
Corrosion Control and Monitoring**ENGINEERING PROCEDURE**

1.0 SCOPE

This Engineering Specification includes external, internal and atmospheric corrosion control and monitoring for DOT Regulated pipelines.

Design, construction, construction inspection, construction acceptance, operation and maintenance of DOT Regulated pipelines are covered by this Plant Engineering Specification.

2.0 GENERAL

All DOT Regulated pipelines in the YOUR COMPANY will require protection from the environment.

Pipeline streams that contain corrosive elements must have those elements neutralized or the pipe material must be resistant to the corrosive elements.

Determination of the type of protection required will be made by a qualified Corrosion Engineer who will include at least the following considerations:

2.1 External Corrosion Control:

2.1.1 All buried DOT Regulated pipelines will be coated with a coating system that is approved for the operating environment of the pipeline.

2.1.2 All buried DOT Regulated pipelines will be cathodically protected.

Approved: _____ Date: _____
Manager Safety, Health, and Environmental

Approved: _____ Date: _____
Environmental Manager

2.2 Internal Corrosion Control:

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2.2.1 Known corrosion rate based on historical data or,

2.2.2 Corrosion rate based on data from a national standard data base or,

2.2.3 Data collected from laboratory prototype testing.

2.3 Atmospheric Corrosion Control:

2.3.1 All aboveground DOT Regulated pipelines will be coated with a coating system that is approved for the operating environment of the pipeline.

3.0 REFERENCES

Corrosion control systems will be designed, maintained and operated in accordance with Company Engineering Specifications and the latest addition of the following specifications.

3.1 NACE RP 0169 (83)

3.2 SSPC-SP-5,6,7,10

3.3 Recommended Practices and Test Methods for Coating Systems are listed in Appendix A of this document

4.0 SERVICE CONVERSIONS

Any pipeline that is considered for conversion from one service to another will be reviewed by Plant Engineering and must be approved by the Operations Manager.

As a minimum the following items must be addressed:

4.1 Corrosion damaged by the previous service.

4.2 Corrosion control system requirements.

4.3 Coating system condition.

5.0 PERSONNEL REQUIREMENTS

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- 5.1 Engineering design for corrosion control systems will be performed by a Corrosion Engineer trained and experienced in the type of corrosion control systems that are being used.
- 5.2 Coating, lining and painting inspection will be performed by an inspector trained and experienced in the inspection of coatings, linings or paints.
- 5.3 Cathodic protection installations will be inspected by an inspector trained and experienced in cathodic protection inspection.
- 5.4 Internal corrosion monitoring installations will be inspected by an inspector trained and experienced in internal corrosion monitoring inspection.

6.0 DESIGN REQUIREMENTS FOR EXTERNAL CORROSION CONTROL SYSTEMS**6.1 Cathodic Protection Criteria**

- 6.1.1 Buried onshore pipelines shall have a pipe-to-soil potential that is more negative than -0.850 volts with reference to a standard copper/copper sulfate half cell. For impressed current systems, the potential shall be taken immediately after the current supply has been interrupted.
- 6.1.2 Offshore pipelines shall have a pipe-to-water potential that is more negative than -0.800 volts with reference to a standard silver/silver chloride half cell. For impressed current systems, the potential shall be taken immediately after the current supply has been interrupted.
- 6.1.3 Tank bottoms shall have a steel-to-soil potential that is more negative than -0.850 volts with reference to a standard copper/copper sulfate half cell. For impressed current systems the potential shall be taken immediately after the current supply has been interrupted.
- 6.1.4 The potential on the pipeline shall not be more negative than -1.5 volts referenced to a standard copper/copper sulfate half cell.

6.2 Coating Requirements

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6.2.1 All new buried pipeline sections shall be coated. Coating systems reduce the amount of current required to protect buried pipelines.

6.2.2 Coating systems should be one of the following types:

1. Fusion bonded epoxy
2. Coal tar epoxy
3. Polyolefin tape
4. Prefabricated Films

6.2.3 Other types of coating systems shall be tested in accordance with standards listed in Appendix A of this specification and require the approval of Plant Engineering.

6.2.4 Surface preparation shall be compatible with the coating system to be applied. Additional information on surface preparation can be found in Appendix B of this specification.

6.3 Methods Used for Cathodic Protection

6.3.1 Galvanic Anode Systems provide protection to the structure by the potential difference generated by the electrochemical reaction between the structure, the anode and the soil or water in which the structure is located. Galvanic anodes, singularly or in groups are typically used in soils or waters with resistivity less than 5000 ohm-cm.

