Delineation of pipeline coating defects company engineering essay

The business sector of corrosion monitoring and control solutions we provide expertise in consultation, evaluation, design and installation of cathodic protection systems. With established field assessment techniques and specialized equipment such as CIPS/DCVG survey equipment. Engineers collect record and analyze field data efficiently so that clients are able to run safe and highly optimized systems. Corrosion solutions are provided in a cost effective and with highly professionalism to enable clients to enhance their facilities integrity management systems.

Introduction:

The external inspections using DCVG-direct current voltage gradient technique was performed on this pipeline on March 10th 2011 to March 24th 2011. Cathodic protection and coating are complementary to each other and when applied together, result in reliable corrosion mitigation. Cathodic design presupposes certain coating breakdown criterion for the given type of coating and given environment. If coating break down exceeds beyond the maximum percentage limit presupposed by the CP system design, cathodic protection may become ineffective.

To ensure the effective cathodic protection and effective corrosion control, it is desired to access the condition of the coating of the underground pipeline. Exposing the pipeline by excavation all along the length, for this purpose is impractical. Various methods have been evolved for the assessment of coating condition without excavation. One of the methods is Direct current voltage gradient survey.

Safety:

The site activities were performed as per the applicable safety procedures. Work permit was obtained prior to commencing of site activities. The HSE requirements were explained by PCML engineer to the site team. All personnel safety gears such as safety boots, coverall. Hard hat, googles etc were used during the site work.

Codes and standards:

The measured potentials and performance of the cathodic protection system, equipment and materials shall comply with the requirements PTS and NACE standards code and other authority having jurisdiction over the system.

NACE RP-O502-2002 Pipeline external corrosion Direct Assessment Methodology.

NACE RP-0169-96 control of External corrosion of underground or submerged metallic

Piping systems.

NACE RP-05-75 Design, installation, operation and maintenance of impressed current

Deep ground bed.

The scope of work performed in this project is in accordance to industry standards has been maintained to ensure international codes of practice in corrosion control. The criteria used for protective potentials of buried steel are indicated in NACE international national association of corrosion engineer’s standards.

Pipeline details:

The pipeline has the following physical characteristics and these details shall be applied to design the cp system.

GSPC on shore gas pipeline

Length : 67km

Coating : three layer polyethylene

Service : gas

Source station : poc (chain age 10 km)

Destination station : metering station (chain age 67 km)

Introduction to DCVG coating survey equipment:

The direct current voltage gradient (DCVG) pipeline coating survey test equipment is version 9, and is the most technologically advanced version of the equipment that can be traced directly back to the original invention of the technique in Australia by john mulvany.

With the equipment described in this document, through experience in its use and interpretation, it is possible to gather with a reasonable degree of confidence the following information about the pipeline being inspected.

Coating fault epicenter location to within a 15cm circle, which means that excavation costs can be reduced.

The approximate severity of the coating fault can be established so that coating faults can be prioritized for repair.

The approximate corrosion behavior of individual coating faults can be established to ease identification of those coating faults that do not have sufficient cathodic protection.

DCVG technique does not however detect metal loss but identifies sites where metal loss is possible.

Identification of where coating faults gets its cathodic protection from, cp that the vulnerability of coating fault to being unprotected if a CP source becomes inoperable can be established.

Identification of coating faults that are discharging or picking up DC Traction interference so that more effective mitigation technique can be implemented.

Establish the effectiveness of insulating flanges.

Identification of interfering structures that robs CP from the pipeline.

Identification of defective test probes at which pipe to soil potentials are routinely monitored.

Rapidly establish sections of pipeline that have a larger number of coating faults by studying the rate of decay of the DC voltage gradient signal on the pipeline.

The data gathered by DCVG technique is not absolute but relative and is influenced by a series of parameters such as soil resistivity, depth of burial etc whose effects must be taken into account to improve the accuracy of any data.

