Points to Remember in Design and Installation of CP Systems

Most important stage of the pipeline life is the installation:

a) Casings inhibit CP and should be eliminated wherever possible.

b) Improper coating installation causes increased current required to protect the pipeline.

c) Poor backfill causes coating damage and also increases current requirements. If small areas of pipeline have a high current density requirement, this area can go undetected during normal cathodic protection monitoring at test stations. Conduct a close interval survey every five years.

d) improper test station installation means additional excavation and restoration which can be quite costly. In presence of AC lines consider AC test stations

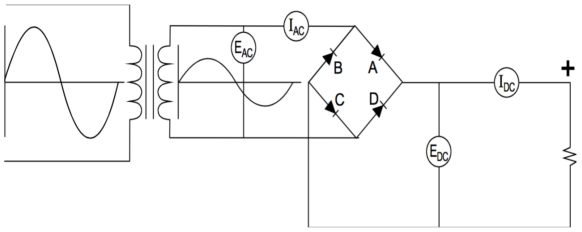
e) Monitoring is essential to maintaining cathodic protection

- Annual survey at test stations
- Bi-monthly rectifier checks
- Close interval survey every 3 to 5 year

Don't Bury Your Problems

Below your feet there is a world of pipe, cable, communication and signal lines that reach across 1,155,000 miles of American soil. Add to that an unknown quantity of storage tanks and other





metallic structures, and you have a fairly elaborate maze of metal that most will never see until something goes wrong. If your industry depends upon the functioning of underground components, you would like to keep it that way. The way in which this can be achieved is Cathodic Protection. ***Cathodic protection is a reduction of the corrosion rate achieved by shifting the corrosion potential of the electrode toward a less oxidizing potential by applying an external EMF (pumping electrons).*** In layman's terms, a uniform and corrosion resistant coating is achieved by applying a negative current to the structure. There is not much argument, at least in the oil and gas industry, about the effectiveness of cathodic protection for extending the life of underground facilities and safeguarding against corrosion attack. For years, these industries have relied

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upon cathodic protection to minimize the catastrophic results that corrosion attack can have upon their miles of pipeline, allowing them to build in environments unimaginable before the advent of such technology. At Matco there are four NACE certified cathodic protection specialists with design, installation, maintenance and failure analysis experience for oil & gas, refining, production and transportation industries.

There are two methods for supplying DC to protect a structure cathodically: a galvanic or sacrificial anode cathodic protection system, and an impressed current cathodic protection system. The designs are based on an empirical model that may consider current and potential distributions. Wrong currents and anode positions may lead to unprotected or under-protected areas. Optimization methods combined with the boundary elements technique have become a useful tool to analyze such situations. The following items should be considered in the analysis:

Optimization methods combined with the boundary elements technique have become a useful tool to analyze such situations. The following items should be considered in the analysis:

Structure geometry, soil properties, environmental parameters and structure coating are salient factors that should be included in any cathodic protection design tool.

Our experts can design and install galvanic and rectifier cathodic protection systems according to your specifications, at a competitive price. Close interval surveys, detailed inspections, and advice for selecting the right inhibitors for cathodic protection is also available.

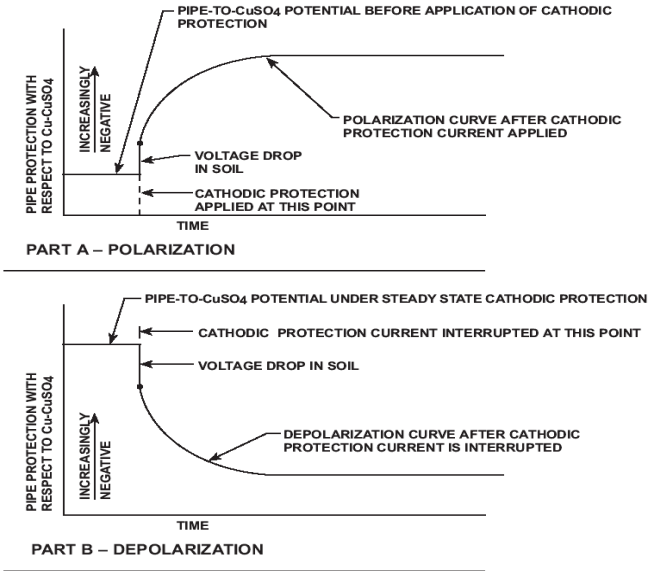
Criteria for Cathodic Protection

Pipe-to-Soil Potential- If a buried pipe line can be maintained at least 0.85 volts negative (IR free) with respect to a copper sulfate reference electrode in the adjacent soil, it is generally considered adequately protected. This is the criterion normally used to check the level of protection on an existing pipeline.

