PIPELINE REHABILITATION
& MAINTENANCE
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External Corrosion Direct Assessment

(ECDA)

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All underground/underwater metallic pipelines are subject to corrosion where there are inadequate levels of cathodic protection. Cathodic protection is the only method of reducing or halting external corrosion on underground/underwater pipelines.

Figure 1Corrosion of an Underground Pipeline

NACE International through Standard Recommended Practice RP0-502 has developed a five step approach to corrosion control of underground/ underwater metallic pipelines, this process is known as External Corrosion Direct Assessment (ECDA). The ECDA process is as follows:

External Corrosion Direct Assessment is a five-step process as follows:

1. Pre-Assessment (Gather Information on the System)
2. Indirect Examination (Gather Data on System)
3. Direct Examination (Excavation of Priority Areas)
4. Remediation (Repair or Replacement)
5. Post-Assessment (Effectiveness of Remediation)

Pre-Assessment may include mapping the physical location of the pipeline, its appurtenances, test facilities, valves, pump stations, take-offs, test stations, bonds, rectifiers, etc.

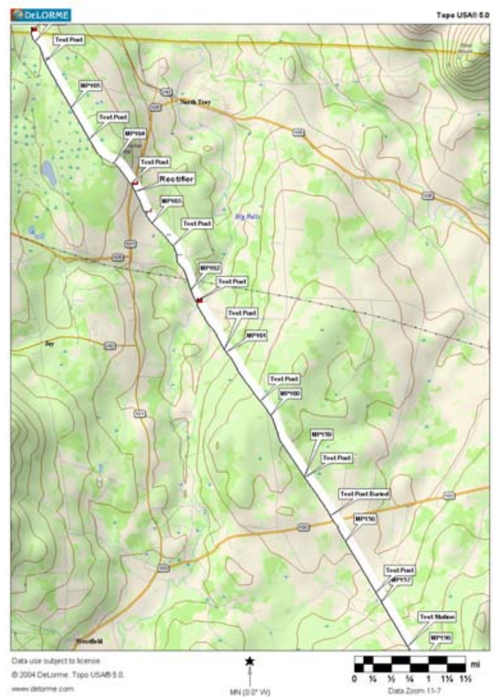

Figure 2 Map of Pipeline Location

Indirect Examination may include historical information on the operation and maintenance, repairs, damage and other factors that may influence the longevity of the pipeline system. The indirect examination may also include operating pressures (stress) metallurgy of the pipeline system and its susceptibility to hydrogen embitterment and stress corrosion cracking.

ECDA is not limited to steel or iron pipelines but should be applied to reinforced concrete pipelines as well.

Figure 3 Failure of a Pre-Stressed Concrete Pressure Pipe due to corrosion of the tensioned reinforcement

Direct Examination may include the use of the ECDA tools to determine the effectiveness of the cathodic protection system, the condition of the protective coating and if warranted the excavation of areas where the level of cathodic protection is inadequate.

Remediation and repair may include improvements to the cathodic protection system to increase the level of cathodic protection as well as repair of coating defects or refurbishment of the protective coating or replacement of pipe sections if warranted.

Post Assessment would include a close interval potential survey to verify the effectiveness of any coating repair, pipe replacement or improvements to the cathodic protection system.

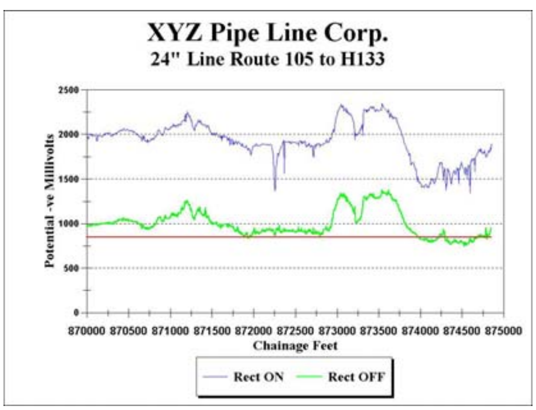

Figure 4 Graph of Rectifier ON and OFF Pipe-to-Soil Potentials of a Coated Steel Pipeline

ECDA tools commonly used include:

- Close Interval Potential Surveys (CIPS)
- Direct Current Voltage Gradient surveys (DCVG)
- Alternating Current Voltage Gradient surveys (ACVG)
- Current Attenuation
- Pearson Surveys

Close Interval Potential Surveys (CIPS) is the only effective method of determining the level of cathodic protection on underground /underwater metallic pipelines. All other survey methods indicate coating integrity, which is not indicative of the level of cathodic protection on an underground/underwater pipeline.

