Long term Preservation of the Power Delivery System Infastrucutre

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INTRODUCTION

Twenty years ago, electric utility customers throughout the US were actively engaged in scheduled transmission structure maintenance painting programs. Most were painting hundreds of steel towers and poles per year and were making a serious effort to assure long term protection to this most important asset, but this all soon changed.

By the early 1990's, almost all of these programs came to a screeching halt. The poor economy at the time resulted in severe budget cuts, and as we all know, when money is tight, maintenance painting is usually one of the first things to be cut from the budget. This scenario was a national pattern. So, with a few exceptions, maintenance painting of transmission structures was minimal for the next several years. Many painting contractors specializing in this work were forced out of business and paint manufacturers felt the effect as well.

Above all however, it was the utilities themselves that were impacted the most. Deteriorating structures resulted in service interruptions, reliability issues, image problems and costly repairs. But even these issues were not enough to force most utilities back to painting their transmission structures. Finally though, something came along that seemed to have gotten the ball rolling again on transmission structure painting: The National Energy Policy Act of 1992.

This law began the process of deregulating the electric utility industry by allowing each individual state to determine how to make customer choice available to consumers. This law deregulated only the generation side of the business, however. The transmission side – the part that carries the electricity to homes and businesses – remained regulated. California became the first state to open the electricity market to choice in March, 1998. Deregulation was in full swing in most states by 2002.

One of the biggest issues associated with deregulation centers on "stranded costs". These are the debts utilities took on believing they always would be regulated monopolies. The major stranded costs are the power plants, especially the older less efficient generating stations, as well as nuclear plants. These costs will make it difficult for the utilities to remain competitive with independent power producers and other utilities without these high cost investments.

As a result, many utilities have decided to sell off their generation assets and become strictly transmission companies. Some electric companies, rather than divest their power plants are splitting their company into separate subsidiaries concentrating on generation, transmission and distribution.

The bottom line to all of this is that money is being freed up, and a strong incentive is in place, for electric companies to maintain their transmission assets. With budget dollars not being devoured by generation costs, and the fact that transmission is where the guaranteed income is, utilities are realizing this is the time to protect their transmission structures for the long term. They are looking for the most cost effective method of gaining the longest term protection available for these critical assets. Fortunately there is a solution.

PURPOSE OF PAINTING TRANSMISSION STRUCTURES

Most often the painting of electrical transmission structures involves the application of a protective coating over weathered and/or previously painted galvanized steel. Although many transmission structures, mainly tubular poles, are painted carbon steel, most structures, especially lattice type towers, are galvanized and are either unpainted and weathered or previously painted.

The history of painting galvanized structures over the past 50 years, and the evolution and usage of different paint systems, play an important role in the selection of present day coating systems. Cost evaluation of different generic paint types are necessary, as well as the application characteristics or each, as the painting of these structures is extremely labor intensive. The ultimate goal is to minimize overall cost per year to paint and protect these structures.

Galvanizing and paint serve the same function; the protection of the carbon steel substrate from corrosion attack. Each works as a barrier to separate the components of the electrolytic cell that causes corrosion. When properly specified, manufactured and applied this barrier of paint or zinc iron alloy will keep the moisture (electrolyte) from contacting the anode and cathode (steel and its impurities – corroding surface). When this is successfully accomplished corrosion cannot occur and the substrate will not be detrimentally affected.

Over time, both galvanizing and paint will degrade to a point where they will not provide adequate protection to the steel substrate. The rates of degradation will vary widely. Exposure conditions have the greatest effective on the longevity of protection, but the quality of product and its application are other critical factors.

When it is determined that the galvanizing or paint film can no longer adequately protect the substrate, a new barrier must be applied to fend off the costly ramifications associated with corrosion. The most practical and cost effective method of "reprotecting" the structure is the application of a paint or coating specifically intended for this use. When properly formulated, specified, manufactured and applied, certain coatings can protect a transmission structure for 25 years or more.

The protection provided by galvanizing is clearly beneficial to enhancing corrosion resistance of steel structures, and for this reason such structures will enjoy a longer life-span than conventional carbon steel. Even though galvanized steel will last longer than carbon steel, its durability needs to be understood because it will last only for a certain time frame, as well.