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Potential Change - In the preliminary design of a cathodic protection system based on calculations rather than on field tests, the potential change criterion is frequently used. In this case, a change in potential of at least 0.1 volt in the negative direction with respect to the initial potential may be assumed to indicate adequate protection.

The attenuation equations deal with current and voltage changes in the pipeline; for this reason, the voltage change criterion is readily applicable to calculations involving these equations in charts based on them.

Current Requirements

For bare metal in the ground, a current of 11 to 22 mA/m2 of bare metal surface has been found adequate, except under extreme or unusual conditions. This value must then be modified to suit the particular conditions.

For coated pipe, the current required is difficult to estimate without field tests. The primary reason is the unknown condition of the protective coat which can vary from nearly 0% to 98% coverage. For a fairly new protective coat properly applied,. assume 2 percent bare and 22 mA/m2 for use in tentative calculations. Field test may show that this figure should be modified.

Bare pipelines can usually be protected by 11 to 22 mA/m2. This is seldom justifiable economically for extensive or long lines, however, and the necessary protection is usually afforded by the application of cathodic protection to localized areas called "hot spots."

Bare steel tanks are treated the same as bare pipelines. Inside steel surfaces in contact with fresh water at zero or low velocities require from 22 to 65 mA/m2, depending on the nature of the water. The low value is used for water which is scale forming. That is, the water will form a calcareous coating on the surface of the metal.

Protecting steel surfaces in contact with water in motion presents another problem. Water in motion produces a scouring effect which prevents the formation of the above-mentioned coating and even the formation of a hydrogen film. Therefore, surfaces exposed to water in motion require a higher current density. The amount required is hard to predict. In this case, an experimental determination of the current requirement should be made.

Point of Minimum Protection -

Since potential varies with distance along a pipe line due to attenuation, the point of minimum protection (least negative potential) must be adequately protected to assure complete protection of a pipe line. With a uniformly coated line protected from a single drain point, the point of minimum protection will be the end most remote from the drain points. With a multiple-drain- point system, points of minimum protection will exist between drain points. One of the main problems encountered in field tests on pipe lines is to determine the locations of

these points of minimum protection. Once these points have been located, it is normally a relatively simple matter to adjust the system (assuming it is adequately designed) to achieve adequate protection at these points and thus complete protection of the line.

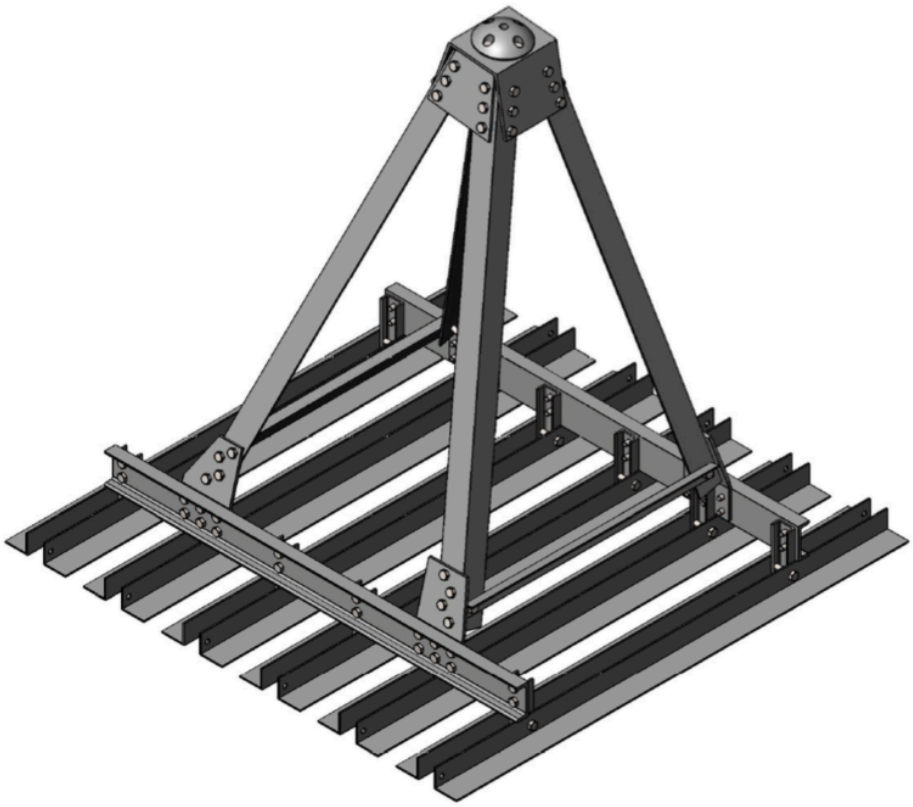
Matergenics Develops Software for Cathodic Protection Design of T&D Structures