Figure 5 Close Interval Potential Surveyor with Sub-Metre GPS System

A close interval survey is the measurement of the rectifier ON and Instant OFF potentials (IR Free) along a pipeline cathodically protected by an impressed current cathodic protection system, or the measurement of, the polarized potential of a pipeline in the case of a sacrificially protected pipeline. Potential readings are correlated with distance and GPS coordinates and are usually recorded on a 1 to 3-metre interval directly over the pipeline under test.

A close interval potential survey undertaken with all rectifiers influencing the survey area synchronously interrupted utilizing the GPS timing signal reveals the true polarized potential of the pipeline and any defects in the cathodic protection system.

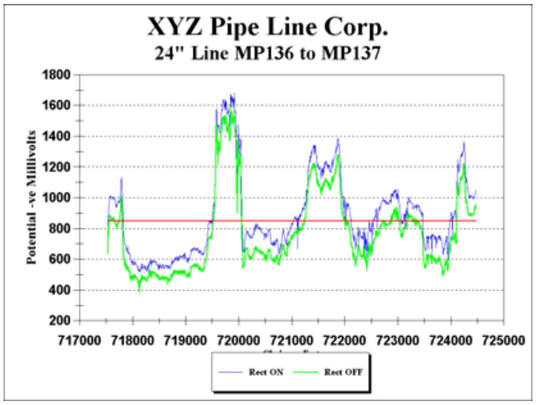

Figure 5: Potential Profile of 30 Year Old Pipeline showing sub-criterion potentials

Figure 5 shows the potential recorded on a 30-year-old pipeline. The potentials at test stations where sacrificial anodes have been installed to supplement the impressed current cathodic protection system falsely indicate that the pipeline is cathodically protected.

Direct Current Voltage Gradient Surveys (DCVG) is the application of a pulsed DC current either from the interruption of the cathodic protection rectifiers or the application of pulsed DC current from a temporary source. Voltage gradients are measured along the pipeline. DCVG surveys have traditionally been undertaken utilizing an analogue instrument.

Figure 6 Analogue Direct Current Voltage Gradient Survey Instrument

A direct current voltage gradient is generated by direct current flowing through the soil to a defect in the coating from a source of direct current power such as a rectifier or temporary power source. The magnitude of the voltage gradient is determined by Ohms Law (E=IR), where E is the voltage gradient, I is the current flow through the soil between the measuring electrodes and R is the resistance of the soil circuit between the measuring electrodes.

Generally the larger the voltage gradient the larger the coating defect, but soil resistivity and current attenuation must be considered in the interpretation of the magnitude of the voltage gradient. DCVG surveys do not indicate the level of cathodic protection on a pipeline system.

Alternating Current Voltage Gradient Surveys (ACVG) are identical to DCVG above only an isolated AC power source is used to supply current to the pipeline for the measurement of the voltage gradient. AC voltage gradient surveys do not indicate the level of cathodic protection on a pipeline. Defects in the pipeline coating are usually marked with flags and their location chained at the end of the day or survey.

Current Attenuation is the measurement of the current attenuation on a pipeline with distance from the power source. The current attenuation is indicative of the coating quality and integrity. Current attenuation does not indicate the level of cathodic protection or the effectiveness of the CP system.

Pearson survey is an electrical method of locating holidays in a pipeline coating by the application of an AC signal on a pipeline and the reception of the signal by two surveyors wearing metal cleats and connected to the Pearson receiver.

Traditional Survey Methods

Test station surveys have been traditionally used to indicate the level of cathodic protection on a pipeline. Figures 5 and 8 graphically indicate how Reliance on test station surveys can lead to corrosion and pipeline failure.

Close Interval Potential Surveys (CIPS) have been utilized to supplement test station surveys determining the level of cathodic protection on underground /underwater pipelines.

