

Laboratory and Field Corrosion Investigation of Galvanized Utility Poles

M. Zamanzadeh¹, C. D. Kempkes², D. Aichinger³ and D. Riley⁴

¹MATCO Associates, Inc., President, Department of Research & Development, 4640 Campbells Run Road, Pittsburgh, PA 15205; PH (412) 788-1263; FAX (412) 788-1283; email: zee@matcoinc.com

²Valmont Industries, Manager of Division Quality Systems, 7002 North 288th Street, Valley, NE 68064-0358; PH (402) 359-2201; FAX (402) 359-2201 email: carl.kempkes@valmont.com

³Valmont Industries, Manager of Engineering, Valmont/Newmark, 7002 North 288th Street, Valley, NE 68064-0358; PH (402) 359-2201; FAX (402) 359-2201; email: dick.aichinger@valmont.com

⁴MATCO Associates, Inc., Manager, Sales & Marketing Division, 4640 Campbells Run Road, Pittsburgh, PA 15205; PH (412) 788-1263; FAX (412) 788-1283; email: debra.riley@matcoinc.com

Abstract

Electrical transmission poles are often made of galvanized steel. As a relatively new industry, the steel pole industry is becoming more aware of the potential problems and their solutions associated with underground corrosion of poles. This paper will explore methods to enhance the service life of poles as well as present new findings on how galvanic action can protect the painted portion of a pole in moderately corrosive soils. In general, zinc extra poles, corrosion resistant backfills, maintenance and corrosion monitoring will greatly increase the life of galvanized poles. However, in environments with corrosive reducing soils, stray currents and high water tables, additional protective measures to extend life expectancy are required. Environmental information such as soil resistivity, pH, chemistry, and water tables should be utilized to determine the “hot corrosion spots” and the type of utility pole that should be installed for that particular environment. New findings from field and laboratory work confirm that galvanic action will protect the painted portion of a pole in moderately corrosive soil environments due to cathodic protection by zinc. Case histories for galvanized transmission poles will also be presented.

Introduction

Transmission electric utility poles are generally made of galvanized steel. The steel material conforms to the mechanical and chemical properties listed in American Society for Testing and Methods (ASTM) specification A572-04. The minimum yield strength of this material shall be 65,000 PSI. The maximum silicon content of all steels shall be 0.06 % to ensure an adequate free zinc and uniform galvanized finish.

The galvanized poles are often embedded with the depth dependent on soil strength and applied overturning moment. Galvanizing is to meet the ASTM A123 requirements for pole and A153 for hardware. The Society for Protective Coating (SSPC) SP7 surface preparation will precede galvanizing. Repair of damaged areas can be performed in accordance with ASTM A780. Additional ground line corrosion protection is normally done with either ground sleeves or polyurethane coating.

Galvanized steel first became an important material for pole manufacturers in the 1950's. As relatively new industry, the pole industry is just now becoming aware of possible problems that can be associated with corrosive soils, mechanical damage, storage and stock rotation, ground level and underground/water table corrosion, coatings requirements and interference induced from other structures. Specifications from paint and coating suppliers do not always take these issues into consideration. As a result, the service life of a utility pole can be diminished if the pole specifier doesn't take into consideration the different environments that utility poles can be exposed to.

The Role of Galvanizing (Zinc)

Hot dip galvanizing has been an attractive and economical means of corrosion protection for utility tubular and lattice structures. Galvanized steel poles are protected from corrosion attack due to both barrier effect and also due to galvanic (sacrificial) action of zinc. Zinc does a fine job of protecting a steel pole in moderately corrosive and oxidizing soils. It provides long term protection both above ground and underground portion of poles. We have inspected galvanized lattices in service which date back to early 20th century. Upon inspection we found out that galvanized layer is present even after 100 years of service. The key point in long service life is that the soil in that location provided the protective layer on galvanized surface.

Not all galvanizing facilities are the same, however, and some times the quality of the galvanized layer is compromised due to lack of quality control in the process. The production of high quality galvanized steel poles depends on the metallurgical reaction between steel and molten zinc. The micro-structural characteristics, grain structure (spangle formation), surface segregation and corrosion of galvanized coatings depend on both steel and bath compositions, coating processes and post-coating processing. Factors often associated with corrosion failure of galvanized steel poles are improper thickness, excessive brittle intermetallic alloy layer, galvanizing, substrate surface preparation if coated, storage conditions, soil service conditions, or unsuitable coating selection for the soil exposure in service.