Typical applications of DC voltage Gradient Technology:

Shown below are some typical applications of DC voltage gradient technology to evaluate the protective coatings and cathodic protection on buried pipelines. It has to be remembered that the protective coating on a buried pipeline is premier corrosion protection mechanism but all coatings have coating faults in them. To control corrosion of steel exposed at coating faults, cathodic protection is used. Cathodic protection is supportive technique. The relationship between cathodic protection and protective coatings is important and since DCVG studies this relationship and provides valuable information to control corrosion.

Typical Applications are:

Evaluate pipeline coatings to define rehabilitation requirements.

Define weakness in the cathodic protection system.

Validate that the pipeline has been constructed with minimum coating faults.

Investigate interference effects.

Establish effectiveness of insulating flanges and other methods of pipeline isolation.

Provides data for operating license validation.

Surveying complex pipeline networks not possible by other methods.

Surveying under concrete and asphalt in city streets.

Capable of surveying under over head power lines.

Electrical continuity checking of mechanically jointed pipelines.

Principle of the DCVG Technique:

When DC is applied to a pipeline in the same way as cathodic protection (CP) the current flow through the soil to steel exposed at coating faults generates a voltage gradient in the resistive soil.

The larger the current flowing the greater the soil resistivity and the closer to the coating fault location all give rise to larger voltage gradient.

In general larger the defect, bigger the current flow and hence the voltage gradient, which is used to size coating faults so they can be prioritized for repair.

In the DC voltage gradient technique the DC signal impressed on to the pipeline is pulsed at a frequency of 1. 25 hertz.

The DC signal can be impressed on top of the existing CP system of the pipeline or the CP system itself can be utilized by inserting a special switch or interrupter into one of the output cables from the nearest transformer rectifier.

Only one transformer rectifier nearest to the survey area needs to be interrupted at any one time, thus the limitations of the other over line surveys where all DC influences have to be switched at precisely the same time does not apply for coating fault location.

For more precise and intensive studies it is advisable to interrupt synchronously a number of rectifiers that are affecting the area being surveyed.

For fault location the pulsing DC signal can even be imposed at a test post using batteries or a portable DC generator and temporary ground bed.

Unique feature of DC voltage gradient technique is that the pulsed signal is irregular in shape i. e. switched ON for 0. 45 sec of a cycle and OFF for 0. 8 sec of a cycle.

The irregular pulse allows the direction of current flow to be determined and compared to all other DC influences at an individual coating fault, enabling the degree of protection against corrosion at individual faults to be determined at the time of survey.

To monitor the voltage gradient in the soil the technique utilizes measuring on a sensitive and especially constructed milli voltmeter, the difference in voltage between two copper/copper sulphate half cells placed in the soil at ground level.

When spaced one meter a part in a voltage gradient one half cell will adopt a more positive potential than the other which enables the direction of current flow which caused the voltage gradient to be established.

In surveying a pipeline the operator walks over the pipeline route testing for pulsating voltage gradient at regular intervals.

As coating fault is approached the surveyor will observe the milli voltmeter needle begin to respond to the pulse, pointing in the direction of current flow which should always be towards the coating fault on the pipeline.

When the coating fault is passed the needle direction completely reverses and slowly decreases in amplitude as the surveyor moves away from the defect.

By retracing to the coating fault a position of the electrodes can be found where the needle shows no deflection in either direction (a null).

The coating fault is then sited midway between the two electrodes this procedure is then repeated at right angles to the first set of observations, and where the two midway positions cross is the location of the voltage gradient epicenter.

The coating fault epicenter location is then pegged. In order to determine various characteristics about a defect, such as severity shape, corrosion behavior etc. Various electrical measurements around the epicenter and from epicenter to remote earth are made for detailed interpretation.