The durability of hot dip galvanizing is dependent upon two major factors: the quality of the original zinc coating and the type of exposure to which the surface is subjected. These 2 factors also determine the service life of painted carbon steel as well. In general, galvanized surfaces will exhibit a life expectancy of 10-40 years (Figure 2) in normal exposures before any preventative maintenance painting is required. However, galvanized surfaces that are subject to chemical fumes, salt air or humid atmospheres, may begin to show pin-point failure and light rusting in a shorter period. Galvanized Steel exposed in atmospheres having a pH of 6 or less will exhibit severe deterioration in a very short time.

Changes in color are an indication of the condition of life expectancy of galvanized structures. As galvanizing weathers, it loses its brightness and turns dull gray, then in turn, becomes a darker gray as it gradually erodes. This change is mainly due to the formation of zinc corrosion products on the surfaces. This is a general indication that most of the pure zinc layer has eroded away and that only zinc-iron alloys protect the bare steel. This is the optimal point at which to consider painting because surface preparation, the most costly portion of any painting project, requires only minor attention (Hand Tool Cleaning; SSPC,SP2)

Failure of galvanizing will often become initially apparent on the edges, corners and bolted connections. When the surfaces exhibit signs of failure to a large proportion, the galvanizing has provided its maximum service and should be coated with a rust inhibitive paint. Painting is necessary when the galvanizing becomes thin and a reddish-brown, zinc-iron alloy (Figure 3), which appears to be rust, is deposited on the surface. This condition is the forerunner to active rusting. The importance of painting at this time cannot be overstated, as true cost-effectiveness (short term and long term) requires the surface be protected prior to corrosion of the base steel. This not only prohibits the formation of further corrosion requiring more extensive surface preparation, but also allows a single coat system, comprising an oil alkyd/zinc dust paint (hi-build zinc dust tower paint), to protect the remaining galvanizing, resulting in its continuing performance as a rust inhibitor. Once the base steel has begun to pit and corrode, repainting becomes more involved, (surface preparation, priming) leading to a much more expensive project.

Though discoloration is an indication of galvanizing deterioration and failure, the actual thickness of the zinc layer is the definitive measurement. The American Zinc Institute [4] states" the purpose of galvanizing is to protect the bare metal from rust. Even though it may stain early in life, the galvanizing coat need not be painted until the zinc protection has been reduced to about 1.5 mils thickness." It is recommended that this 1.5 mil criterion be used as an absolute minimum determining factor for consideration of when to paint galvanized structures. Newly galvanized steel transmission towers normally are coated with 3-4 mils of galvanizing.

Many utilities paint their galvanized structures too soon, but it is better to paint too soon than too late. It is widely reported [1,3] maintenance coating life increases 2-3 times when applied over galvanizing as compared to the same application over a carbon steel surface. Furthermore, a maintenance coating over an intact galvanized surface requires little or no surface preparation.

The other approach to protecting carbon steel from corrosion is the use of paint as a barrier coating. Objections are often raised about the appearance of overhead transmission lines built with lattice towers. In an attempt to appease these objections, as well as for other reasons, including construction costs, tubular steel structures are used. Though sometimes galvanized, most often these structures are fabricated from carbon steel that is painted for aesthetics as well as protection. Table 1 lists some of the more common coating systems for painted steel poles. Painted poles often require maintenance painting 10-15 years following erection, depending upon their environment.

The shop-applied systems on poles are applied by spray, while field maintenance is performed in the same manner as with lattice towers. Primers are often required as corrosion is generally more severe and surface preparation requirements are usually more extensive, but when painted at the correct time the same long-term corrosion protection can be received by the application of a high-build zinc dust tower paint.

RECOMMENDED COATINGS FOR LATTICE STRUCTURES AND POLES

The coating system recommended today to protect weathered galvanized and previously painted steel transmission structure surfaces has evolved from experience since the 1930's. The painting of galvanized structures was done only on a limited basis until the late 1940's as a result of World War II when maintenance painting was practically non-existent. The first paint systems used to repaint these surfaces involved a spot coat or full coat of red lead primer followed by a full coat of oil-based aluminum paint. These systems averaged 50-60 percent solids by volume and established a service life of 10-12 years when applied at 2-3 mils dry film thickness per coat in a normal non-corrosive atmosphere. These same systems lasted only 5-8 years in a more severe industrial or coastal environment.