Corrosion Characteristics of Galvanized Utility Transmission Poles

Zinc is a highly reactive metal. It exhibits a low corrosion rate only if a continuous passive film forms on the surface. A key requirement of corrosion control with zinc is that the surface needs to remain largely dry and in contact with the air in order to

develop and maintain this passive film. Storage stain (white rust) is simply the chemical compound, zinc hydroxide/carbonate zinc/oxide zinc, which forms when zinc is kept in contact with moisture during storage or transportation.

Zinc corrosion products are typically white, but under certain conditions may also take the form of a grey or black deposit on the metal surface. Accelerated corrosion of galvanized steel pole, white rust and storage stain (tiger striping) can occur when galvanized surfaces are held for extended periods in wet conditions immediately after the hot dip process. The surfaces may become wet either by rain fall or by condensation. The corrosion products form after zinc reacts with moisture. Corrosive compounds such as chlorides from marine and sulfur containing atmospheres accelerate the formation of white rust.

Utility poles can be divided into three portions as far as corrosion is concerned:

1. Above ground atmospheric exposure.
2. Ground level exposure.
3. Underground soil /ground water exposure.

The extent of the corrosion in storage and transportation is primarily dependent on:

- a) The duration of the exposure to moisture.
- b) The temperature that is experienced during storage or transportation.
- c) The presence of accelerating corrosive agents, such as chloride-containing salts.
- d) Position of galvanized component (vertical or horizontal).
- e) Metallurgical structure of galvanized layer and surface composition.

The surface of the galvanized coating in the area that experiences extensive white rust formation will be “etched” and no longer will have the bright, reflective appearance of as-produced galvanized sheet. In this case removing the white rust will not eliminate the etched appearance. This is why, for applications where appearance is critical, galvanized surfaces should be treated by conversion coatings. The conversion coating (chromate or non-chromate treatment) that preserves brightness also inhibits the formation of storage stain during storage and transportation.

Corrosion Mechanism of Painted and Non-Painted Galvanized Poles Storage Yards

White rust, storage stain and “tiger striping” develop on freshly-coated non painted galvanized surfaces if they are stored in environments that allow drops or thin layers of water to remain on the surface of the zinc before it has developed protective zinc carbonate coating. The presence of moisture either as condensed droplet or thin layer of water on freshly prepared galvanized steel is necessary condition for the formation of white rust. Water drops allow the solution of the zinc metal, changing and increasing the pH within the drops and promoting further accelerated dissolution of zinc, promoting the formation of unsightly corrosion products of zinc.

The diagram devised by Marcel Pourbaix, Figure 1, illustrates the influence of pH on the rate of corrosion and thermodynamic stability of zinc and shows the large increase in corrosion rate in both acidic and alkaline solutions. The shape of the corrosion-rate-versus-pH curve can be explained by the type and form of corrosion products that may be present on the surface. In the near neutral solutions, compact, adherent, insoluble corrosion products retard corrosion. Conversely, in highly acidic or alkaline water, soluble corrosion products are formed, destroying protective films and permitting corrosion to proceed. Water drops allow the solution of the zinc metal, changing and increasing the pH within the drops and promoting further accelerated dissolution of zinc, promoting the formation of unsightly corrosion products of zinc. Localized pH under droplet will markedly differ from normal neutral pH, especially as the freshly prepared galvanized steel dissolves in droplet of water. Conversely, if basic carbonate forms, the increase in pH does not take place and no more white rust forms. In the presence of passive basic carbonate zinc, the corrosion resistance of galvanized layer is increased because of the formation of protective basic carbonate, which extends the region of passivation toward neutral pH values.

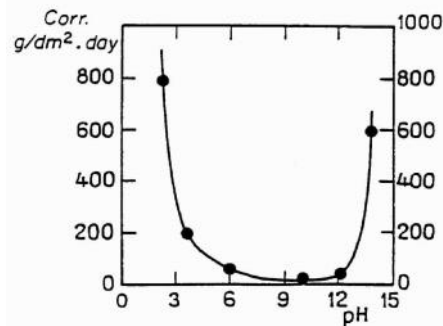


Figure 1: Influence of pH on dissolution (corrosion) rate of zinc. The pH in droplets of water will change according to this diagram.