Matergenics is developing a practical expert system software for use in cathodic protection design of underground pipelines. This design approach is the only one of its kind that considers the variation in soil resistivity and Shielding in the design of cathodic protection systems

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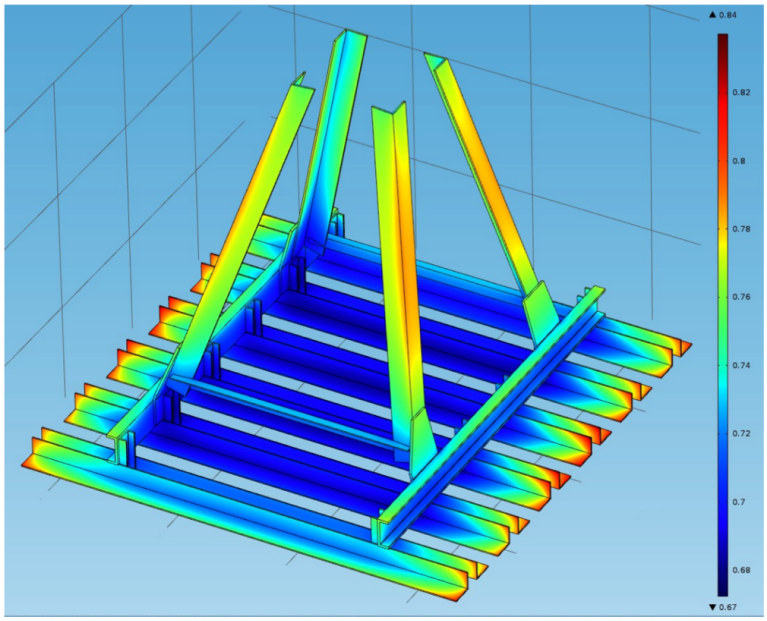


The primary goal in the proposed modeling approach is to find detailed distributions of potential and current density on the buried surfaces of the structure. Such information allows to examine the performance of the cathodic protection system and modify the anode bed design in order to sufficiently polarize the structure in order to meet the NACE criteria for cathodic protection.

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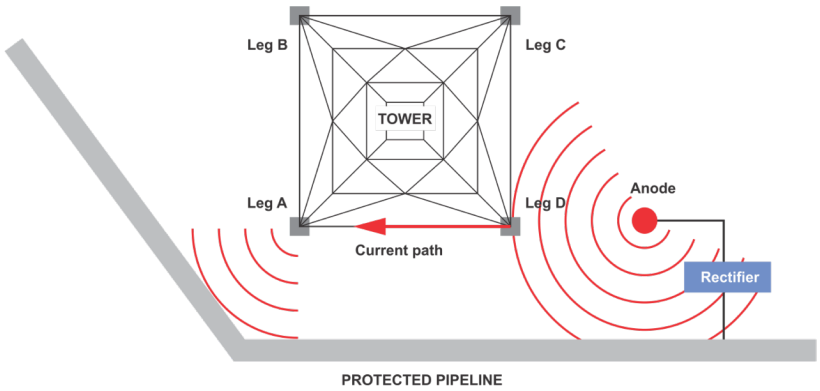


Potential Distribution when you install two vertical anodes

Matergenics is developing a practical expert system software for use in cathodic protection design of underground pipelines. This design approach is the only one of its kind that considers the variation in soil resistivity and Shielding in the design of cathodic protection systems.

Stray Current Corrosion and Lattice Towers

Stray current corrosion caused by interference with ICCP systems can turn into a serious corrosion risk for metallic transmission and distribution (T&D) structures. Depending on the magnitude of stray current, it can result in significant rates of material loss.