In 1955 the hi-build, single coat, self-priming, rust inhibiting tower paint was developed. This material reduced labor costs and provided an extended service life. The formula incorporated metallic zinc dust and linseed oil [(5)] as major ingredients in a zinc-lead-aluminum combination. Stainless steel flake was added to the formulation to increase the life expectancy for coastal or corrosive exposures. High solids by volume (92%) assured a single coat application with an equivalent dry film thickness of two conventional coats. This in turn, translated to longer life, reduced labor costs, and ultimately a **Lower Cost Per Square Foot Per Year Of Protection**.

This formulation along with the traditional oil-based, lead-aluminum formulation was used extensively throughout the 1950's and 1960's. It became evident, however, during this time lead was coming under the scrutiny of the environmentalists. Paint manufacturers and end users became more aware of the problems encountered when using lead-based formulas. The manufacturer was required to monitor the health and safety of all employees who came in contact with lead during the manufacturing process. It became necessary to employ a physician to comply with these requirements. Although it was not illegal to use lead, the user was susceptible to similar restrictions and furthermore if lead based paints had to be removed from existing structures, disposal problems became almost insurmountable. Specific problems relating to the application to structures included sickness or death resulting from the lead poisoning of livestock, since many of these structures ran through farm areas. Of course today the problems associated with the use and removal of lead are much more regulated and expensive.

In the early 1970's the hi-build tower paint was modified in order to eliminate lead. The fact that lead did not constitute a major portion of the pigmentation made it simple to eliminate, based upon laboratory testing and short term field testing. Barrier pigments, such as micaeous iron oxide were used as a replacement for lead compounds.

During the 1970's and 1980's it was determined that thicker applications of the hi-build zinc dust tower paint increased the longevity proportionally. Minimum dry film thickness recommendations were increased from 4 mils to 6 mils and later to 8-10 mils. This changed the anticipated life expectancy to 20-30 years for rural areas and proportionally less for corrosive environments. Experience has shown longer life is directly proportional to thicker coating application within a practical range. The hi-build tower paint erodes at about an average of 0.3 mils per year in non-corrosive environments. This translates to a 18-20 year life when applied at 6 mils minimum dry film thickness and a 27-30 year life when applied at 9 mils DFT.

One of the most important aspects of evaluating the maintenance painting of galvanized structures is the determination of the **Cost Per Year** for a documented service life. Figure 4 illustrates the calculation of the Cost Per Square Foot Per Year (Material Only) for a hi-build zinc dust tower paint. Taking this a step further, Figure 5 illustrates the comparative cost (Labor and Material) during a 60 year maintenance painting cycle for a 100 foot lattice tower using a conventional tower paint (60-70% Solids by Volume applied at 3-4 mils DFT) versus a hi-build zinc dust tower paint (90% Solids by Volume at 6-8 mils DFT). The application cost figures are based upon costs obtained from qualified contractors. The repaint costs reflect an average inflation rate of 5% per annum.

In addition to evaluating the Lowest Cost Per Year, another important factor for consideration of cost is the number of times a structure must be repainted. As shown in Figure 5, the conventional tower paint requires four repaints in 60 years, compared to two repaints for the hi-build zinc dust tower paint. These two additional repaints contribute greatly to the differential in cost as displayed in Figure 5. The total savings when using the hi-build zinc dust tower paint is $11,408.28 per structure. Figure 5 further illustrates the cost of application represents 80-90 percent of the total cost.

Any discussion of painting transmission structures should include a **generic specification** for material, the required **surface preparation**, and **application methods**.

SURFACE PREPARATION

The surface preparation methods recommended for weathered galvanized or previously painted structures normally require hand tool cleaning (wire brushing or scraping) in accordance with SSPC-SP2. In some specific instances, it may involve more advanced methods, but as surface preparation is the slowest, hardest and most costly aspect of painting a transmission structure, the primary objective is to paint at a time and with a coating designed for minimal surface preparation. The goal is to paint BEFORE the galvanizing or the existing coatings have deteriorated to the point where involved surface preparation and multiple coat systems are required. The most cost effective time to paint a transmission structure is when spot scraping or wire brushing is all that is required. The hi-build zinc dust tower paint exhibits excellent surface tolerance, as well as low stress characteristics, and is ideal for application to surfaces prepared in this manner.

To further complicate the situation most coatings existing on transmission structures contain lead. Therefore, the contractor must use containment to eliminate lead fallout, as well as implement the OSHA Lead in Construction Standard to protect his workers.. More extensive surface preparation will result in much higher worker exposure to airborne lead, as well as environmental exposure, and will require much more elaborate and expensive protection procedures. Total job costs will rise exponentially if significant surface preparation procedures are required.

