can be substituted with revised data at a later time. Originally only a hard bound book was acceptable in court and, if a mistake was made, the incorrect information was not erased but crossed out.

Another method is to preprint a table on loose pages that anticipate the required information. If the table is blank, the readings will be recorded in the order taken but if the table has locations inserted the chronological order of the readings is not known. In addition pages can be lost, inserted in the wrong order and revised at a later date. Preprinting locations also sends a message to the tester that this is the only information that is needed. With continual modifications made in the field additional readings should always be expected.

An extension of the above method is to record data on last year's hard copy report. This is unacceptable as the chronological order of taking readings is not known and often data with irrelevant comments from the prior year is copied into the next year's report.

The use of a hard bound book such as that used by land surveyors has worked well in the past (Figure 1). They are available in a convenient pocket size and also in waterproof paper. A book should be reserved for a particular system or area so that easy reference can be made at a later time. The disadvantage of the book is that it requires the tester to enter all information on each page.

The disadvantage of all hard copy methods is that they normally need to be transcribed into a file document.

With laptop computers in the vehicle, data can be typed directly into the computer in the field. This has the advantage that the data can be processed without transcribing it at a later time. Unfortunately there is a high risk of error in entering the data directly and since this is the original copy the accuracy can not be confirmed.

The safest method to record data electronically is to use a voltmeter with a memory but many dataloggers require manual entry of other information. Technology is available now that the readings, GPS location date and time can be automatically entered with the measurement. Although there is a risk of making typographical errors in entering remarks, the other key data itself will be recorded automatically and accurately by the instrument. This information can be downloaded to a computer and processed in another file. The original file from the instrument must be stored unaltered.

BASIC RECORD REQUIREMENTS

Regardless of the method of recording, the following information is considered as the basic essential information.

Name

Although it is obvious that the tester's name(s) should be on the data, in many cases it is not. The tester must take responsibility for the readings and one must know who to contact with any questions regarding the data. The training, experience, certifications and other qualifications of the tester(s) need to be with the data to establish competence and therefore the quality of the information.

Date and Time

The date and time of each measurement including power supply readings and potentials is to be recorded to allow an analysis of the chronological order of the readings. Those readings taken before and after a rectifier adjustment or the repair of a shorted isolation must be known.

The date of the installation, repair or replacement of cathodic protection equipment must be known.

If the data is to be transcribed on to a spreadsheet, this information needs to be on each row to keep relevant information during a "data sort".

Weather and Ground Conditions

Measurements can change due to temperature conditions and to the ground conditions. Readings taken in January compared to those obtained in July may be different due to the temperature change of the reference electrode (0.9 mV/°C)[3] and to frozen versus thawed soils rather than due to a change in the operation of the cathodic protection system. There is a possibility of poor reference electrode contact to soil under either frozen or extremely dry soil conditions which can cause an error of ±20% or more of the true value. Knowledge of the environmental conditions is therefore important.

Location

In Western Canada reading locations can be related to legal land divisions of townships, sections and legal subdivisions (LSD) that provide a location to within 1/16th of a one (1) square mile section. This may be accurate enough for a well location however it may not be accurate for a location on a pipeline.

Global Positioning System (GPS) locations can now be taken to locate most readings. This works well in the field but a drawing or map with these co-ordinates is needed to help relate the locations to each other. Instruments are now available to record this information directly.

In addition to the general geographical location, the detailed location of the measurement also needs to be defined. For example, when recording a structure-to-electrolyte potential, the point of contact to the structure and location of the reference electrode must be identified. The point of contact not only describes which structure potential is being taken but can also determine electrical continuity along the structure. The reference electrode must be left in one position to establish the effectiveness of an isolating fitting but leaving the reference over the same side does not give a true potential of the structure on the other side of the isolating fitting. Therefore additional readings must be taken and each identified accordingly in this case.