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The above figure presents a common scenario for stray current in transmission structures. The source of stray current is the anode bed in the ICCP system for a foreign pipeline. The protection current in soil seeks the path with least resistivity to reach the pipeline, and since a metallic tower is located in the vicinity of the pipeline, it provides a shortcut for the current. The location at which the current is picked up (Leg D) is cathodically protected; however, the location where the current discharged (leaves the structure) (Leg A) is under stray current corrosion

AC Corrosion Interference and Corrosion

Rapidly growing energy demands promote construction of a large quantity of high-voltage transmission lines and buried oil and gas pipelines, the land for energy construction become increasingly crowded. Thus, the steel pipelines and overhead electric power transmission lines have to share proximal rights-of-way. In such cases, the buried pipeline is subject to an alternative current （AC） electromagnetic interference caused by the neighboring power lines, which will result in AC corrosion problems on the pipelines and affect the effectiveness of cathodic protection （CP） system seriously.

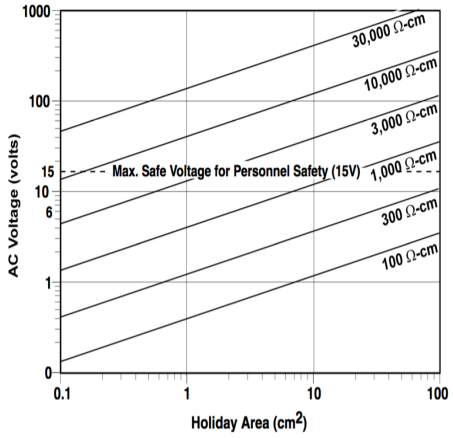


Figure 2-6: AC Voltage vs Holiday Size for i_{AC} = 100 A/m^2

Source: R. A. Gummow, R. G. Wakelin, and S. M. Segall, "AC Corrosion – A New Challenge to Pipeline Integrity," CORROSION/98, paper no. 566, (Houston, TX: NACE, 1998).

The risk of AC corrosion on a cathodically protected structure is a function of the AC current density at the metal/electrolyte interface. Up to an AC current density of 20 A/m^2 (2 A/ft^2), there is "probably no risk" of corrosion using conventional criteria for cathodic protection. At A current densities greater than 20 A/m^2 (2 A/ft^2) and less than 100 A/m^2 (10 A/ft^2), AC corrosion is unpredictable and corrosion was possible. However, with AC current densities greater than 100 A/m^2 (10 A/ft^2), corrosion damage would be expected



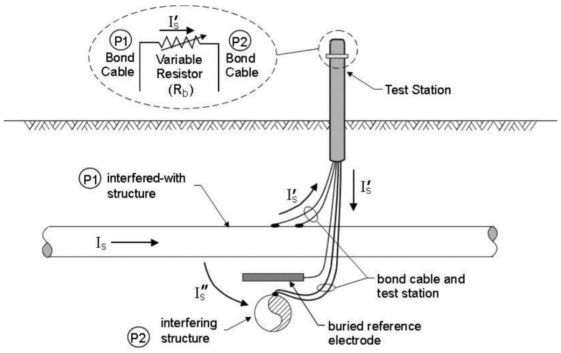
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Test Stations For AC Interference

CP coupons must be made from a metal whose corrosion behavior in the electrolyte approximates that of the structure. Since most cathodically protected buried structures are steel pipelines or tanks, CP coupons are usually made from plain carbon steel. Earliest CP coupons were short steel rods with two lead wires attached. Dual lead wires are used so that the current carrying wire is separate from the wire used to measure potential, thereby eliminating a possible error source. Coupons of this design can be purchased commercially as stand-alone units or attached to a permanent reference electrode by a short lead wire. Ring shaped coupons bonded to the housing of a reference electrode are also available. This design does reduce electrolyte path length between the reference and the coupon, but in many cases, salts leaching from the reference electrode will attack the coupon changing its characteristics.



Attaching a CP coupon to the base of a test station riser can also reduce electrolyte path length. A reference electrode is placed in the riser and the measurement path is through the inside of the riser; in this case the riser is acting as a salt bridge. The only portion of the measurement path where voltage drop error can accumulate is between the bottom of the riser and the exposed coupon. A comprehensive discussion of CP coupon technology can be found in NACE Publication 35201 prepared by NACE TCC Task Group 210[2].