Survey Switch (Interrupter):

The survey switch utilizes a solid state device to switch the applied DC at one of two speeds determined by the position of the STD/SLOW switch. The STD/SLOW switch has two positions which represent:

STANDARD (STD) setting 0. 45seconds ON followed by 0. 9 seconds OFF

SLOW setting 0. 9 seconds ON followed by 1. 8 seconds OFF

The STANDARD setting of the switch is used for normal surveying to find coating faults. This speed of switching matches the typical response time of a survey operative.

The SLOW switch position is used in conjunction with a digital voltmeter for pipe to soil potential measurements or current measurements via an inline calibrated shunt.

The interrupter is connected in series into either the negative or positive cables from the DC source being interrupted. The negative cable is preferred. This is setup so that the cable coming from the transformer/rectifier is connected to the BLACK terminal on the interrupter and the cable from the pipe is connected to the RED terminal on the interrupter.

Danger : under no circumstances should the terminals of the interrupter be directly connected across the terminals of the DC power source/ transformer rectifier as this will short out the power source and do serious damage to the interrupter and the DC power source. Also do not under any circumstance connect the DC interrupter terminals to an AC source.

Survey meter:

Survey Meter:

The dominant visible feature of the survey meter is the analogue meter movement. The meter has a center zero needle position. This means that with voltage across the meter input, the needle rests at mid scale irrespective of the range switch position.

The survey meter has the following voltage ranges 10mv, 25mv, 50mv, 100mv, 250mv, 1v, 2. 5v, 4v. the voltage range of the meter can be selected using the voltage range switch sited on right hand side of the meter front panel. The range switches correspond to various ranges or multiples of the ranges on the analogue meter scale.

The 10mv on the voltage range corresponds to the zero to ten milli-volts full scale deflection on the analogue meter (plus or minus 5mv about the center rest position of the meter needle).

The 25mv on the voltage range corresponds to the zero to ten milli-volts full scale deflection on the analogue meter (plus or minus 12. 5mv about the center rest position of the meter needle).

The 50mv on the voltage range corresponds to the zero to ten milli-volts full scale deflection on the analogue meter (plus or minus 25mv about the center rest position of the meter needle).

When not in use the range switch should be turned to the 4-volt range to minimize any chance of meter damage.

Probes and Handles:

The standard probes used with the DC voltage gradient equipment are especially adapted approximately one meter long copper/copper sulphate reference electrodes. The probes are lightweight, high strength tubes fixed at one end to an insulated stainless steel stud that provides both electrical and mechanical connection to the probe handle.

The other end of the probe electrode contains a conductive wooden plug to make electrochemical contact between the soil and the copper sulphate solution/copper electrode. The wooden plug is a push fit into its plastic holder with PTTE tape used a washer. The plastic holder screws onto the probe using a flat rubber washer as the seal.

Only one probe handle is switched on and used at any one time during the survey. The other is used as a spare. Plain handles that have no bias are available since only one bias handle is used at any one time for surveying.

The probe handle has a built in bias that is controlled via an ON/OFF/Range switch and a Bias adjustment potentiometer.

Preparing Equipment For Survey:

Battery charging:

Generally the DCVG meter and the interrupter will require charging more frequently than the handles. Each equipment will require separate continues charging for two days if the batteries are entirely flat.

When operating several sets in order to ensure all components parts of the equipment sets are adequately maintained it is advisable to number each component and set up a charging register to keep a tally of what equipment has been charged when and for how long.

Probes:

A wooden probe tip should first be wrapped around its cylindrical section with white PTFE tape applying sufficient to ensure the wooden tip is a firm push fit into the probe tip holder. All the three holders should and tips should be soaked in portable water overnight. Water uptake causes the wood to expand and give a liquid tight seal.

The copper/copper sulphate probes are filled with copper sulphate solution. The probe is filled almost full of copper sulphate solution through the probe tip holder end. The presoaked tip and holder plus washer are screwed onto the probe to make a liquid tight seal, the probe is inverted to correct position and the handle is screwed.

Surveying

Setting up DCVG signal:

The most important parameter in ensuring an accurate survey and in determining the survey speed is the amplitude of DCVG pulsed signal.