DC Power Supplies

Since cathodic protection must be maintained continuously, the need to inspect and keep complete records of the CP dc power source is obvious. The information that is needed is the complete name plate data, voltage and current output, the tap setting or equivalent and if applicable, circuit outputs all as found and as left. If available the power service KWH readings should also be taken.

One measurement that is seldom obtained is the dc back emf with the rectifier turned off temporarily which is a measurement of the galvanic difference between the anode and the structure. The back emf opposes the rectifier voltage and therefore is a critical component of a true calculation of the overall circuit resistance calculated in equation 1.

$$R = \frac{(E - E_b)}{I} \qquad \ldots 1$$

Where:

R - Circuit resistance (Ohms)
E - Rectifier output voltage when operating (Volts)
E_b - Rectifier back emf measured with rectifier off (Volts)

If the back emf is not considered, the circuit resistance appears to change with a change in the output voltage especially at a lower circuit resistance and/or a lower voltage output.

When there are two (2) or more dc power supplies, there is a point between each set of units where the influence of one ends to be taken over by the next one. If one unit should go off, this point of influence then moves into the territory of the de-energized unit thus current is still influencing this area (Figure 2). When recording true polarized (instant off) structure-to-electrolyte potentials, it is important to know which DC power supplies have an influence over the section being tested and all of these units must be synchronously interrupted to measure a true polarized potential. Unless it is planned to interrupt all units on a known synchronized cycle, area of influence surveys need to be completed for each DC power source and clearly documented. In both cases, the DC power sources that are interrupted or the cycles of interruption during each test segment needs to be recorded.

The number of relocated rectifiers with reversed polarity connections is an embarrassment to industry. This occurs as a lack of training and an appreciation of the catastrophic consequences of accelerated corrosion that occurs with this error. Only trained cathodic protection personnel should be allowed to re-energize a new or relocated rectifier after appropriate testing. The polarity of the unit itself can be confirmed by noting the polarity of a portable voltmeter connected to the DC output but this does not confirm that the DC cables are connected correctly. The latter can only be confirmed by a structure-to-electrolyte potential with the current off and on noting a more electronegative potential with the current on (Figure 3). The fact that this test has been completed needs to be documented.

Determination of a CP Criterion

In the absence of evidence that corrosion has not occurred, there are essentially two criteria that can be used. These include a polarized structure-to-electrolyte potential or a polarization criterion. In the first case the polarized potential can be determined by either interrupting all influencing DC power sources and measuring the polarized potential directly as an "instant off" potential or by measuring the "on" potential and eliminating the IR drop component that is determined by some means (equation 2).

$$E_p = E_{off} = E_{on} - E_{IR} \qquad \ldots 2$$

Where

- E_p - Polarized structure-to-electrolyte potential
- E_{off} - Instant off structure-to-electrolyte potential
- E_{on} - Structure-to-electrolyte potential with current applied
- E_{IR} - Voltage drop in the electrolyte between the reference electrode and the structure surface with current applied.

The polarization criterion is determined by the difference between the polarized potential and either the native p`otential or the depolarized potential (equation 3).

$$\Delta E_{pol} = E_{off} - E_{native}$$
$$\Delta E_{pol} = E_{off} - E_{depol} \qquad \ldots 3$$

Where:

- ΔE_{pol} - Polarization
- E_{off} - Instant off structure-to-electrolyte potential
- E_{native} - Structure-to-electrolyte potential before CP applied
- E_{depol} - Structure-to-electrolyte potential after CP current has been turned off

If proving a polarization criterion by decay, "instant off" and "native" or "depolarized" potentials are taken at the same reference electrode position for each location. In the first part of equation 3, the native potentials are measured and then after time is allowed for polarization the polarized (instant off) potentials are obtained. The difference between the "instant on" and the "final on" is due to polarization if practical to take these measurements. In the second part of equation 3, the instant off potentials are recorded and after time is allowed for depolarization, the depolarized potentials are then recorded.

