PIPELINE
ENGINEERING CAPABILITIES

IEV's high level of engineering services provide a good understanding of the client's needs and is custom-tailored to the client with a high level of quality requirements. IEV's engineers are retained as specialists in corrosion problems and control techniques for pipelines.

IEV Engineers provide expertise in the following engineering works:Soil Corrosivity Survey

- Soil Electrical Resistivity Measurements
- Sulphate Reducing Bacteria (SRB) testing
- Water Content Measurements
- Chemical Analysis (Chlorides, Sulfides, etc.)
- Existence of Stray Current in Soil

❑ **Indirect Pipeline Surveys**

- Close Interval Survey (CIS) Surveys
- Coating Resistance Measurements
- Direct Current Voltage Gradient (DCVG) Surveys
- Alternating Current Voltage Gradient (ACVG) Surveys
- GPS Locating

❑ **Direct Pipeline Surveys**

- Excavate and Inspection
- Coating Evaluation
- Corrosion Measurements
- Corrosion Rate Estimates

❑ **AC Interference Modeling and Mitigation**

- Multi-layer Soil Resistivity Measurements and Modeling
- Electrical Ground Resistance-to-Erath Measurements
- High Voltage Transmission System Analysis
- Modeling of Induced AC and Fault Currents
- AC Interference Mitigation Design

- **Cathodic Protection (CP)**
  - CP Design Survey for Budgetary Cost Estimate
  - Third Party CP Design Review
  - CP Design
  - CP Interference (Stary Current) Investigation and Solution
  - CP Troubleshooting
  - CP Operation and Maintenance
  - Electrical Continuity Testing of Pipeline(s)
  - Insulation Joint Testing
  - Spark Gap Testing
- **Pipeline Coating Rehabilitation**
  - Pipe Excavation
  - Removal and Disposal of Existing Coating
  - Pipe Surface Preparation
  - Pipe Defect Inspection and Repair
  - Stress Corrosion Cracking (SCC) Evaluation
  - Coating Application

1. Soil Corrosivity Survey

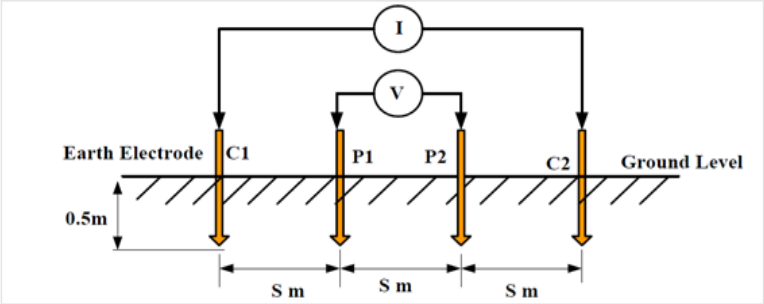
Soil and their inherent properties play a very significant role in aggravating the corrosion process of metallic pipes as they are buried underground. The most common causes of corrosion are:

- Lower resistivity of soil
- Lower and higher pH
- Presence of sulfate-reducing bacteria (SBR)
- Chlorides
- Sulfate and sulfides
- Difference in soil composition
- Differential aeration of soil around the laid water pipes

The most widely known of the approaches to determine the soil corrosivity is the 10-point scoring method proposed by the American Water Works Association (AWWA) and the American National Standards Institute (ANSI).

Soil Resistivity Survey:

Soil resistivity is affected by the soil solution which contain different concentrations of ions (e.g. salts), produced due to the action of the subsurface water on the chemical minerals and the characteristics of soil. The electrical resistivity of soil is influenced by the degree of moisture content in the soil, temperature of the soil, degree of compaction of the soil and concentration of different salts and their movements.



Wenner 4-Pin Method

Soil Moisture Content Measurement:

Prevailing soil moisture content is one of the most important parameter that affects the soil corrosion. At a low percent of soil moisture content, the electrical resistivity of soil is very high and vice versa. When the soil moisture content is less than 20%, there will be a rapid change in soil resistivity. However, when soil moisture content is above 20% the soil resistivity seems constant and falls under the category of low resistivity, which manifests highly corrosive soil environment.

Soil moisture content is also affected by variability of ground water. If the water table is near the top part of the soil, it would normally indicate that the soil has a high percent of moisture content. Higher soil moisture content, on the other hand, indicate that aeration of soil porous media is very low and vice versa.