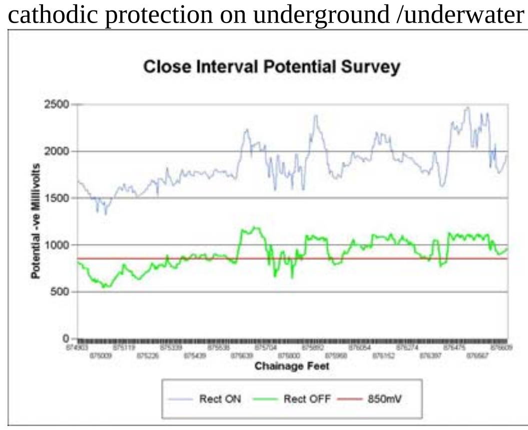

Figure 7 Typical CIPS Survey Result

Figure 7 shows a typical potential profile of a cathodically protected pipeline. Although the rectifiers ON potentials are all in excess of –1400 mV the instant OFF (IR Free) potentials indicate significant areas where the polarized potential is below the criterion of –850 mV and may be corroding. Test Station surveys give a false indication of the effectiveness of a cathodic protection system. Often sacrificial anodes are added at test stations to improve the level of cathodic protection. This can lead to a situation where test station surveys indicate adequate cathodic protection levels, when the pipeline may be actively corroding at areas remote from the test stations as shown in Figures 5, 7 and 8

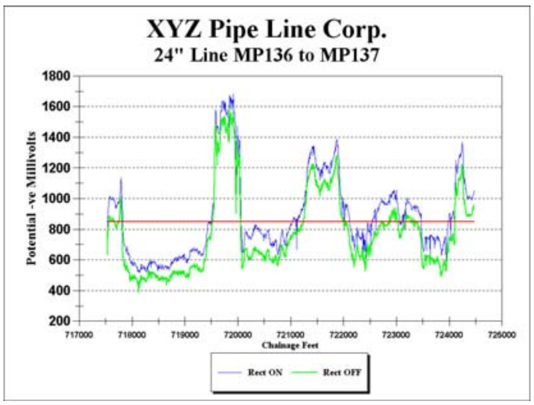

Figure 8 Close Interval Potential Survey

Figure 8 shows the potential of a coated pipeline in mountainous terrain and the effect of rock and high resistance soil on the structure-to-electrolyte potentials. In areas where insufficient current is reaching the pipeline to achieve adequate levels of cathodic protection, both the rectifier ON and instant OFF (IR Free) potential is sub-criterion and active corrosion may be occurring.

Figure 9 CIPS Surveyor with wire chainer and GPS system

CIPS surveys allow the rapid collection of structure-to-electrolyte potentials on a pipeline, usually on 1 to 3 meter spacing, thus the level of cathodic protection is measured and recorded thorough out the survey area. The corrosion engineer will have sufficient data to determine if corrective action is required or if improvements to the cathodic protection system are necessary. Each reading can be accurately located on the pipeline by both the chainage and by the GPS coordinates. The surveyor in Figure 9 is using a GPS engine with a position resolution of 200 mm (8").

Traditionally DCVG surveys have been undertaken with an instrument that amplifies the DC voltage between two half cells in contact with the ground and displays the voltage gradient as a millivolt value on an analogue metre. The coating defect locations are staked or flagged to indicate there location.

Figure 10: Staked out DCVG Indications

Most analogue DCVG survey instruments do not store the voltage gradients measured or the location of the voltage gradients indicating defects in the pipeline coating. The defects are marked with stakes or flags see Figure 10 and a table produced of the location and size of the defect as shown in Figure 11.

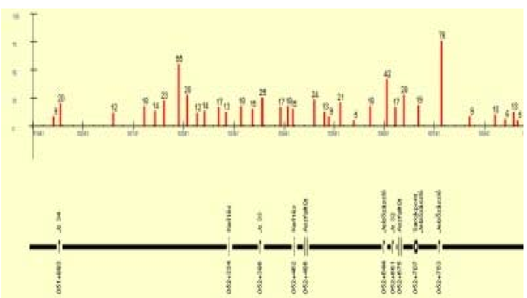

Figure 11 Table of Coating Defects

Following the DCVG survey traditionally coating defects have been excavated and the coating repaired. This results in an increasing the ratio between cathodic and anodic areas; with the effect that corrosion may be accelerated at small corrosion defects on the pipeline if is not adequately protected by cathodic protection.