It is worth to spend time during setting up the DCVG signal is atleast 150mv and no larger than 1500mv.

As the signal amplitude or strength vary along a pipeline, the signal strength at start(drain point) should be 1500mv and that at the other should be at least 150mv.

A rapid decay of signal as described as above measured at two locations say would be an indication of poor coating on the pipeline.

The presence of many coating faults or some large drain on the CO system can be expected. Whereas good coating would show very little attenuation of signal amplitude.

The signal strength or amplitude is the difference between ON and OFF potentials measured on the pipe to remote earth, whilst the interrupter is switching ON and OFF the applied DC source.

The amplitude is measured on the DCVG meter as the pulse size, the milli volts size of pulse is determined by measuring the difference in extremities of the pulsing meter needle using the bias and range switches to bring the full pulse onto the meter dial.

The pulse amplitude at test posts measured to remote earth in not the same as the difference between ON and OFF pipe to soil potentials measured only at the test post.

To get full value and meaning from DCVG measurements, the ideal source is CP system itself set at the same level of output as normal operation. Some adjustment to the TR unit output might be required if signal levels are inadequate.

Rectifier:

If there is no CP system installed then a temporary CP system must be setup. Ideally maximum of 50 amperes should be installed.

A temporary ground bed may be steel poles inserted into the soil, or any steel structure such as a fencing post, overhead power line earthing systems, scrap, steel pipe, etc. caution need to be exercised in order not to burn out the interrupter.

The interrupter should be connected into the electrical circuit as shown in the fig, utilizing short wire of optimum 10mm in cross section. The black terminal of the interrupter should be connected to the cable going to the pipeline. The polarity connection in important, if connected around the wrong way the interrupter will not switch the DC output if this happens just reverse the terminal connections on the interrupter.

The interrupter should be inserted with the transformer rectifier set in its lowest output setting and the transformer rectifier mains electricity switch in the OFF position.

For TR with a known output that is less than 25 amperes, after the interrupter has been inserted and the interrupter switch set to the ON position and interrupting speed switch to standard, the TR should be switched on and the output slowly increased to give normal output or higher to give an adequate DCVG signal.

Poor temporary anode setup is the usual cause of inadequate signal.

With a temporary setup where the DC source are batteries, a welding set or rectifier with no ammeter it is important that the following procedure is followed in order not to damage the interrupter by passing too much current.

Adjustment to ensure good signal require trail and error and patience but extra time spent in setting up the signal will give greater confidence in the quality of the survey, which is usually achieved at a greater speed than on pipelines with a poor signal.

Measurement of the signal level at test posts are carried out in exactly the same way as , measurements made to measure pipe to soil potentials, except there are two measurements in this case :

From the copper wire or test post terminal to the soil alongside the test post.

From the soil position alongside the test post to remote earth.

Assembling the DCVG equipment:

Thr reference probes previously filled with cu/cuso4 solution and fitted with tips are screwed onto the probe handles.

The meter strap is placed around the neck and waist so that the meter fits snugly on the operator.

The connecting leads are fitted into the meter and into the probes to interconnect the two probes to the meter. The meter function switch is then turned ON and the range switch adjusted from 4volts to 1000mvolts.

With the probe tips placed in the soil the bias to the right hand probe is switched ON. The bias to the left hand probe is not switched on, it is a spare available if needed, also to increase the amount of bias available should that from one handle not be sufficient because of large background DC in the soil.

Move to the test point at which the signal is to be measured. With right hand probe make contact with the soil and with the left hand probe or with the plug end of the left hand cable, make connection to the test point wire. Adjust the right hand bias control knob and meter range switch until the full extent of the meter needle deflection is visible on the meter scale.

Adjust the meter range until the deflection cane be read accurately . if for example the meter is on the 1000mv range and the mater needle deflection is from 225mv in the OFF position to 850 mv in the ON position , the signal on the pipeline at the test post is 850-225= 625milli volts.