6.3.2 Impressed Current Systems use external sources of DC power, usually an AC/DC transformer with an AC to DC rectifier, to provide the driving voltage to the structure to be protected. The negative terminal of the DC power source is connected to the structure with a suitable cable and the positive terminal is similarly connected to the anode bed. The potential difference impressed between the anode bed and structure causes the current to flow from the anode bed into the soil and onto the pipeline thereby stopping corrosion on the pipe.

6.4 Equipment

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6.4.1 Galvanic Anode Systems are simple systems that have the following components:

1. Galvanic anode - magnesium onshore and Galvalum III offshore.
2. Junction box/test station where the leads from the structure and anode are connected.

6.4.2 Impressed Current Systems are more complex than galvanic systems and are available in several types. At LCCC we will only consider transformer/rectifiers that are powered by available AC power. Transformer/rectifiers have the following components:

1. DC transformer/rectifier (supplied as a Unit).
2. Anode bed with anodes made of an inert or low reactivity material.
3. Terminal box with adequate number of resistors for adjusting current flow to each anode or anode string.

6.4.3 All AC powered and permanently installed instruments will have lightning arrestors installed.

6.4.4 Electrical Isolation shall be provided for all new installations. Isolation locations will be determined by the Corrosion Engineer and will be based on current distribution requirements. The following hardware may be used to provide electrical isolation:

1. Insulating flanges may be used when the product is electrically non-conductive.
2. Insulating spools must be used when the product is electrically conductive.

6.4.5 Bonding Stations are used to connect two or more adjacent structures when one or more of the structures are cathodically protected and

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interference could be a problem. Bonding stations are electrical terminal boxes fitted with variable resistors used to control the current flow between the structures. Resistor settings are based on the outcome of interference testing described in Appendix C of this specification.

6.4.6 Test Stations are electrical terminal boxes where an electrical cable is brought from the buried structure to and aboveground terminal box to facilitate cathodic protection testing. Test stations shall be installed at approximately one mile intervals on pipelines.

6.4.7 Each cathodic protection installation shall have the following documentation:

1. Rectifier and/or anode bed data sheet
2. Bonding station data sheet
3. Test station data sheet

6.5 Impact on operating equipment

6.5.1 The design of cathodic protection equipment shall include safety requirements of the area in which it is installed. The NEMA electrical class must be applied to impressed current equipment and all terminal boxes, bonding station and test stations.

6.5.2 Every effort shall be made to install cathodic protection equipment in locations that will not require hot work permits to perform monitoring. Some monitoring activities will have the potential to generate sparks.

6.5.3 Cathodic protection anode beds shall be located to minimize the effect on other structures. Testing to determine locations is discussed in Appendix E of this specification.

6.6 Interference testing shall be performed on all equipment that could be damaged by the new cathodic protection equipment. Interference testing is described in Appendix E of this specification

6.6.1 Interference testing shall be performed on but is not limited to the following situations.

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1. Pipelines crossing within 5 feet.
2. Metal structures within 5 feet of the pipeline.
3. Metal structures within 200 feet of the anode bed.

6.7 Design capacity of the cathodic protection system shall allow for current loss through interference bonds and future loss due deterioration of coating systems.

6.8 Casings installed for protection of the carrier pipe shall be minimized. When casings are necessary, interference testing shall be performed in accordance with Appendix E of this specification. Bonding stations shall be provided on each casing.

7.0 DESIGN REQUIREMENTS, INTERNAL

7.1 Pipeline streams with corrosive elements can cause two problems for the carrier pipe. Products of corrosion may cause pipeline stream contamination that reduces quality or it may cause deterioration of the pipeline by general thinning or pitting action, or both. Corrosive elements that should be considered are listed in NACE RP 0175 paragraph 3.2.1.1.

Pipeline streams with corrosive elements shall be handled in one of the methods below:

7.1.1 Corrosive elements can be neutralized by chemical inhibition or by removing the corrosives elements from the pipeline stream. When inhibitors are recommended, the equipment for holding, transferring and injecting the inhibitor shall be included in the design. The inhibition program shall be provided as part of the design package or;