CP for Underground Storage Tanks(UST) and Above Ground Storage Tanks

"UST's are regulated in the United States to prevent release of petroleum and contamination of groundwater, soil and air. The 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA) required the United States Environmental Protection Agency (EPA) to develop regulations for the underground storage of motor fuels to minimize and prevent environmental damage, by mandating owners and operators of UST systems to verify, maintain, and clean up sites damaged by petroleum contamination.

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In December 1988, EPA legislation asking owners to locate, remove, upgrade, or replace underground storage tanks became effective. Each state was given authority to establish such a program within its own jurisdiction, to compensate owners for the cleanup of underground petroleum leaks, to set standards and licensing for installers, and to register and inspect underground tanks.[citation needed]

Most upgrades to USTs consisted of the installation of corrosion control (cathodic protection, interior lining, or a combination of cathodic protection and interior lining), overfill protection (to prevent overfills of the tank during tank filling operations), spill containment (to catch spills when filling), and leak detection for both the tank and piping.[citation needed]

Many USTs were removed without replacement during the 10-year program. Many thousands of old underground tanks were replaced with newer tanks made of corrosion resistant materials (such as fiberglass, steel clad with a thick FRP shell, and well-coated steel with galvanic anodes) and others constructed as double walled tanks to form an interstice between two tank walls (a tank within a tank) which allowed for the detection of leaks from the inner or outer tank wall through monitoring of the interstice using vacuum, pressure or a liquid sensor probe. Piping was replaced during the same period with much of the new piping being double-wall construction and made of fiberglass or plastic materials.



Tank monitoring systems capable of detecting small leaks (must be capable of detecting a 0.1 gallons-per-hour with a probability of detection of 95% or greater and a probability of false alarm of

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5% or less) were installed and other methods were adopted to alert the tank operator of leaks and potential leaks.

U.S. regulations required that UST cathodic protection systems be tested by a cathodic protection expert (minimum every three years) and that systems be monitored to ensure continued compliant operation.

Many owners, who previously stored fuel in underground tanks, switched to above-ground tanks to enable closer environmental monitoring of fuel storage and to reduce costs. Many states, however, do not permit above-ground storage of motor fuel for resale to the public.[citation needed]

The EPA Underground Storage Tank Program is considered to have been very successful. The national inventory of underground tanks has been reduced by more than half, and most of the rest have been replaced or upgraded to much safer standards. Of the approximately one million underground storage tanks sites in the United States as of 2008, most of which handled some type of fuel, an estimated 500,000 have had leaks. As of 2009, there were approximately 600,000 active USTs at 223,000 sites subject to federal regulation. In 2012, EPA published how to screen buildings vulnerable to petroleum vapor intrusion and in June 2015, U.S. EPA finally released its "Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air" and "Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites”

Above Ground Tanks

Since the tank floor is in contact with the sand fill, it would be subject to corrosion. The rate of this corrosion would be dependent on the aggressiveness of the sand fill. To control this corrosion, an impressed current cathodic protection system is required. This system results in effective corrosion control which will in turn result in a longer tank service life, lower API inspection costs and reduced risk of product loss.

Failure Analysis Walkthrough

A thorough analysis of attacks or pipe line failure can often uncover errors in materials selection, design, fabrication or operating conditions. By determining the mode and root cause of failure, information is gained to prevent the recurrence of similar problems in the future.

This introductory survey will acquaint the reader with field and laboratory testing procedures commonly used in failure analysis investigations. Failure analysis is a technique by which facts are gathered and studied to determine the cause of an equipment or part failure so that preventive action may be taken A component is considered to have failed in service when it is damaged to the point of unsafe operation or when it has become only marginally capable of performing its intended function.

FIELD SAMPLING.

Improper sampling jeopardizes all future work. Following these general steps in the field will make good results much easier.



Determine when, where and how the failure occurred. Materials specifications cathodic protection records and service history reveal much about the nature of a failure. When submitting a sample for analysis some background information will need to be provided. Interview all operators involved. Write down the background and history of the failed part. Did the failed part recently come out of overhaul? If so, was the overhaul accomplished in-house or by a vendor? How many times was the part installed after its last shop visit? Was the part stored for an extended period of time prior to installation for an excessive length of time? Were there warning signs that a failure was imminent?