If the minimum amount of polarization (depolarization) can be seen by datalogging the on / off cycles and if sufficient, the second survey would not be necessary with this information. Figure 4 is an example of an immediate measurement of depolarization for the 100 mV criterion however in this case the -850 mV_{CSE} polarized potential criterion was also met.

Depending on the criterion to be proven, there is a considerable amount of information that needs to be recorded. This would include the following information for each reading location in addition to the name, date and time described above.

- Point of contact to the structure
- Reference electrode position
- Structure-to-electrolyte potential with the current applied
- If applicable, the native potential, the potential with the current interrupted momentarily and/or the depolarized potential.
- Remarks applicable to the measurements or structure.

Interference Test Data Requirements

Stray current interference can cause corrosion even on a structure that has cathodic protection. Unfortunately, interference testing and documenting the results of these tests is often taken very lightly which may be due to the difficulty in conducting the tests properly and the costs associated with detailed tests.

Interference is often assumed to occur only at pipeline crossings or at isolating features. In the latter case the same test to determine the effectiveness of an isolating fitting, that is, a fixed reference electrode test, is often used as an interference test. This is incorrect as the:

- interfering DC power source may not be interrupted
- reference electrode position may not be at the interfered-with structure and
- point(s) of maximum exposure can be at another location

Due to the amount of organization required to conduct a n interference test properly, when an it is to be completed as a part of an adjustive survey, the interference test is often minimized even though it is the test that deserves a great deal of attention. In such cases it would be planned as a separate test as the consequences of interference can be significant. Proper documentation of all steps of an interference test must be made.

In addition to the tester's name, date and time, the information that needs to be documented for steady state stray current interference includes:

- With mitigation disconnected, and the interfered-with CP system operating record "on" / "off" "interfered-with" structure-to-electrolyte potentials with reference at this structure while the "interfering" dc power source is interrupted.
- With mitigation disconnected and "interfered-with" CP system not operating, measure "on" and "off" potentials (reference at "interfered-with" structure) with "interfering" dc power source interrupted.
- With mitigation connected and "interfered-with" CP system operating, record "on" potentials (reference at "interfered-with" structure) with interfering dc power source operating.
- With mitigation connected and "interfered-with" CP system not operating, record potentials (reference over "interfered-with" structure) with interfering dc power source interrupted. (Note that "off" potentials with bonds in place are no longer a valid polarized structure-to-electrolyte potential.)
- In all cases the effect of mitigation on the "interfering" structure should also be measured.
- Record current associated with the mitigation equipment.
- Record the dc power source data of the "interfering" and the "interfered-with" systems.

Spreadsheet Records

In the past records have been transcribed into spreadsheets such as shown in Figure 5. Although at first glance it appears there is sufficient information recorded there are deficiencies and also it does not take advantage of the features of a spreadsheet such as sorting. A data sort is useful to summarize all sub-criterion potentials, to sort by chronological tests or to sort by location.

The deficiencies in Figure 5 include:

- the type of reference electrode used is not indicated
- "Other" potentials are listed in the wrong columns,
- current is listed under the potential column with units of milliVolts
- multiple information is listed under "Location" that will not be tracked if a data sort was attempted. In fact a data sort will not be successful with data in this arrangement.

Figure 6 is a sample of pipe-to-electrolyte potential data format that could be sorted without a loss of identification and associated remarks. Figure 7 is additional critical bond data that could be incorporated into Figure 6 or handled separately.

FUTURE QUALITY CONTROL

The cathodic protection industry needs to embrace the technology that is available today to improve the quality of the field data.

GPS datalog type voltmeters are now available and equipped with many functions (Figure 8). This allows potential measurements at different locations to be compared at precisely the same moment. Software is also available to process this information to facilitate the analysis of this data (Figure 9).

The instrument automatically enters the routine information of date, time and GPS location with the actual readings thus eliminating the possibility of human error in entering this information.