7.1.2 Pipe shall be manufactured of a material that is corrosion resistant for the corrosive elements being carried or;

7.1.3 Pipe shall be lined with a material that is resistant to the corrosive elements.

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- 7.2 The design package shall contain provisions for upset conditions that can reasonably be expected to occur during normal operations or shutdown and startup including emergency shutdown.
- 7.3 The design package shall contain a recommended corrosion monitoring program.
- 7.3.1 When corrosion monitoring equipment is recommended, the equipment shall be included in the design package.
- 7.3.2 Corrosion monitoring equipment shall be installed at the location where the most severe corrosion can be expected to occur. If erosion/corrosion is expected the worst case location shall be selected for monitoring.
- 7.3.3 In all cases, the safety of the personnel performing the monitoring shall be given due consideration. This includes installation of personnel safety devices and platforms required for safe performance of their duties.
- 7.4 The design package shall contain a recommended pigging program if required.
- 7.4.1 When pigging facilities are included in the design package, a pigging procedure shall be provided.
- 7.4.2 Pigging procedures shall comply with the regulations of all local, state and federal jurisdiction.
- 7.5 **Documentation Requirements**
- 7.5.1 Baseline thickness data shall be collected on all new installations prior to the introduction of product into the system. Thickness measurement locations (TMLs) shall be determined by the Corrosion Engineer based on the most probable locations for corrosion or erosion - corrosion damage.
- 7.5.2 Corrosion monitoring data sheets shall be provided for the type of monitoring system installed.

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8.0 DESIGN REQUIREMENTS, ATMOSPHERIC

- 8.1** All above ground pipelines will be coated with a coating system that is suitable for the environment that the pipe is operating in.
- 8.2** Surface preparation shall be in accordance with the coating system manufacturer's recommendations. Refer to Appendix B of this specification for definitions of the types of surface preparations commonly used for pipeline coating systems.

9.0 INSTALLATION**9.1 Quality Control, External Systems**

- 9.1.1** A high level of quality control is essential for efficient corrosion mitigation on pipeline externals. Coating damage increases the current requirements of the cathodic protection system for the lifetime of the system and may result in premature failure of the system. Damage to cathodic protection cables can result in immediate failure of the cathodic protection system.
- 9.1.2** An Inspector trained in the inspection of pipeline coatings shall be present during all field applied coating systems.
- 9.1.3** All field applied coating systems shall be 100% inspected for holidays and repairs to the coating shall be inspected to the same standard as the original coating.
- 9.1.4** Shop applied coatings shall be 100% holiday inspected and shall have mill certification that all holidays were repaired and inspected to the same standard used to test the original coating.
- 9.1.5** All coating material stored at the construction site shall be protected from the elements in accordance with the manufacturer's recommendations.
- 9.1.6** The pad in the pipe trench shall be inspected just prior to laying the pipe in the trench. All trash and construction debris shall be removed.

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- 9.1.7** All cables shall be inspected upon receipt at the job site. Cables shall be free of nicks and damage.
- 9.1.8** All cables shall be 100% inspected for holidays at the mill and shall have mill certification that all holidays have been repaired and were inspected to the same standard as the original cable material.
- 9.1.9** Cables shall be handled with care as to avoid damaging the insulation during installation.
- 9.1.10** Cable splices shall be made aboveground in terminal boxes.
- 9.1.11** If cables are installed in conduit, non-conductive conduit shall be used.
- 9.1.12** Whenever possible, cathode cable connections shall be made above grade. If below grade connections are required, coating shall be repaired in accordance with the original coating manufacturer's recommendations.
- 9.1.13** Transformer/rectifier systems shall be installed by a qualified electrician.
- 9.1.14** Rectifier shall be tested at maximum design load to assure that the DC output meets the manufacture's specifications including the maximum AC ripple. Rectifier efficiency will be calculated and recorded on the rectifier data sheet.
- 9.1.15** Care shall be taken to assure that the positive cable is attached to the anode bed and the negative cable is attached to the carrier pipe.
- 9.1.16** All cables located in terminal boxes shall be labeled to indicate the structure to which it is connected.
- 9.1.17** All test stations and bonding stations and associated hardware shall be manufactured for cathodic protection service.
- 9.1.18** Owners/operators of pipelines that cross the pipeline being installed shall be contacted and given the opportunity to test their equipment before and after the new system is energized.
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9.1.19 Cathodic protection systems shall not be energized until the cathodic protection technician has taken base line readings on the unprotected system. Potentials shall be made at all interference bonds and at all test stations.

9.1.20 Impressed current systems shall be energized at a low current output and the pipeline shall be surveyed and current output stepped up in small increments until protection is achieved. All bonding stations shall be checked for interference problems.

9.1.21 All information developed during the energizing of the system shall be documented and will become part of the original equipment file.

9.2 Quality Control Requirements, Internal

9.2.1 The Corrosion Technician shall inspect all corrosion monitoring installation. Work shall not begin until all design package information, including the manufacturer's recommendations, are at the job site and the Corrosion Technician has reviewed the package.

9.2.2 Baseline data shall be taken prior to introduction of product to the pipeline.

9.2.3 Lined pipelines shall be installed according to the design package recommendations and to any special recommendations provided by the lining manufacturer.