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Take on-site photographs. Before removal of the failed part a photograph of the piece of equipment including the sample(s) should be taken. This will show the relationship of the questioned area to the remainder of the piece of equipment. If more than one sample is to be taken, proper designation of the sample and its location relative to the piece of equipment should be noted. The dimensions and description of the sample should be listed on the photograph as well as the date the failure occurred. The failure analyst should write his own observations, perhaps video tape the disassembly process and take photographs. Always thoroughly label photographs so positive identification of parts can be made. Avoid extreme close-up photographs unless they show important details.



Collect samples for laboratory examination. Mark areas for collection of samples. Marks from lead pencils or other devices that leave, carbon, zinc, copper, or other materials, commonly interfere with later observations. Samples selected should be characteristic of the material and contain a representation of the failure or corrosive attack. For comparative purposes, a sample should be taken from a sound and normal section. Samples can be removed by acetylene torch, air arc, saw, trepan, or drill. However, all cuts made with an acetylene torch should be made at least six inches from the area to be examined. Cuts made by air-arc should be at least four-six inches away from the area to be examined to avoid altering the microstructure or obscuring corrosive attack.



Visually examine the sample. Examine the sample with unaided eye or low magnification field micro- scopes. Note the condition of the accessible surface, searching for cracks, corrosion damage, the pres- ence of foreign material, erosion or wear damage, tooling marks, handling damage or evidence of im- pact or other distress. Also consider the condition of protective coatings. Are they cracked, missing, chipped, flaking, or missing altogether?

LAB ANALYSIS. Lab analysis can refer to many failure analysis testing procedures. A thorough analysis should, however, contain these basic testing procedures: Non-Destructive testing; chemical

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(surface) analysis; SEM/EDS; FTIR; fractography; metallography; fracture mode determination, root cause of failure determination and finally, Finite Element Analysis (FEA)

Cathodic Shielding

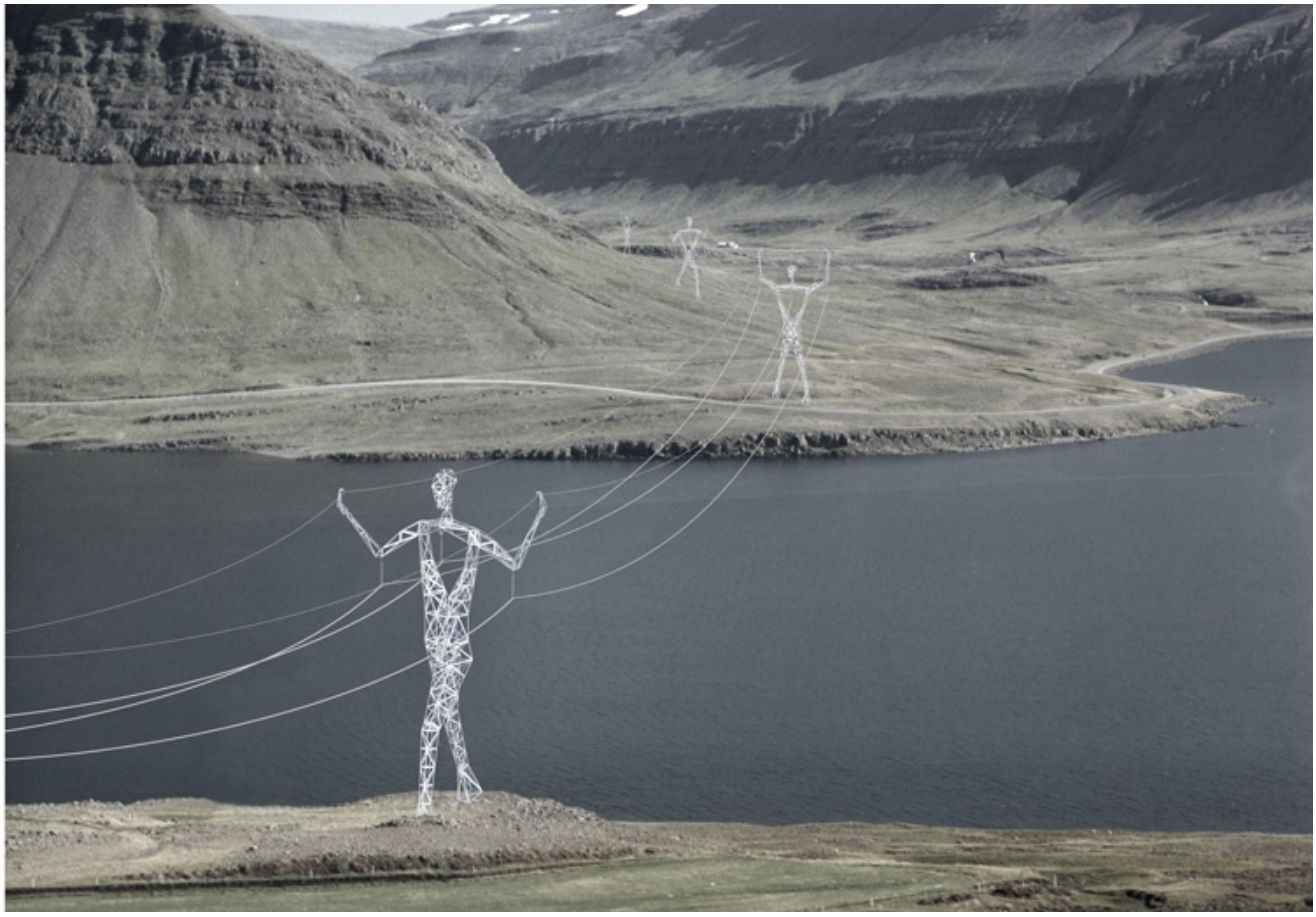
Effectiveness of cathodic protection (CP) systems on steel pipelines can be impaired by the use of solid film backed dielectric coatings such as polyethylene tapes, shrinkable pipeline sleeves, and factory applied single or multiple solid film coatings. This phenomenon occurs because of the high electrical resistivity of these film backings.[47] Protective electric current from the cathodic protection system is blocked or shielded from reaching the underlying metal by the highly resistive film backing. Cathodic shielding was first defined in the 1980s as being a problem, and technical papers on the subject have been regularly published since then.