Using this equipment, a series of data can be obtained at each reading location that will provide a profile of the potentials as the power source is interrupted. This clearly provides a more accurate instant off potential as opposed to reading a digital voltmeter display.

In addition the amount of depolarization in the “off” cycle chosen is evident at the stationary location and may cause a change in the interruption cycle selected (Figure 9). If the rectifiers should go out of synchronization, the stationary datalogger will illustrate this fact and also the length of time that is necessary for the instant off measurement to be accurately captured (Figure 10).

The effect of telluric current or dynamic stray current will be evident by observing the change in potential with time either at the stationary datalog or at the portable datalog location (Figure 11). Both the raw data and the corrected data must be filed for such cases.

CONCLUSIONS

The cathodic protection industry needs to establish and require higher minimum standards for cathodic protection records beyond that required by the present code or standards.

The cathodic protection industry needs to embrace the new technology which offers the opportunity to capture and greatly assist with the assessment of cathodic protection test data.

FIGURES

FIGURE 1: Typical Hard Bound Field Book

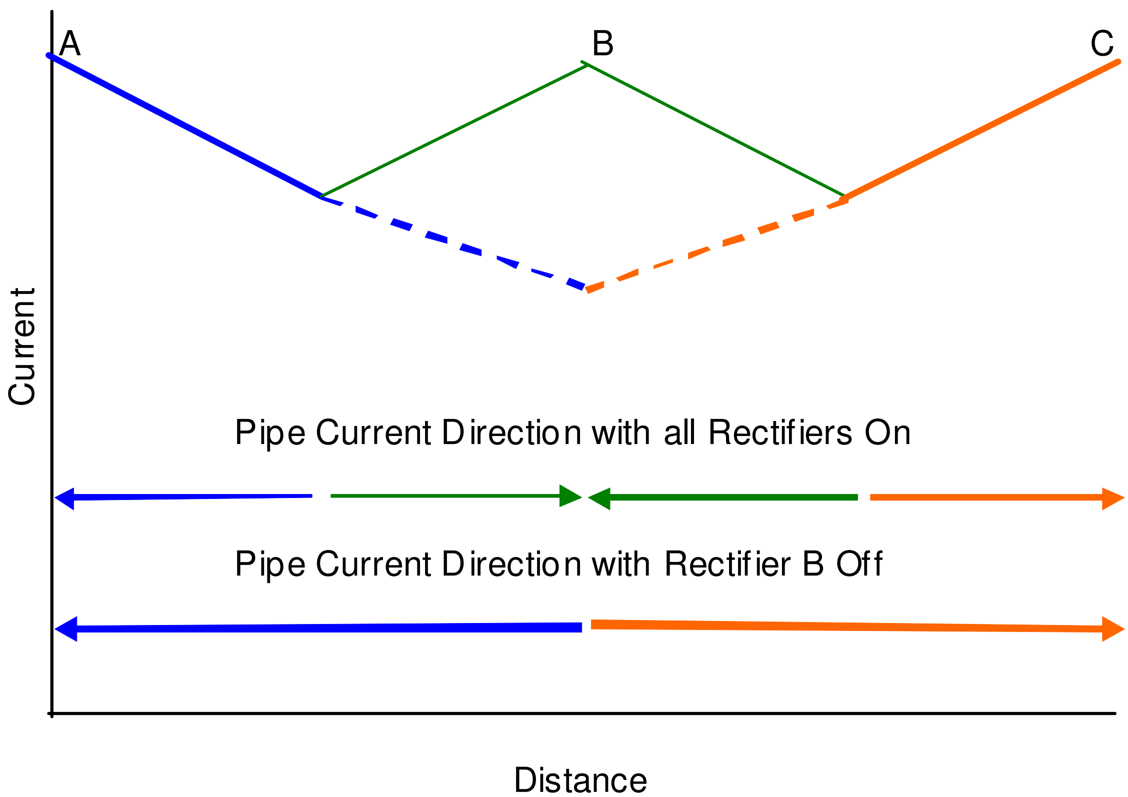

FIGURE 2: Changing Rectifier Influence With a Rectifier Off

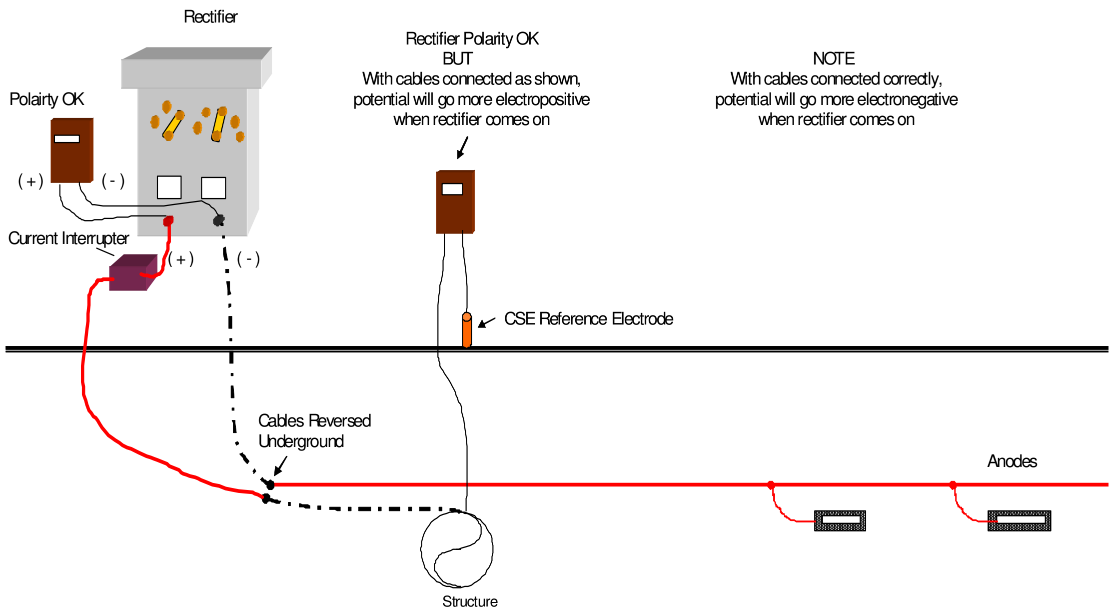

FIGURE 3: Testing for Correct DC Polarity

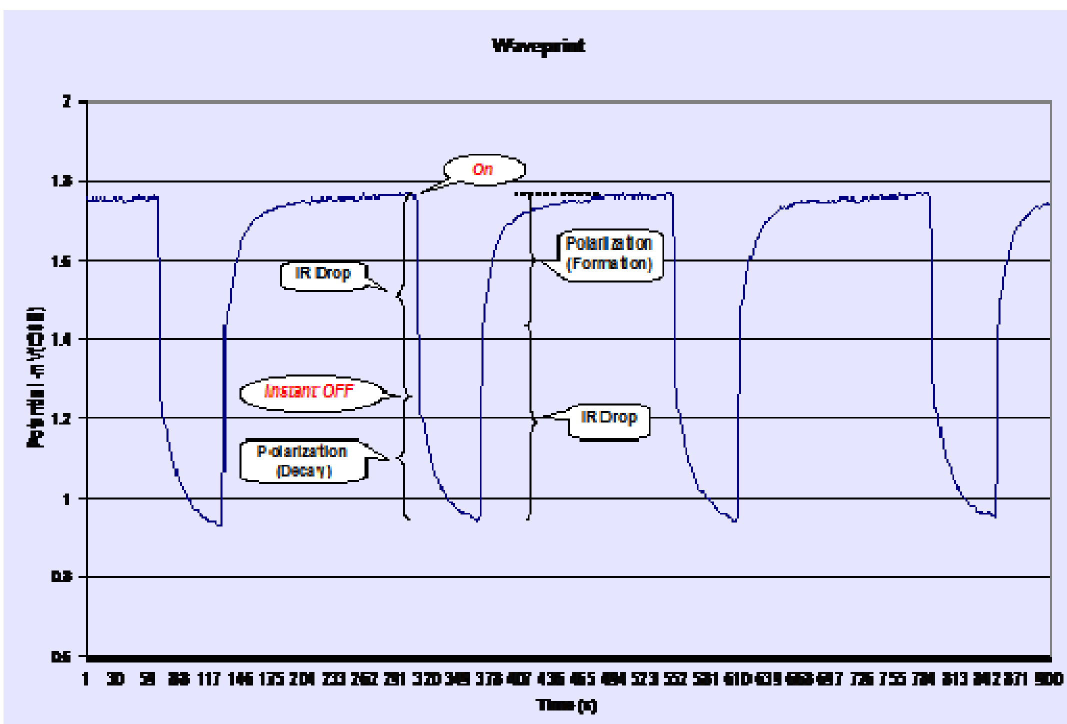

FIGURE 4: Datalog of an Interrupted Pipe-to-Electrolyte Potential with Time

LOCATION	GPS		LINE	POTENTIAL (-mv) ← *see Note A*				REMARKS
				STRUCTURE		OTHER		
	NORTH	WEST		ON	OFF	ON	OFF	
01-02-03-04 W4M	xx°xx.xxx'	xxx°xx.xxx'				← *see Note B*		
CB#xx			xxx					
Owner				-1100	-1000			Bond Connected
XYZ Oil				-1050	-950	← *see Note C*		
Current				150	60	← *see Note D*		
Owner			xxx	-1200	-1100			Bond Disconnected
XYZ Oil				-800	-900	← *see Note C*		
Current				0	0	← *see Note D*		

↑ *see Note E*

Notes:
A - Reference electrode type not indicated
B - Location information is not on the same line as data thus it will be separated in a sort or search
C - Foreign potentials in IPF "Structure" column instead of "Other"