In the pole manufacturing industry it is customary to coat some or all of the area of the embedded portion of a pole with an organic protective coating. Contrary to popular belief, the main reason for this coating is not because the embedded environment is the most corrosive, rather it is because this area is the highest stress area and it should have additional protection. The coated area of the pole, however, is also susceptible to corrosion attack while in storage.

Field and laboratory studies indicate poles held in storage for an extended period of time experience a different type of corrosion mechanism than when they are service. The corrosion initiates with an accumulation of moisture at pinholes and discontinuities in the coating. This results in the formation of corrosion cells in pin holes, defects, voids, and mechanically damaged areas. As a result, accelerated corrosion of zinc takes place and blistering, cathodic delamination; pitting and eventual failure of the coating will take place. These phenomena also take place if the coating is not a good barrier and or has low thickness. It should be noted, ultra violet (UV) sensitive coatings may also be susceptible to this type of failure. This corrosion mechanism in storage is shown in Figure 2.

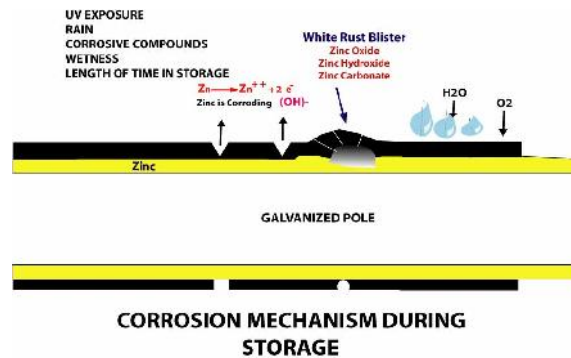


Figure 2: Corrosion mechanism of stored galvanized pole in horizontal position.

Coating and Surface Preparation

Lack of experience in the pole coating industry has resulted in less than adequate specifications for surface preparation and coating formulation for this service. The industry as a whole utilizes the same specifications for underground carbon steel structures as it does for galvanized steel structures. Pole manufacturers follow paint and coating supplier recommendations for galvanized components. As a result, the role of UV damage, a surface profiling technique of 2-3 mils and galvanized cracking, is not taken into consideration.

Surface preparation is a critical factor in achieving good adhesion. The factors that are required for good adhesion are cleaning and profiling of the galvanized steel structure. If both are done correctly a compatible paint/film should not have any problem adhering to the galvanized surface. However, if done incorrectly the galvanized layer or coating adhesion could be compromised.

Metallographic studies of galvanized pole specimens indicate the galvanized surface preparation techniques recommended by paint and coating suppliers can result in extensive cracking and removal of the zinc layer. The cracked areas are known initiation sites for corrosion and delamination of the coating in wet corrosive soils, even after only a few years in service.

Prior to implementing a recommended surface preparation technique, pole specifiers should require paint and coating suppliers to supply independent scientific evidence, such as metallographic cross section analyses, to confirm their recommended practice does not introduce cracking to the substrate surface. Recommended practices should include methods to clean a galvanized surface prior to coating. The goal is to remove any dirt, grease or oils but not to remove too much of the galvanized coating. To obtain good adhesion, the galvanized surface should be slightly roughened to provide a larger surface area of adhesion. Care must be taken not to damage or remove the galvanized coating. Finally, after all the necessary steps have been taken for good surface preparation, the coating itself should be compatible with the galvanized coating to create a synergistic effect.

Polyurethane Coatings and Ultraviolet Radiation (UV)

Polyurethane coatings are typically thermoset resin systems that are created by the reaction of polyols (R-OH) and an isocyanate (N=C=O). Polyurethane resins are then formulated with a variety of materials to achieve a wide range of coating properties. From a pole and their application in service point of view, this coating chemistry has its limitations that should be taken into consideration.