Soil Resistivity (Ω cm)	Corrosion Classification
Up to 1000	Very severely corrosive
1001-2000	Severely corrosive
2001-5000	Moderately corrosive
5001-10,000	Mildly corrosive
> 10,000	Very mildly corrosive

Soil resistivity values and corrosivity effects (ASTM, 2012).

Soil pH:

Soil pH is a measure of soil acidity or alkalinity and is the measure of hydrogen ions (H^+) and other ions that carry currents in the soil. Carbonic acid, various minerals, organic and inorganic acid (produced by microbial activities, as a result of waste disposal and acid rain) are used to determine the pH value of soil.

A high amount of current carrying ions corresponds to a low pH value and low amount of current carrying ions indicates a high pH. For the current to flow, there must be a potential difference between two points that are electrically connected in the surrounding soil electrolyte. Most often, corrosion occurs through the loss of metal ions at anode areas.

Redox Potential:

Redox potential is a measure of the attraction of substance to electrons (i.e. its electro-negativity) and measured in volts (V). In soil, the oxygen concentration and the soil moisture content determine the redox potential. Higher oxygen content of soil implicates higher redox potential. Lower redox potential indicate less aeration in a soil porous media, which gives a favourable environment for aerobic bacteria to act.

Sulfides Content:

The presence of sulfate and sulfate-reducing bacteria in the soil might be a risk for buried metallic pipes. In a microbial process, sulfate can be converted to highly corrosive sulfide by anaerobic sulfate-reducing bacteria. Hence, detailed analysis and testing for microbial activities by analyzing soil samples for presence of sulfides content may indicate the corrosiveness of the soil due to the sulfides content.

Chloride Content:

Low levels of chloride tend to cause general corrosion while high levels of chloride likely induce localized corrosion. The chloride concentration also increases the corrosion rate.

Soil Corrosivity by Chloride Content in Soil

Chlorides (mg/kg or ppm)	Corrosivity
> 5,000	Severe
1,500 – 5,000	Considerable
500 – 1,500	Corrosive
100 - 150	Negligible

10-Point Scale for Soil Corrosivity
American Water Works Association (AWWA C105)

Soil Resistivity	Points	pH	Points	Redox Potential	Points
< 700	10	0 -2	5	> 100 mV	0
700 - 1,000	8	2 - 4	3	50 - 100 mV	3.5
1,000 - 1,200	5	4 - 6.5	0	0 - 50 mV	4
1,200 - 1500	2	6.5 - 7.5	0	Negative	5
1,500 - 2,000	1	7.5 - 8.5	0		
> 2,000	0	> 8.5	3		

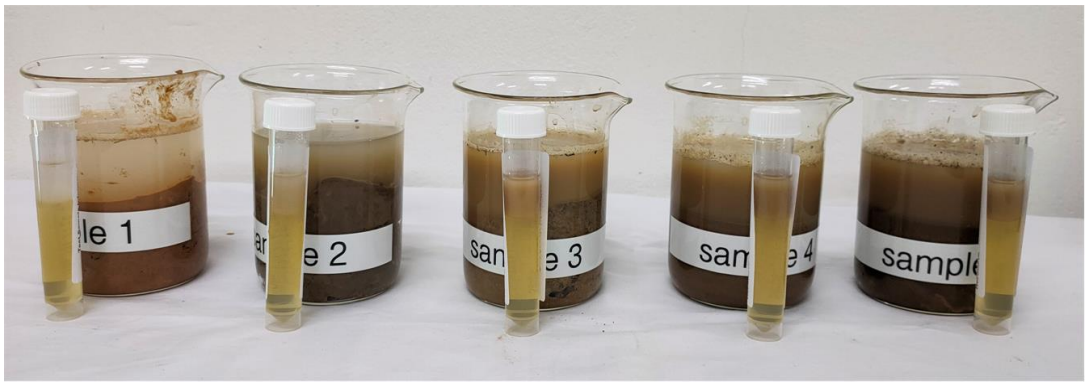
Sulfides	Points	Moisture	Points
Positive	3.5	Poor drainage, continuously wer	2
Trace	2	Fair drainage, general moist	1
Neagtive	0	Good drainage, generally dry	0