9.2.4 Special attention must be paid to lining repairs of field joints.

9.2.5 All corrosion monitoring devices shall be installed in strict accordance with the design package and manufacturer's recommendation.

9.2.6 All electrical installations shall be made by qualified electricians.

9.2.7 All pre-commissioning steps shall be performed in accordance with the design package recommendation and any recommendations made by the manufacturer.

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- 9.2.8** All information developed during commissioning shall be documented and will become part of the equipment file.

9.3 Quality Control Requirements, Atmospheric

- 9.3.1** No work shall commence until the design package with all of the coating manufacturer's recommendations has arrived at the job site and the coating inspector has reviewed the data.
- 9.3.2** All coating material stored at the job site shall be protected from the elements in accordance with the recommendation in the design package and the coating manufacturer's data.
- 9.3.3** Surface preparation shall be in accordance with the recommendations of the design package.
- 9.3.4** Surface preparation shall be made just prior to installation of the coating.
- 9.3.5** The manufacturer's recommendations for maximum dew point and humidity allowed shall be strictly followed.

10.0 OPERATIONS

- 10.1** Cathodic protection potential surveys shall be performed on cathodically protected pipelines annually in accordance with the Company cathodic protection procedure.
- 10.2** All bonding stations and test stations shall be monitored.
- 10.3** Rectifier output shall be read and documented monthly, changes in rectifier output will be reported to the Sr. Inspector for evaluation.
- 10.4** Deficiencies shall be corrected in timely manner.

11.0 MAINTENANCE

- 11.1** Rectifier stacks shall be tested for proper performance annually.

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- 11.2 Anode bed resistance shall be checked annually.
- 11.3 Insulating flanges and spools shall be checked annually.
- 11.4 Casing insulation shall be checked annually.
- 11.5 All maintenance tests will be documented and added to the equipment file.

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APPENDIX A**COATING REFERENCE INDEX**

<u>TITLE</u>	<u>SOURCE</u>
Material Recommendations in Prefabricated Plastic Films for Pipeline Coatings	NACE MR0274 (latest revision)
Methods of Measuring Leakage Conductance of Coatings on Buried or Submerged Pipelines	NACE 2D157
High Voltage Electrical Inspection of Pipeline Coatings Prior to Installation	NACE RP0274-74
Standard Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel	ASTM G12-77
Standard Test Method for Cathodic Disbonding of Pipeline Coatings	ASTM G8-79
Standard Test Method for Disbonding Characteristics of pipeline Coatings by Direct Soil Burial	ASTM G19-77
Standard Test Method for Water Penetration into Pipeline Coatings	ASTM G9-77
Standard Test Method for Penetration Resistance of Pipeline Coatings (Blunt Rod)	ASTM G17-77
Standard Test Method for Abrasion Resistance of Pipeline Coatings (Rolling Drum Method)	ASTM G6-77
Standard Test Method for Bendability of Pipeline Coatings	ASTM G10-77

TITLE**SOURCE**

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Standard Test Method for Impact Resistance of
Pipeline Coatings (Limestone Drop Test)

ASTM G13-77

Standard Test Method for Impact Resistance of
Pipeline Coatings
(Falling Weight Test)

ASTM G14-77

Standard Test Method for Pipeline Coatings and Patch
Materials Evaluating

ASTM G56-77

Standard Test Method for Joints, Fittings, and Patches
in Coated Pipelines

ASTM G18-77

Standard Test Method of Adhesion of Organic
Coatings

ASTM D2197-68 (1979)

APPENDIX B**SURFACE PREPARATION**

Surface preparation shall be compatible with the coating system applied. Four joint standards by NACE and Structural Steel Paint Council (SSPC) cover the most commonly used surface preparations.

NACE No. 1
SSPC-SP 5

White Metal blast cleaning.

A white metal blast cleaned surface is defined as a surface with a gray-white (uniform metallic) color, slightly roughened to form a suitable anchor pattern for coatings. This surface is free of all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint, and other foreign matter.

NACE No. 2
SSPC-SP 10

Near White Metal Blast Cleaning

A near-white metal blast cleaned surface is defined as a surface from which all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or other foreign matter have been removed except for light shadows, streaks or slight discoloration's (of oxides bonded to the metal) At least 95% of any given surface area has the appearance of NACE No. 1 and the remainder of the areas is limited to slight discolorations.

NACE No. 3

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SSPC-SP 6

Commercial Blast Cleaning

Commercial blast cleaned surface is defined as a surface from which all oil, grease, dirt, rust scale, and foreign matter have been completely removed and all rust, mill scale, and old paint have been removed except for slight shadows, streaks, or discoloration's caused by rust stain or mill scale oxide binder. At least two thirds of the surface area shall be free of all visible residues and the remainder shall be limited to light discoloration, slight staining or light residue mentioned above. If the surface is pitted, slight residues of rust or paint are found in the bottom of the pits.