Ultraviolet radiation from the sun in storage can lead to UV damage, decreased performance and an undesirable appearance change in the coating. Photodegradation of a cured polyurethane film can occur by any of two main routes. It is believed that the polymer absorbs UV radiation and produces free radicals that attack the backbone of the polymer via hydrogen abstraction, forming hydro-peroxides and more free radicals. As the process continues, more bonds break, leading to deterioration of the desired coating properties. This degradation can take the form of cracking, checking, loss of gloss, chalking pigment fading, delaminating or peeling, degradation and loss of physical and protective properties of the coating.

From a production point of view the appearance of bubbling in the polyurethane coating is often caused by the presence of moisture, carbon dioxide or air bubbles. However, when the coatings are combined for application they will not show any visual effect. The cured film will have less cross-linking and so the effect will be more noticeable by soft and poor solvent resistance performance than a similar formula that is free of moisture or air. The bubbling of cured coatings may be more of a result of moisture trapped on the substrate than actual moisture introduced by the coating. As the coating ages due to weathering the adhesion fails and moisture/water will cause the spots to form blisters and delaminate.

The thickness of the coating also plays an important role in whether or not a pole will corrode in service. Some coating suppliers, however, do not conduct testing to correlate the recommended thickness with the expected life of the coating. This has resulted in premature coating failure in the field. Therefore, any specifications for coating thickness should be based on scientific laboratory and field testing to assure the coating will provide adequate protection for the intended life. New techniques have been developed, such as electrochemical impedance spectroscopy (EIS), to determine the minimum coating thickness for a given environment.

As an additional note of precaution, coating suppliers have not always notified pole manufacturers of coating formulation changes. Some of these changes may not have been tested and may result in premature coating failure. As such, it is highly recommend that any changes to be made to a coating formulation should be approved by the pole manufacturer.

Case History 1: In-Service Poles Exhibit Corrosion at the Ground-Line

During a field study of galvanized transmission utility poles, it was observed that some of the poles exhibited corrosion at the ground-line. One pole in particular, as shown in Figure 3, exhibited extensive red rust formation on one side of the underground and ground line sections of the pole. At the time of the investigation, the pole had been in service for approximately three years when red rust (discoloration) from the coated surface was observed. Under normal conditions, above ground vertical pole conditions do not produce red rust in four years.

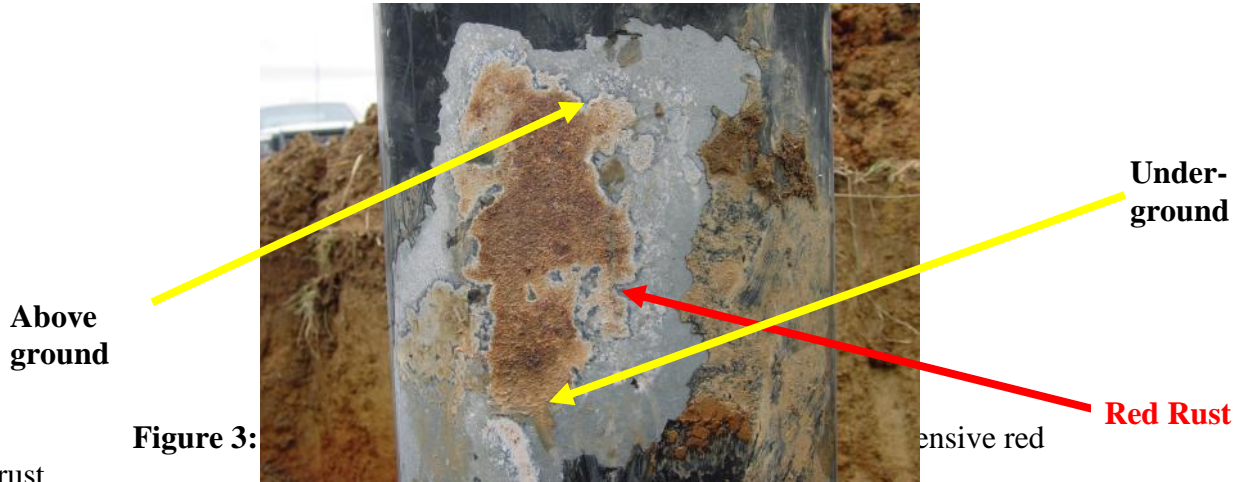


Figure 3: Extensive red rust formation on one side of the underground and ground line sections of the pole.