D - Current in Potential column suggesting it is a structure-to-electrolyte potential and is in mV.
E - Multiple information is in Location column making a search or sort impractical

FIGURE 5: Data Transcribed Incorrectly into a Spreadsheet

Date	Time	Location (Legal Description)	"Other" (Foreign Owner)	GPS		Potential (-mV_{CSE})*				Contact to	Reference	Remarks	By
				North	West	Structure		Other					
						On	Off	On	Off				
xx-xx-xx	xx.xx	01-02-03-04 W4M	XYZ Oil	xx°xx.xxx'	xxx°xx.xxx'	-1100	-1000	-1050	-950	I/F	CSE over NPS 6 line	IF tested good	J Doe
xx-xx-xx	xx.xx	01-02-03-04 W4M	XYZ Oil	xx°xx.xxx'	xxx°xx.xxx'	-1200	-1100	-800	-900	I/F	CSE over NPS 4 line		J Doe

* Same reference position for readings in same row

FIGURE 6: Pipe-to-Electrolyte Potential Data transcribed into a Spreadsheet to allow a Data Sort

Time	Location (Legal Descripti	"Other" (Foreign Owner)	GPS		Critical Bond #	Bond	Bond Current** (mA)		Bond Critical to	Remarks	By
			North	West			ON	OFF			
xx.xx	01-02-03-04 W4M	XYZ Oil	xx°xx.xxx'	xxx°xx.xxx'	CB#xx	Across I/F	+150	+60	XYZ Oil	Bond Connected	J Doe
xx.xx	01-02-03-04 W4M	XYZ Oil	xx°xx.xxx'	xxx°xx.xxx'	CB#xx	Across I/F	0	0	XYZ Oil	Bond temporarily disconnected	J Doe