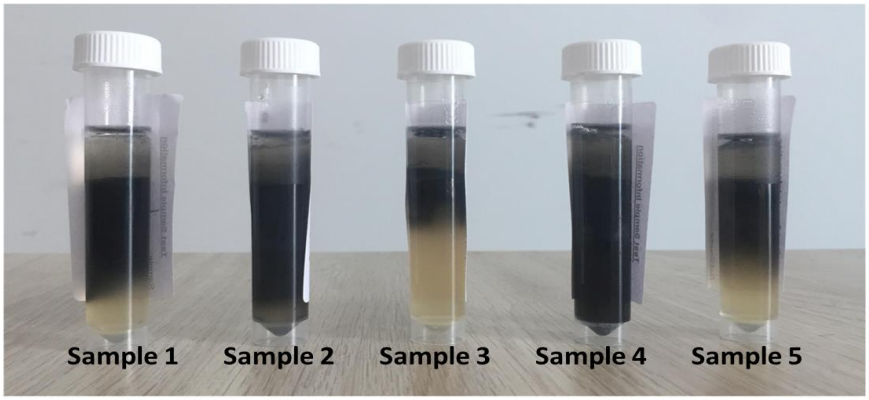
10 points or more → Corrosive Soil

Below 10 points → Not Corrosive Soil

Microbiologically Influenced Corrosion (MIC) Testing

Sulphate Reducing Bacteria (SRB) Test





More back color contains more SRB.

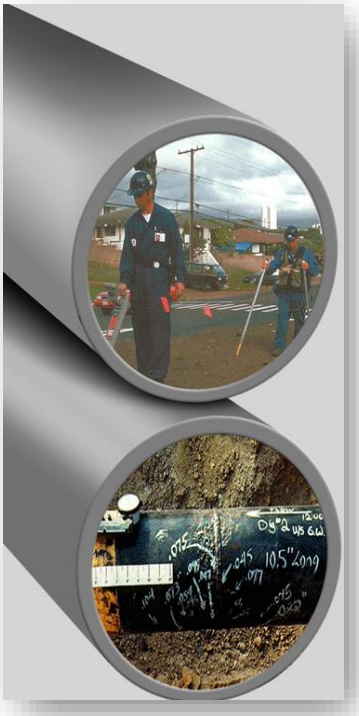
2. Indirect Pipeline Surveys

Close Interval Surveys (CIS)

A **close interval survey** (CIS) is a measurement tool used to ensure the cathodic protection system for the buried or submerged pipeline is operating to the CP Criteria (-0.85V CSE).

Coating Resistance (Conductance) Measurement

A coating's resistance decreases greatly with age and directly affects pipe-to-soil resistance. With the coating deterioration caused by lower resistance, the amount of cathodic protection current to protect the pipeline increases. In addition, the CP attenuation increases, resulting in poor CP current distribution from a single anode groundbed location.



Direct Current Voltage Gradient (DCVG) Surveys

Unlike Close Interval Potential Surveys, Direct Current Voltage Gradient (DCVG) surveys do not involve an electrical connection to the pipe, other than, temporarily, to determine IR drop values at pipe connection locations. Instead, readings on DCVG surveys involve soil-to-soil potential difference measurements, as opposed to pipe-to-soil potential difference measurements.

DCVG surveys are typically performed on well-coated pipelines with a view to determining the location of coating-related anomalies (defective areas).

Alternating Current Voltage Gradient (ACVG) Surveys

Similar to a DCVG survey, **Alternating Current Voltage Gradient (ACVG) Surveys** utilize an alternating current signal applied to the pipeline to create the voltage gradient at the location of a coating holiday.

2. Direct Pipeline Surveys

- Excavate and Inspection
- Coating Evaluation
- Corrosion Measurements
- Corrosion Rate Estimates

Coating Evaluation

A coating's resistance decreases greatly with age and directly affects pipe-to-soil resistance. With the coating deterioration caused by lower resistance, the amount of cathodic protection current to protect the pipeline increases. In addition, the CP attenuation increases, resulting in poor CP current distribution from a single anode groundbed location.

Coating Thickness Measurements

Magnetic film gages are used to nondestructively measure the thickness of a nonmagnetic coating on ferrous substrates. The thickness measurements determine the quality of coating application based on the product specification.

Coating Adhesion Testing

Pull-off adhesion tester using a dolly is used to determine the adhesion strength of the coating. Since surface preparation and coating application are by far the most expensive and difficult portions of any coating work, the poor surface preparation may be the source of most coating failures.