Visual inspection of the above ground section of the pole revealed red rust and minor mechanical damage that consisted of a slight depression around it (1/2 foot deep). The above ground galvanized thickness range was 4.2 to 5 mils; polyurethane plus galvanizing was 17 to 25 mils. Visual inspection of the below ground section of the pole also revealed red rust and mechanical damage that consisted of several small spots on the corner, and a larger triangle area to one side. The coating in this area was easily peeled away to reveal red and white rust as shown in the photo. The below ground polyurethane plus galvanized coating thickness was measured at 15 to 22 mils. Uniform corrosion attack and thickness loss around the circumference of the pole was not observed, indicating the corrosion attack was localized in nature. The soil measured and found to be mildly corrosive.

The corrosion observed on this pole was uncharacteristic to what would have been expected under these circumstances. It was evident that corrosion had been accelerated by some other unknown factor(s). Further studies revealed the corrosion on this pole had initiated in storage prior to installation due to the atmospheric corrosion conditions. It was found that poles held in storage for an extended period of time experience a different type of corrosion mechanism than when they are in-service. The corrosion initiates with an accumulation and permeation of moisture and corrosive compounds at the galvanized coating interface. Once moisture is present at

the coatings/ground interface the formation of corrosion cells in pin holes, defects, voids, and mechanically damaged areas can take place.

The Role of Soils

According to the National Cooperative Soil Survey, there are over 20,000 different kinds of soil in the United States. The soils are categorized based on texture, color, and natural drainage abilities. The amount of permeability that the soil has with air and water is a key factor in determining corrosivity. Soils such as sands and gravels that have a coarse texture allow for free circulation of air which corresponds to corrosion rates similar to atmospheric exposure. Soils with a fine texture, such as silts and clays have poor aeration as well as poor drainage abilities that can lead to a more corrosive environment. Table 1 shows the relationship of soil corrosivity to its electrical resistivity.

Corrosion Resistance	Electrical Resistivity -cm
Progressively Non-Corrosive	>10,000
Moderately Corrosive	5,000 – 10,000
Corrosive	1,000 – 5,000
Highly Corrosive	<1,000

Table 1: The relationship of soil corrosivity to electrical resistivity is shown.

Factors influencing the corrosion of galvanized poles in soil are more numerous than those prevailing in the atmosphere or water table, and the electrochemical effects are more pronounced. The following section will help to establish a basis for estimating the *probability* of corrosion of the buried proportion of a pole whose external surfaces are in contact with soil. However, the probability of corrosion of these items is not only governed by the corrosiveness of the soil and the properties of the galvanized steel, but also by their design, size, manufacturing/welding characteristics, and by external electrochemical effects (i.e. stray currents, etc.). Since these parameters cannot always be described with adequate accuracy, the likely corrosion behavior can only be estimated.

1. Normal Soils

The life of coated galvanized poles in normal soils will be determined by the underground portion of the pole and the amount of zinc on non-coated portion of the pole. In normal (mildly corrosive) soils, corrosion attack on the underground portion of the pole is protected by the anode affect of the bottom portion of the galvanized pole. Therefore, corrosion of zinc in pinholes and mechanically damaged areas does not take place. The on-site and subsequent lab investigation confirmed this hypothesis and showed numerous cases in which there were no white corrosion products even though there were pinholes, mechanically damaged areas and low thickness areas in the coating. The concept and practice of cathodic protection has been used to protect underground facilities for decades. In this case, zinc on the bottom of the pole is acting as an active ground bed.

2. Corrosive Soils

Corrosive soils are defined as those that produce reducing conditions for zinc and have less than 1000 ohm-cm soil resistivity. In corrosive soils, coatings with pinholes and or mechanical damage will not act as a good barrier to corrosive compounds. As a result, there will be a reduction of life of the pole when compared to poles placed in non-corrosive soils. The extent of reduction in life depends on the type of soil, resistivity, pH, reducing behavior and the water table present. In this condition both the galvanized layer inside (if water table is present) and outside surface at pinhole areas will corrode at a much faster rate.