Having measured the pipe to soil signal strength there is another measurement that to remote earth which must be added to that from pipe to soil to give the full signal strength at the test post.

In measurement to remote earth the probes are used like a set of dividers by starting at the soil position at the test post and moving away at right angles, summing the voltages observed for each position of the half cells. Remote earth is reached when two or more readings small in size are the same.

The signal strength should be noted at every test post and all other potential monitoring points along the pipeline route. Measurements must be taken at either end of a section under

Overline To Remote Earth Potential Measurement.

Survey as well as the distance apart, as these readings are required for calculating pipe to remote earth potential.

Similar measurements to that described above are taken from the coating fault epicenter at ground level to remote earth at every coating fault and are used in calculating the coating fault severity.

Operating instructions:

Finding a defect:

Adjust the meter a range switch to the 100mv range, and ensure that only one handle bias switch is ON adjusted to position 3. This is all that is necessary for normal surveying.

Place the probes one in front of the other. Contact the soil with the probes approximately at 1. 5 to 2meter spacing. Turn the bias control potentiometer to bring the needle of the meter onto the scale. Keep the needle on the meter scale the whole time the probes are in contact with the soil. Look for the meter needle to be flicking in response to the pulsed DC.

Lift the probes srep out from the test point at which the signal strength was previously measured. Move forward 2 paces and contact the ground with the probes. Use the bias if necessary to bring the meter needle onto the scale. Look dor a needle deflection. If there is no deflection then step out another 2 paces and then bring the needle onto the scale with the bias control.

If there is a deflection observes the needle to see which direction the coating fault lies. If you are unsure either change to a lower meter scale or move the probe forward along the pipeline. The meter needle points to the probe, which is nearest to the defect.

The interrupter if OFF for longer than for what it is ON and when it is ON the current normally flows through the ground towards the defect. It is the size and direction of the needle flick or swing that you are interested in. it may be possible that the coating fault is small and lies behind you so correct identification of direction of the needle swing.

If you observe a deflection lift the probe which is closest to the coating fault and move it 0. 5meter towards the defect. Bring the second probe forward and place it where the first probe used to be keep moving forward in this manner.

As you move towards the defect the amplitude of deflection will increase so there may be a need to change to a higher range required.

When the coating fault is passed the needle deflection completely reverses and slowly decreases as you move away from the defect. Retrace the steps to the suspected coating fault position where the change in meter needle direction occurs. At the approximate null position with the probes at about 1, 5 meters apart observe any meter deflection. If the deflection is from left to right move the left probe 15cm to the right hand probe. At the point of no deflection, the coating fault location lies midway between the two probe locations. Scratch a mark on the ground at the midway position.

Turn through 90 degrees to work across the pipeline direction. Stand facing the mark in the ground and repeat the coating fault location process described above. At the new null position mark the midway position between the probes on the ground to cross the first mark. Recheck the first mark by turning back to the original position and checking for the null. Where the two lines cross is above the centre of the coating fault voltage gradient and is called the coating epicenter. As a final check that the location is correct, place one probe at the epicenter and the other about 1. 5 meters away placed in turn at the four points of the compass. At each of the four locations the meter needle should indicate a direction towards the coating fault epicenter. If this is not the case then the epicenter has been incorrectly located or the coating fault location is at one end of a long crack in the pipe coating.

Determining the Coating Fault Severity:

Coating fault severity which is related to its geometric size although there are other influencing factors is determined from electrical measurements taken at the coating fault epicenter.

The size/importance or severity of a coating fault titled %IR is calculated by expressing the over line to remote earth potential as a percentage of the actual pipe to remote earth potential (the signal amplitude) on the pipeline at the defect

Once all information about a coating fault has been logged continue surveying along the pipeline route.