NACE No. 4
SSPC-SP 7

Brush-Off Blast Cleaning

Brush-off blast cleaned surface is defined as a surface from which oil, grease, dirt, loose rust, loose mill scale, and loose paint are removed, but tightly adhering mill scale, rust, paint and coatings are permitted to remain if they have been exposed to the abrasive blast pattern, so that numerous flecks of the underlying metal are uniformly distributed over the entire surface.

APPENDIX CSAMPLE DATA SHEETS

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Anode Bed Data Sheet.....	20
Galvanic Anode Data Sheet.....	21
Potential Survey Data Sheet.....	22

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RECTIFIER DATA SHEET

Unit ID	Location	Service Date
Manuf.	Model	Serial No.

Structures Protected	
Anode Bed Location	

Input	Output
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AC Volts	AC Amps	DC Volts	DC Amps

Actual Efficiency	$(\text{DC Volt} \times \text{DC Amps}) / (\text{AC Volt} \times \text{AC Amps}) \times 100$

[illegible]

ANODE BED DATA SHEET

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Location	
For Rectifier (Unit ID)	
Type of Anodes	
Type of Anode Bed (V, H or D) ₁	
Service Date:	

[illegible][illegible]

Note 1. V = Vertical, H = Horizontal, D = Distributed

APPENDIX D**PREDESIGN TESTING**

Visual Inspection:

The entire right-of-way should be visually inspected and all structures, including powerlines, that are within 25 feet of the proposed pipe route shall be documented.

Road crossings, rail crossings, bayous and ditches shall be documented including the owner or jurisdictional authority.

Potential Survey:

If possible, a potential should be taken on all structures within 25 feet of the proposed pipeline route. All potentials shall be documented.

A potential grid survey shall be performed in the right-of-way at any location where high voltage equipment could be distributing current to ground (high voltage powerlines, electric trains, electric equipment, etc).

The potential grid shall be at 10 feet intervals for the width of the right-of-way and for 50 feet on either side of the power source. Using two standard copper/copper sulfate reference electrodes, one electrode shall be placed at one corner and a potential shall be taken with the second electrode at each of the other grid locations.

Potentials shall be taken during peak usage if possible.

Soil Resistivity Testing:

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Soil resistivity test provide two kinds of information. Soil resistivity is a key indicator in the corrosive nature of the soil and should also be used to determine the best anode bed site.

In Lake Charles, the water table is high and soil resistivity can reasonably be assumed to be low. Low resistivity soils are considered corrosive and are generally good candidates for anode beds.

Soil resistivity tests shall be performed at each end of the proposed pipeline route and at five mile intervals along the route unless previously documented tests are available and the Corrosion Engineer has confidence that the soil resistivity issue has been adequately addressed and documented.

Soil resistivity tests shall be performed at proposed impressed current anode bed sites. The number of tests required shall be determined by the Corrosion Engineer.

The four pen Wenner method of determining soil resistivity is preferred.

APPENDIX E

TESTING

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Interference Testing:

Cathode field interference measurements (caused by the pipeline) may be conducted by measuring the potential of the foreign structure with respect to a standard copper/copper sulfate half cell placed in the soil at the point where the structures are the closest together, the area of the strongest field. Potential readings shall be taken with the cathodic protection system current alternately off and on. A tendency for interference is indicated if the foreign structure becomes less negative when the cathodic protection system current is turned on.

Anode field interference measurements (caused by the anode bed) may be conducted by measuring the potential of the foreign structure with respect to a standard copper/copper sulfate half cell placed in the soil at the point where the foreign structure is nearest the anode bed and again further from the anode bed. When the cathodic protection system is alternately off and on the following results will indicate a tendency of interference:

1. When the power is on the potential nearest the anode will be more negative than the potential farther from the anode.
2. When the power is off the potentials at both sites will be about the same.

Corrective Measures:

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When interference problems are detected, the owner/operator of the foreign structure must be contacted and invited to participate in the solution.

The usual solution is to install a bonding station with an adjustable resistor and adjust the resistor to allow enough current to flow from the structure to cause the foreign structure to return to its original potential.

A report of corrective measures must be sent to the plant manager with a copy to the owners of the foreign structure and a copy to the equipment file.

Casing Insulation Test:

The pipe-to-soil potential shall be at least 0.100 volts more negative than the casing-to-soil potential (referenced to a standard copper/copper sulfate half cell).