3. Corrosion of Galvanized Pole in Ground Water

Corrosive soils combined with high water tables present the most corrosive environment for in-service poles. In this environment, coatings with pinholes or mechanical damage will not act as an adequate barrier to corrosive compounds. As a result, there will be a reduction of life of the pole when compared to poles placed in non corrosive soils.

The corrosion of galvanized pole in water is largely controlled by the corrosive compounds and bacteria present in the water. Naturally occurring waters are seldom pure. Even rainwater, which is distilled by nature, contains nitrogen, oxygen, carbon dioxide, and other gases, as well as entrained dust and smoke particles. Water that runs over the ground carries with it eroded soil, decaying vegetation, living microorganisms, dissolved salts, and colloidal and suspended matter. Water that seeps through soil may contain dissolved carbon dioxide and become acidic. Groundwater also contains salts of calcium, magnesium, iron, and manganese. Seawater contains many of these salts in addition to its high sodium chloride content.

All of these foreign substances in natural waters affect the structure and composition of the resulting films and corrosion products on the surface, which in turn control the corrosion of zinc. In addition to these substances, such factors as pH, time of exposure, temperature, motion, and fluid agitation influence the aqueous corrosion of zinc. As in the atmosphere, the corrosion resistance of a zinc coating in water depends on its initial ability to form a protective layer by reacting with the environment. In very pure water, which cannot form a protective scale to reduce the access of oxygen to the zinc surface, the attack is more severe than in most types of domestic or river water, which contains some scale-forming salts. The scale-forming ability of water depends principally on three factors: the hydrogen ion concentration (pH value), the total calcium content and the total alkalinity. If the pH value is below that at which the water would be in equilibrium with calcium carbonate (CaCO_3), the water will tend to dissolve rather than to deposit scale. Waters with high content of free carbon dioxide also tend to be aggressive toward zinc. Soil types that influence life expectancy as shown in Table 2.

Type of Soil	Determining Factor
Normal soils or mildly corrosive soils:	Zinc on the in-ground portion of the pole provides cathodic protection.
Very corrosive soils:	Coating thickness and barrier properties of coating and pinhole density.
Corrosive soils with high water table:	Internal zinc weight and the duration of wetness.

Table 2: Life expectancy factors of a galvanized pole under various soil environments.

4. Corrosive Soils and Coatings with Pinholes or Mechanical Damage

In corrosive soils a coating with pinholes or mechanical damage will not act as a barrier to corrosive compounds and there will be a reduction of life of the pole compared to normal soils. Corrosive soils can be defined as those that produce reducing conditions for zinc and have less than 5000 ohm-cm soil resistivity. The extent of reduction in life depends on the type of soil, resistivity, pH, reducing behavior and the water table present. In this condition both the galvanized layer inside (if water table is present) and outside surface at pinhole areas will corrode at a much faster rate.

Case History #2: Corrosion Protection of the Coated Portion of a Pole by Galvanic Action

A field study was conducted on in-service galvanized utility transmission poles that included the excavation of soil around each pole to determine the underground condition of the pole along with the underground corrosion characteristics of the surrounding soils. The data collected provided information that revealed a newly identified and documented form of corrosion protection. This form of corrosion protection is due to the presence of zinc and the interaction of defects in the coating when combined with cathodic protection from the zinc on the substrate and the zinc on the bottom section of the pole.

When pole structures are galvanized and partially buried any non-coated zinc in the ground acts as an anode bed for the coated portion of the pole. Therefore, corrosion of zinc in pinholes and mechanically damaged areas to some extent does not take place in mildly corrosive soils. Essentially, what this means is that the zinc in the bottom section of the pole will sacrifice itself to protect pinholes, mechanically damaged and low thicknesses areas in the coating at the below ground level. However, this mechanism is not operative in above ground portions of the pole since there are no surrounding electrolytes present to conduct ions that will provide cathodic protection. In this location moisture does not accumulate as it does in storage areas due to the vertical geometry of the pole. In addition atmospheric corrosion rates are known and are generally lower.

Field and laboratory investigations confirmed that the presence of a galvanized layer below the coated polyurethane surface of a pole structure does indeed provide cathodic protection that is capable of protecting the pinholes and mechanically damaged areas within the polyurethane coating. The presence of the galvanized layer and the corrosion rate determines the life of the pole structure. In the absence of a galvanized layer, or when the galvanized layer is corroded away, accelerated corrosion in pinhole areas takes place as shown in Figure 4.