** Positive current is from Foreign to Owner through bond

FIGURE 7: Bond Current Data Transcribed into a Spreadsheet to allow a Data Sort

FIGURE 8: Sample datalog type instrument

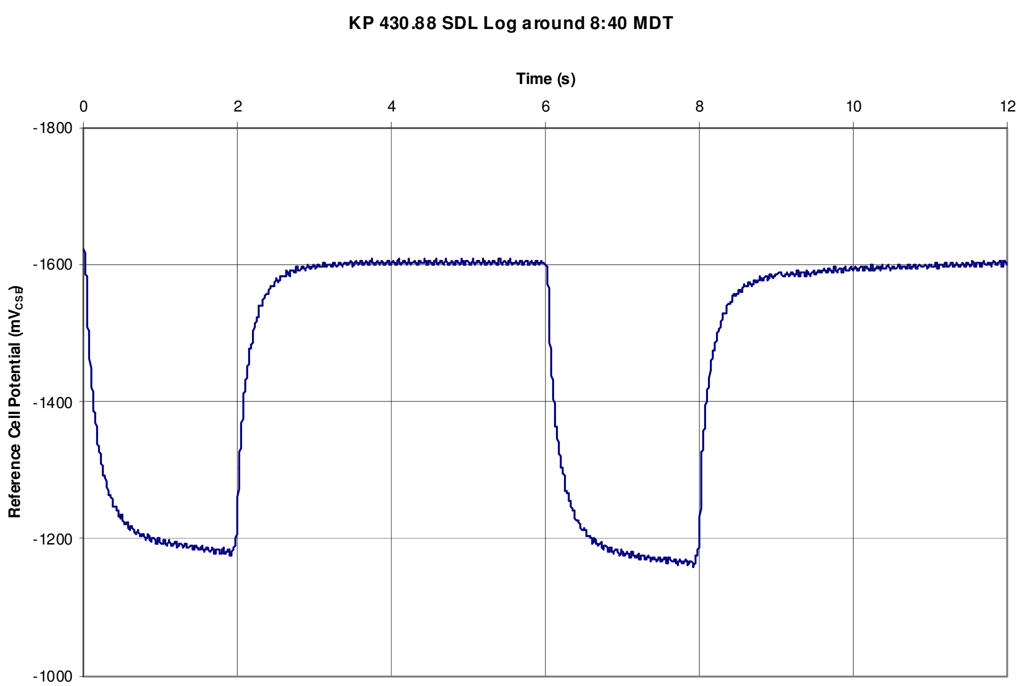

FIGURE 9: Datalog of Rectifier Synchronized Interruption

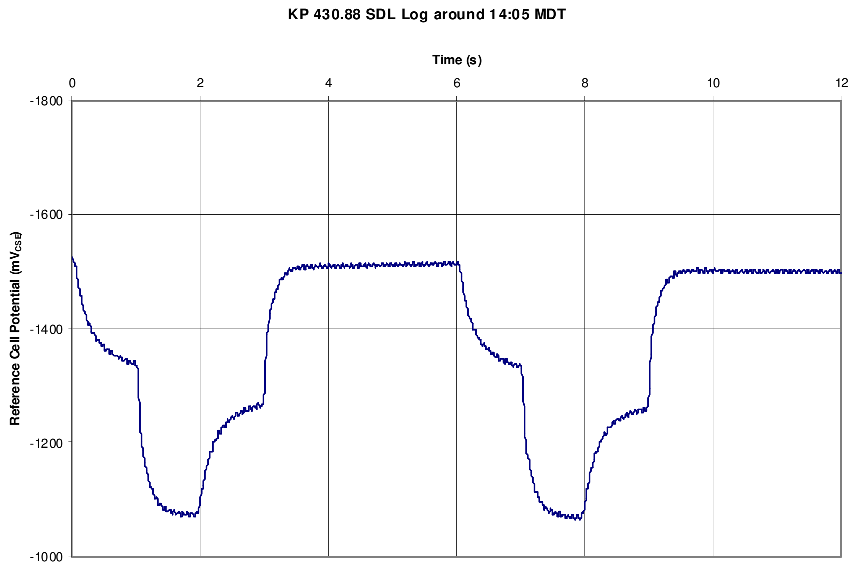

FIGURE 10: Datalog with Nearby Rectifier out of Synchronization
(Off Reading must be delayed)