Modern DCVG survey equipment is equipped with data logging facility as well as a GPS engine to store coordinates. By storing the voltage gradient values and stamping them with the latitude and longitude, chaining each voltage gradient is unnecessary and any spreadsheet software can produce accurate graphs of the data.

Improved Survey Method

By combining a CIPS survey with a DCVG survey the level of cathodic protection and the location and influence of coating defects can by simultaneously measured and recorded, as shown in Figure 12.

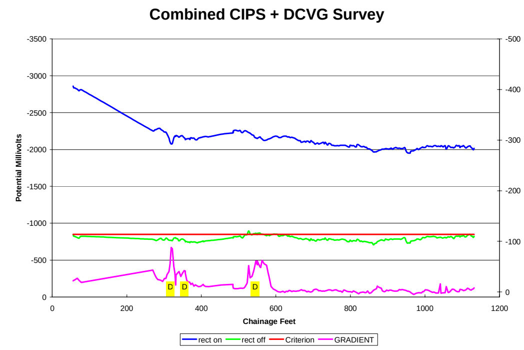

Figure 12 Combined CIPS + DCVG Survey Results

Traditionally CIPS and DCVG surveys were undertaken separately using different equipment and operators. With modern electronic data gathering equipment it is possible to simultaneously measure the Rectifier ON, Instant OFF and voltage gradient along a pipeline at intervals as close as one foot (300 mm). By combining a CIPS survey with a DCVG survey a saving in time and manpower can be realized. Further, the combined survey gives improved correlation, as the survey conditions are identical when both measurements are made simultaneously as shown in Figure 12.

Combined CIPS and DCVG surveys yield considerable information on the condition of a pipeline and its cathodic protection system. Figure 13 shows the results of a combined CIPS + DCVG survey in South America.

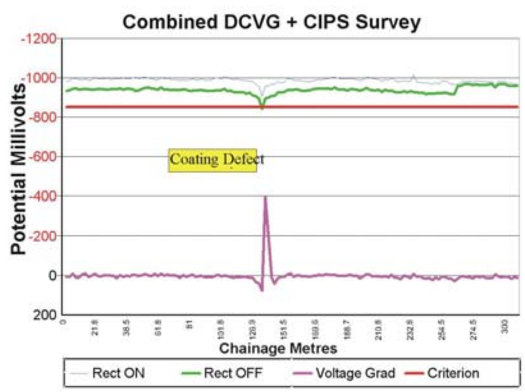

Figure 13 Combined CIPS + DCVG Survey Results

Although the Instant OFF potential in Figure 13 is more negative than the accepted criterion for protection of –850 mV there are significant voltage gradients indicating coating defects. One of the defects was excavated and Figure 14 shows the coating defect found.

Figure 14 Defect located by CIPS + DCVG survey.

The purveyors of DCVG suggest that a mathematical model can be used to determine which coating defect should be excavated and repaired, without reference to the structure-to-electrolyte potential. If there are adequate levels of cathodic protection it may be better to continue to monitor the cathodic protection levels with CIPS surveys rather than excavate the defect and perhaps cause more coating damage. Figure 15 displays the results of a combined DCVG/CIPS survey on a 30" gas line

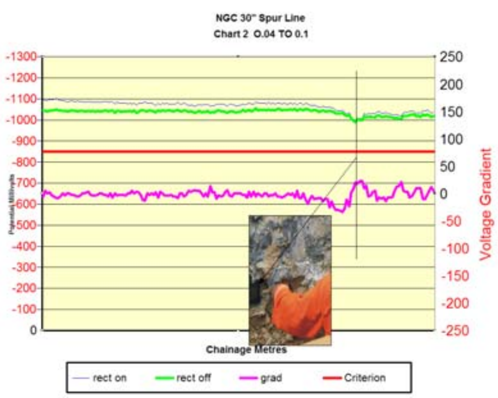

Figure 15 CIPS + DCVG Survey Results

The defects shown above was excavated, Figure 16 shows disbanded coating at the defect location.