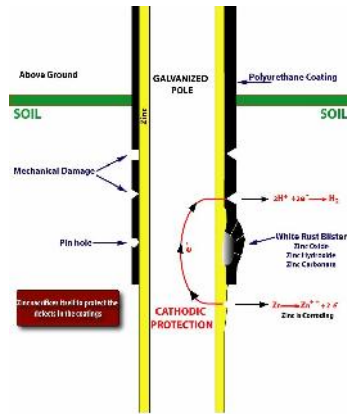


Figure 4: Corrosion Protection of the Coated Portion of a Pole by Galvanic Action.

Methods to Enhance Service Life of Galvanized Transmission Utility Pole Structures

There are various mechanisms of corrosion of galvanized poles in both storage and in service. In the following section methods to enhance the service life of galvanized transmission poles are provided.

1. Select the Right Pole Structure for the Environment

Poles should be designed and installed with a system that maximizes the corrosion protection required for the specific environment where the pole is installed. The pole selection should bring into consideration the pole’s in-service environment, atmospheric environment, water table, weather and location. A map should be constructed that provides information on soil resistivity, pH and water tables. Variation in soil chemistry, however, even in mapped areas will exist. The map should be utilized as a guide to determine “hot spots”, type of pole and corrosion protection that should be installed. The map can also be used to monitor and determine the frequency of monitoring needed.

Soil corrosivity should be determined prior to installation of galvanized poles. In mildly corrosive soils, with soil resistivity above 5000 ohm-cm, extra zinc will perform well and provide a long life. In this type of soils, no coating or ground sleeve is necessary. Corrosion monitoring should be performed in long term increments (5 to 10 years) depending on soil corrosivity. In reducing corrosive soils with soil resistivities less than 1000 (internal and external) ohm-cm and high water tables, galvanized poles should be coated by protective coatings to prevent accelerated corrosion of galvanized surfaces both internally and externally. Soil permeability will play a role in both the rate of penetration of corrosive water and the rate of removal. In normal soils, galvanic protection will prevent corrosion attack at defective sites in the coating. In reducing corrosive soils and high water tables, corrosion attack will occur both externally and internally. Corrosion monitoring should be in place to determine thickness loss due to corrosion attack.

If necessary, maintenance of coating, cathodic protection and galvanic anodes should be installed to protect the poles in service in corrosive soil. The combination of an adequate coating and galvanizing in addition to the use of a corrosion resistant backfill can increase the life expectancy of the poles up to 50 years under normal conditions.

2. Maintain Poles

There are no maintenance free poles. Poles should be inspected and maintained on a routine basis. The frequency of inspections and maintenance will depend on the corrosivity of the soil.

3. Utilize Corrosion Monitoring

Corrosion monitoring should be pursued in corrosive soil conditions and high water environments. A spherical potential field exists around a galvanized pole that is in service that can be monitored to determine the corrosion activity. Any major corrosion activity will change the potential field.

Electrochemical filed potential monitoring, which is a new and novel technique in the pole industry, can provide a means to detect major corrosion attack in the underground portion of the pole in a non destructive fashion. With this method, potential measurements must be obtained around the pole every few years. This technique will also detect interference and stray currents from foreign facilities such as gas lines under cathodic protection. Any major shift in potential or potentials, more noble than 0.6, will indicate steel corrosion activity in the underground portion of the pole. If a shift is detected, the site should be excavated to determine the extent of corrosion attack and repairs should be made. Electrochemical corrosion probes based on EIS and resistance polarization can also be used to determine corrosivity.

4. Consider Using Corrosion Resistant Backfills

A laboratory investigation of select soil types was conducted to determine how soil type correlates with zinc corrosion rates. The investigation revealed that the use of non-corrosive backfills will greatly increase the service life of pole structures if utilized. The select soil types were tested to determine which soil type(s) performed the best under various environments for possible use as backfill for pole structures. The investigation included soil resistivity, instantaneous corrosion rate, and pH measurements of collected soil samples and purchased select soil types. The three different types of purchased select backfill are shown in Figure 5.