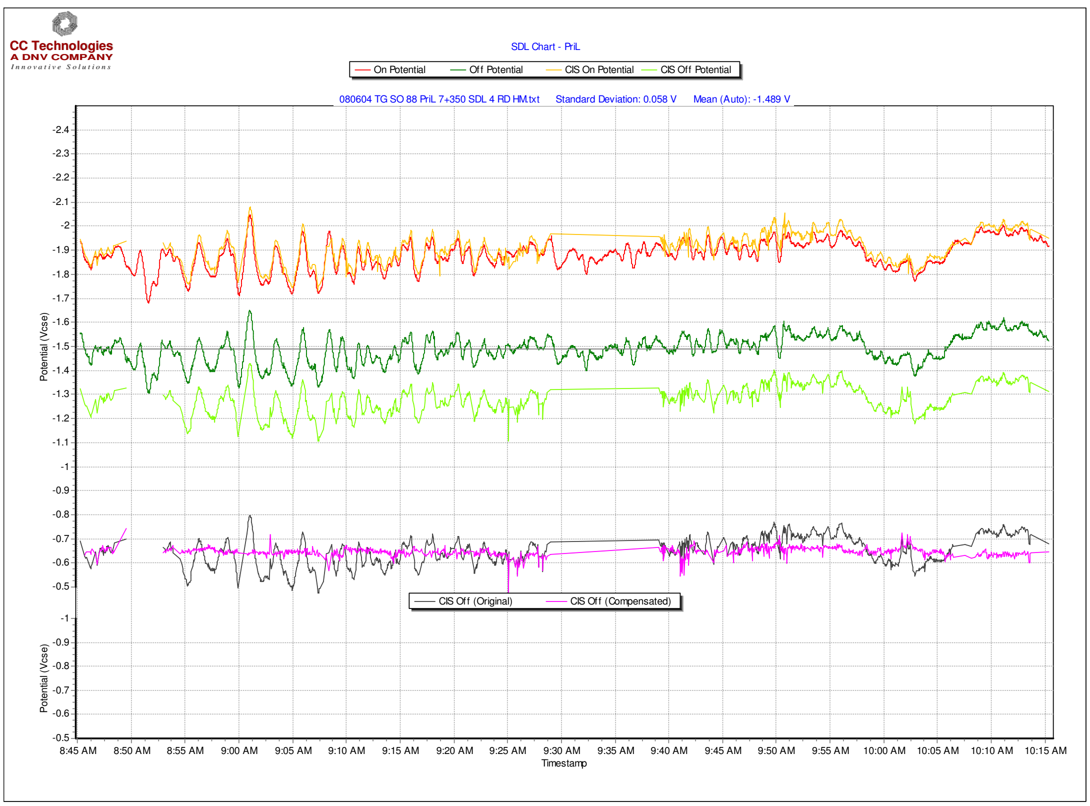

FIGURE 11: Stationary and Portable Datalog of Potentials affected by Telluric Current

REFERENCES

1. Canadian Gas Association, CGA OCC-1-2005, Control of External Corrosion on Buried or Submerged Metallic Piping Systems

2. NACE International, NACE SP0169-2007, Standard Practice, Control of External Corrosion on Underground or Submerged Metallic Piping Systems

3. Frank J. Ansuini, James R. Dimond, Factors Affecting the Accuracy of Reference Electrodes, Materials Performance Vol. 33 No. 11 November 1994