A special but common type of voltage gradient encountered during the surveying has a long sausage shape generated by longitudinal crown cracking in coal tar, ruffling in tapes, and micro porosity in asphalt coatings or where many small coating faults occur in close proximity. Whilst this type of coating fault is often missed during CIPS or Pearson surveys, their presence can readily be recognized by DC voltage gradient technology because such coating fault have strong lateral voltage gradients.

Coating fault size shape and location on the pipeline:

A good indication of a coating fault size, shape and location around the circumference of a pipeline can be gained by plotting of the equipotential lines of the voltage gradient at a coating fault in the soil surface. Start by plotting at a plotting at a point equivalent to 30% of the over line to remote earth potential. Track the equipotential line by the nulling method around the coating fault epicenter all way back to the start point placing markers on the way. The line will indicate the size and shape of the coating fault. The distance from the epicenter to the pipe centre line as determined by a pipe locator will determine whether a coating fault is on the bottom, side or top of the pipeline but this is an awkward way of determining this.

A small discrete coating fault on the top of the pipe will appear as a circular is potential shape. The same sized coating fault on the bottom of the pipe will appear as an ellipse, distorted to one side of the pipe center line.

Because the effect the pipe itself has in distorting the isopotential lines from the pipe centre line, it is easier to determine the location of a coating fault around the circumference of a pipeline on large diameter pipelines than on the smaller diameter pipelines.

Some examples of isopotential plots of coating faults of different shape on a pipeline are shown in figure

An alternative way of determine the orientation of a coating fault is to carry out the four points of the compass readings at each location keeping the probe spacing the same for all four measurements. If the coating fault is on the top of the pipe all four readings will be of similar amplitude. If the two readings to the side are much larger than those taken down the length of the pipeline then the coating fault is on the bottom segment of the pipeline. If one side reading is larger than the other then the coating fault is on that side of the pipeline.

Calculating the severity of coating faults:

The relative severity of a coating fault is expressed by the term %IR, which is calculated using the following formula:

Fault epicenter to remote earth * 100

Coating fault severity (%IR) = ———————————————————-

Calculated pipe to remote earth

OLRE*100

In short version, %IR = ———————-

P/RE

Calculation of the pipe to remote earth potential is an important figure needed to calculate the severity importance (%IR) value for a defect. To be able to calculate the severity of defects it is necessary to know the distance of defects and the DCVG signal strengths at test posts either side of the sector being surveyed.

The pipe to remote earth potential (P/RE) is calculated as follows

P/RE = S1- dx(S1-S2)

D2-D1

S1= signal at upstream test post in = 800mv

S2= signal at downstream test post in = 300mv

D1= distance of upstream test post = 0m

D2= distance of downstream test post= 1000m

dx= distance between upstream test post and defect = 400m

the severity (% IR) is calculated as

over line to remote earth from the figure is 130milli volts

pipe to remote earth calculated above in 12. 0 from figure given then % IR

130 * 100

%IR = ————– = 21. 7

600

Deciding Which Coating Fault To Excavate And Repair:

The coating fault grading is

0-15%IR characterized as a small coating faults. Such coating faults can usually be left unrepaired provided the CP system of the pipeline is in good condition and there are not too many small coating faults in close proximity.

15-35%IR characterized as medium coating faults. These may need repair usually within normal maintenance activities

35-70%IR characterized as medium large coating faults. These faults need to be excavated for inspection and repair in order to fix what could be considered a significant coating fault.

70-100%IR characterized as large coating faults. These coating faults should be excavated early for inspection and repair.

The characterizations of coating faults given above are only one input but a very important input to the excavation and repair decision. Other important factors are shape and method of coating failure, corrosion behavior, soil PH and resistivity, presence of hydrogen sulphide in the soil, operating temperature, age. Coating type, leak and metal loss history etc.

DCVG data for on shore pipeline:

SNO

Chainage

(Km)

ON (-mv)

OFF(-mv)

Potential

Swing(-mv)

OLRE(mv)

Signal

Strength

(mv)

%IR

Remarks

1

0+000

1650

1091

550

2

0+300

20

587. 50

3. 404