Figure 5: Crushed Gravel (Limestone) – Crushed Gravel (Riverbed) – Sand (ASTM 20-30)

The sand used was of the ASTM 20-30 grade, this grade is a measurement of the size of the particles in the sand. Both of the gravels were of the P1 grade, meaning 1/4” to 3/8” in diameter rocks. Table 3, shows the results of the laboratory investigation.

Backfill	Resistivity	pH	Estimated Maximum Field Corrosion Rate of Zinc
Sand (ASTM 20-30)	15,000	7.80	0.114 mpy
Crushed Gravel (Riverbed)	29,000	8.55	0.154 mpy
Crushed Gravel (Limestone)	33,000	8.88	0.122 mpy

Table 3: Results of Laboratory Testing on Select Backfills.

Test results indicate that the select backfills have very low corrosion rates and would provide a longer service life for poles in corrosive conditions. The backfill resistivity is much higher than what would be found in corrosive soils, such as corrosive silts and clays, and for this reason makes the corrosion attack much lower. Additionally, the increased pH of the sand and gravels leads to the formulation of a passive layer and a lesser potential for accelerated corrosion. The estimated field corrosion rate is equal to the laboratory corrosion rate divided by five, which accounts for the time in which the backfill would not be saturated with water. This estimated maximum corrosion rate is the maximum corrosion rate of the zinc in the tested backfills. However, based on our past experience and data found in a literature survey, this rate

could be up to 30 times less than this depending upon the amount of rainfall and the level of the groundwater table.

5. Store Poles Properly and Rotate Stock

As this paper has shown, poles stored in a horizontal position for extended periods of time experience a different type of corrosion mechanism than when they are service. The corrosion initiates with an accumulation and permeation of moisture and corrosive compounds at the galvanized coating interface. Once moisture exposure takes place, the formation of corrosion cells in pin holes, defects, voids, and mechanically damaged areas can take place.

If it is necessary to store poles for extended periods of time, poles should be stored off the ground and elevated on one end to allow moisture run off. The poles should also be coated with a UV resistant coating and stock rotation should be implemented using the “first in, first out” method.

6. Utilize a Surface Preparation Technique that Doesn't Crack the Zinc

Cracking the zinc layer during blasting can result in initiation sites for corrosion and delamination to take place. The goal is to remove any dirt, grease or oils but not to remove too much of the galvanized layer.

7. Require Coating Suppliers to Provide Scientific Testing for Coating Recommendations and Provide Notification of Coating Formulation Changes Prior to Change

Testing to correlate the recommended thickness with the expected life of the coating should be provided by the coating supplier. New techniques have been developed, such as electrochemical impedance spectroscopy (EIS), to determine the minimum coating thickness for a given environment. Pole manufacturers should also be notified and approve of any changes made to a coating formulation.

Conclusion

As a relatively new industry, the pole industry is just now becoming aware of possible problems that can be associated with corrosive soils, mechanical damage, storage and stock rotation, ground level and underground/water table corrosion, coatings requirements and interference induced from other structures. Specifications from paint and coating suppliers do not always take these issues into consideration. As a result, the service life of a utility pole can be diminished if the pole specifier doesn't take into consideration the different environments that utility poles can be exposed to.

In general, zinc extra poles, corrosion resistant backfills, maintenance and corrosion monitoring will greatly increase the life of galvanized poles. However, in environments with corrosive reducing soils, stray currents and high water tables,

additional protective measures to extend life expectancy are required. Environmental information such as soil resistivity, pH, chemistry, and water tables should be utilized to determine the “hot corrosion spots”, the type of utility pole that should be installed for that particular environment and the frequency of inspection needed. In environments where the soil is moderately corrosive, galvanic action will protect the painted portion of a pole due to cathodic protection by zinc.

For poles yet to be placed in service, consideration should be given to selecting a pole system based on the environmental conditions the pole will be located in. Once a pole is in service, the pole will need to be inspected, maintained and monitored as needed. The frequency of inspection may be determined based on soil corrosivity and potential field determinations. If a pole is to be placed in storage for an extended period of time the pole should be coated with a UV resistant coating and stored in an elevated position off of the ground. Stock rotation, as well as a surface preparation technique that does not crack the zinc layer, are also essential if pole longevity is to be expected.