A 1999 report[48] concerning a 20,600 bbl (3,280 m3) spill from a Saskatchewan crude oil line contains an excellent definition of the cathodic shielding problem:

"The triple situation of disbondment of the (corrosion) coating, the dielectric nature of the coating and the unique electrochemical environment established under the exterior coating, which acts as a shield to the electrical CP current, is referred to as CP shielding. The combination of tenting and disbondment permits a corrosive environment around the outside of the pipe to enter into the void between the exterior coating and the pipe surface. With the development of this CP shielding phenomenon, impressed current from the CP system cannot access exposed metal under the exterior coating to protect the pipe surface from the consequences of an aggressive corrosive environment. The CP shielding phenomenon induces changes in the potential gradient of the CP system across the exterior coating, which are further pronounced in areas of insufficient or sub-standard CP current emanating from the pipeline's CP system. This produces an area on the pipeline of insufficient CP defense against metal loss aggravated by an exterior corrosive environment."

Cathodic shielding is referenced in a number of the standards listed below. Newly issued USDOT regulation Title 49 CFR 192.112, in the section for Additional design requirements for steel pipe using alternative maximum allowable operating pressure requires that "The pipe must be protected against external corrosion by a non-shielding coating" (see coatings section on standard). Also, the NACE SP0169:2007 standard defines shielding in section 2, cautions against the use of materials that create electrical shielding in section 4.2.3, cautions against use of external coatings that create electrical shielding in section 5.1.2.3, and instructs readers to

take 'appropriate action' when the effects of electrical shielding of cathodic protection current are detected on an operating pipeline in section 10.9



Artistic Designs for Transmission Towers (give ref)

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Matergenics and Innovation



Cathodic Protection Design for Water Pump that Failed two Times in one year due to stray current corrosion.

About Matergenics

Matergenics is an inspection and engineering firm dedicated to providing corrosion risk assessment and engineering solutions to clients in materials and energy fields.

We value our clients...

Throughout the years, we have noticed that much of our business comes from repeat customers. Our expertise and computer aided design can account for much of this, but we believe there is something more to it. We attribute it to the fact that we promote an open and friendly environment that is never too busy to meet the needs of our clientele. Whether you are a large corporation or a small enterprise, we will provide you with the attention you need and deserve. In so doing, we hope to work with you for many years to come.

M. Zee, PhD
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NACE Certified Cathodic Protection/Corrosion
Coating/Materials Selection Design Specialist
NACE Instructor for CP1, CP2, CP3, Corrosion Fundamentals
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