Coating Damages

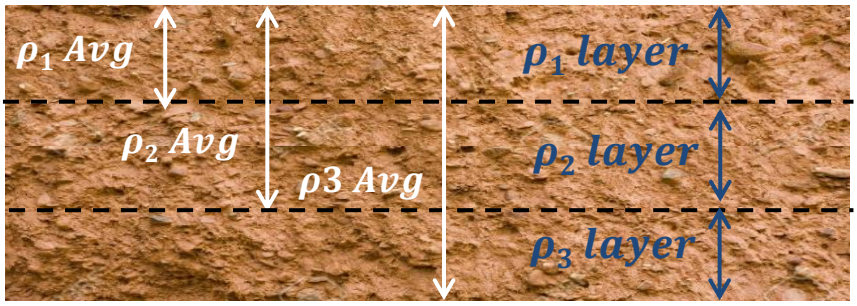
The coated pipeline is subject to abrasion, impact or mechanical damage during the installation. Using a coating holiday detector, any small damages are found in addition to visual inspection.

AC Interference Modeling and Mitigation

Whenever buried pipelines and overhead High Voltage AC transmission systems share a common right of way there is a potential concern with AC interference - the electrical interaction of the two systems—and the adverse impact that it might have on the pipeline.
As a result, the pipeline can incur high induced voltages and currents due the AC interference. The induced voltage on pipeline can be dangerous for operator to touch the pipeline as well as pipe corrosion can result from AC discharge.

To mitigate the problem, the following parameters need to be determine:

1. Multi-layer Soil Resistivity Measurements and Modeling

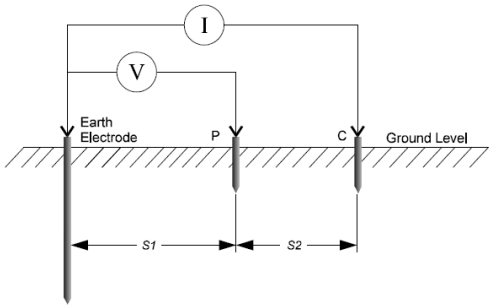


Barnes Method to calculate "Soil Layer Resistivity"

2. Electrical Ground Resistance-to-Erath Measurements

Fall of Potential Method is one of the most common methods employed for the measurement of earth resistance and is best suited to small systems that don't cover a wide area. It is simple to carry out and requires a minimal amount of calculation to obtain a result.

This method is generally not suited to large earthing installations, as the stake separations needed to ensure an accurate measurement can be excessive, requiring the use of very long test leads.



3. High Voltage Transmission System Analysis

4. Modeling of Induced AC and Fault Currents

Based on the results obtained, AC Interference Mitigation method will be designed.

Cathodic Protection (CP)

CP Design Survey

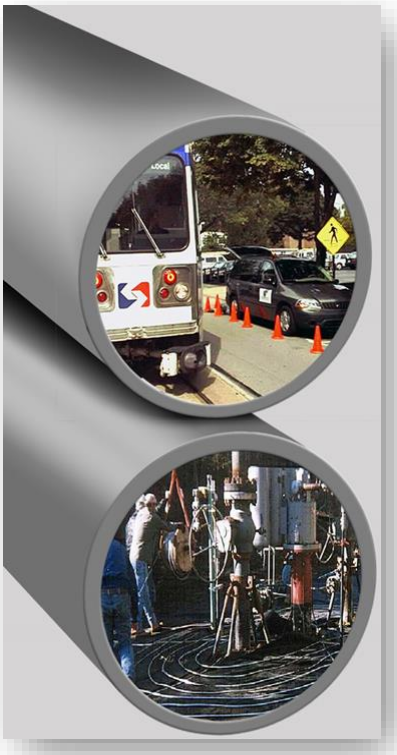
- Anode groundbed locations based on the CP attenuation
- Test station locations

Third Party CP Design Review

- Review all design calculations including the design life
- Evaluate the CP attenuation
- Review the materials used for the project
- Set up the QC program for the materials and installatio

CP Design

- Make all design calculations to meet the project requirements.
- Determine the life requirements for CP materials and testing if necessary.
- Determine the type of test stations.



CP Interference (Stary Current) Investigation and Solution

Stray current is current which flows through paths other than the intended circuit. Once stray current flows onto a nearby underground metallic structure, it will cause severe corrosion in areas where it leaves the structure to reenter the earth. And this corrosion rate is many times greater than the natural corrosion rate.

CP Troubleshooting

In order to ensure corrosion control of underground or submerged metallic structures, adequate cathodic protection is a must. So, periodic function testing and troubleshooting of applied cathodic protection systems is required to ensure correct operation of the system.

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