Figure 16 Coating Defect Located by CIPS/DCVG Survey

The coating is so badly degraded on some pipelines that the only solution is to recondition or replace the pipeline. With modern survey equipment which combines CIPS + DCVG survey techniques in a single pass synchronized by the GPS satellite system to the rectifier interrupters, it is now possible to produce accurate surveys indicating and locating external corrosion on pipeline systems. Figure 19 shows a state of the art CIPS + DCVG survey set, and Figure 20 shows a GPS synchronized current interrupter. By utilizing the timing signal from the GPS system we can archive timing accuracies of 365 nanoseconds.

Figure 19 State of the Art CIPS + DCVG Survey Equipment. Cath-Tech Hexcorder Millennium Shown

With state of the art GPS synchronized survey equipment it is possible to undertake a CIPS and DCVG survey with full confidence that you are correctly measuring and recording the Rectifier ON and Instant OFF potential eliminating the IR drop component from the polarized potential of the pipeline.

Figure 20 GPS Synchronized Current Interrupter CATH-TECH Model CI-50 shown

Modern survey equipment such as that shown in Figure 19 can stamp each CIPS and DCVG reading with the chainage, date, time, latitude and longitude as well as the elevation above sea level and other factors that may influence the accuracy of the location coordinates. Sub-metre engines can be integrated to provide 200 mm location accuracy on the fly.

GPS synchronized current interrupters such as those shown in Figure 20 can be programmed to only interrupt the rectifiers during survey hours and to maintain a steady current output during non-survey hours. By utilizing the timing signal transmitted every second by the GPS satellite system, all GPS synchronized current interrupters interrupting rectifiers on the pipeline under test will be synchronized to interrupt the output of the rectifiers with an accuracy of a few microseconds.

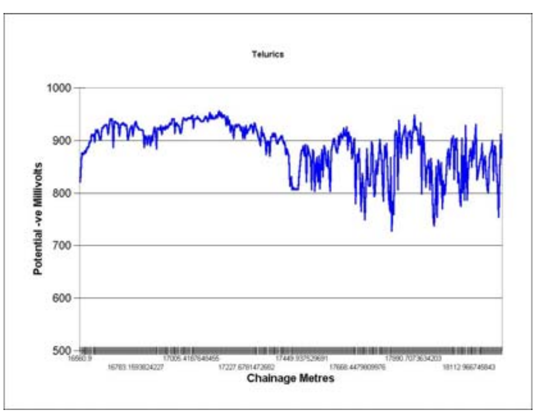

Figure 21 Telluric Current Affect

Stray and telluric currents can affect any close interval potential survey. Figure 21 shows the effect of telluric current on the structure-to-electrolyte potential of a pipeline.

Stray and telluric currents affecting a CIPS survey can be corrected if potential of the pipeline is recorded at each rectifier interruption with great accuracy by utilizing the timing signal from the GPS system. Each reading must be time stamped by both the stationary data logger (Smart Logger) and the CIPS survey instrument. Correction of the data can be easily accomplished by using a simple lookup formula in Excel or Quattro Pro. Figure 22 shows a GPS synchronized stationary data logger.

In conclusion, DCVG, ACVG and low frequency AC surveys are not a panacea. A voltage gradient survey only details the location and perhaps the size of coating defects. It does not indicate the level of cathodic protection or even if the pipeline is cathodically protected. To use the results of a DCVG survey to repair pipeline coating without adequate levels of cathodic protection as detailed by a close interval potential survey recording the rectifier ON and instant OFF values can result in rapid corrosion failure of a pipeline.
Due diligence requires that you inspect your cathodic protection system and ensure that every millimetre of the pipeline has adequate cathodic protection current to meet or exceed the requirements of the NACE International RP0169-200 criterion for cathodic protection of –850 millivolts with the IR drop component eliminated from the reading.

Figure 22 Stationary GPS Synchronized Data Logger. Cath-Tech Smart Logger Shown

Pipeline integrity can be assured if adequate levels of cathodic protection are maintained on all surfaces of a pipeline. This can only be verified with a GPS synchronized CIPS survey undertaken on a regular basis and adjustments or upgrades made to the cathodic protection system in those areas that do not meet the criterion for protection on a regular basis.