APPLICATION METHODS

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The application of paint to a transmission structure is more complicated than it might seem. This type of painting involves climbing lattice type towers or tubular poles which vary in size and configuration depending on voltage. Most often, these structures are painted while energized. Painting a lattice-type structure is a team effort. For example, a crew of 3 or 4 painters will paint a standard 100 ft lattice tower in 2-3 hours.

For the most part, application is accomplished using a pound or oval brush, or a paint mitt. The pounder, as it is referred to, is a circular brush with a 6-inch circumference. These brushes hold large amounts of paint and are particularly effective in working the paint uniformly around nuts, bolts, and sharp edges. Paint mitts are made from a synthetic wool material and fit over the hand like a glove. Most contractors specializing in tower painting prefer mitts to attain maximum and more uniform paint thickness. Experience is an important factor in using either method of application

SAFETY AND ENVIRONMENTAL

The importance of safety and environmental considerations are paramount in today's world. This includes the safety associated with the application of the product to an electrical structure which includes climbing and working around energized lines. Furthermore, it includes possible contact with potentially hazardous materials during the surface preparation of the structures.

In the past, climbing and painting have been accomplished generally without the aid of rigging and most of the time without safety belts. Each year OSHA and/or power company safety regulations have become more stringent and today safety belts, hard hats and safety glasses are becoming mandatory. Written safety programs, fall protection plans, hazardous communication plans and lead compliance plans are now required.

If the specification requires the removal of any old paint from the structure, it is essential to determine whether or not there is lead present in the old coating. A "total lead" test must be performed. If the results indicate there is any lead at all, there is a potential for employee exposure to airborne lead at or above the OSHA Lead in Construction Standard's action level (1926.62). In such cases, the contractor must comply with all aspects of this law which includes an exposure assessment, implementing engineering controls, medical surveillance, use of proper protective clothing, and the formulation of a worker lead protection program. Job specific lead compliance programs have become a required submittal on today's transmission structure painting projects.

State and Federal environmental laws require the contractor take necessary steps to be certain the old lead paint does not pollute the ground, and more importantly the water. In a residential area this becomes much more sensitive. The old paint which is contained and collected must be tested according to a Toxic Characteristic Leaching Procedure (TCLP) test, and if there is more than 5 parts per million lead, the waste must be handled in compliance with EPA requirements and disposed of by a licensed hauler.

UTILITIES ARE REQUIRING GUARANTEED RESULTS

The last 50 years have seen radical changes in both the selection of coating materials and the overall approach to painting transmission structures. The application methods have essentially remained the same, but the 1990's have required a different approach to attaining the desired results. In order to "guarantee" the longevity of the work the approach is to insist upon more detailed specifications and full time inspection of the application. This is the result of the fact that it is no longer a guarantee that superior results will be attained just by specifying a high quality coating material. Labor costs to paint a transmission structure are as high as 85% of the total cost. Therefore, it is mandatory assurance be provided that the application is conducted properly.

In most cases, the utility's Engineering Department in conjunction with the Purchasing Department supervises the entire operation by specifying and/or procuring the coating material, contracting with the applicator, and providing full time inspection or part time surveillance of the coating work. In order to attain maximum results, the program must be managed properly and include the following:

a. Specification of the proper surface preparation
b. Specification of proper coating materials
c. Specification of proper dry film thickness
d. Use of proper application methods
e. Allow only qualified applicators to bid work
f. Use qualified full time inspectors
g. Implement the proper safety and environmental requirements

TECHNICAL DEVELOPMENT

Research and development is constantly creating new products that should be investigated and evaluated in order to comply with changing environmental requirements, to reduce cost, and to increase protective life expectancy.

Epoxies, urethanes, and other high performance coatings offer exciting possibilities for the protection of transmission structures, but in the process of assessing their value, one must realize that the hi-build zinc dust tower paint has over 35 years of proven performance experience. Furthermore, it offers practicality in required surface preparation, convenience in application, and complies with present limits for volatile organic compounds. It provides an old approach that is still not outdated in spite of all the advancement in technology.

SUMMARY

The regular maintenance painting and repainting of electrical transmission structures is critical to the relaibility of our power delivery system. It is quite difficult to deliver electricity if the structures holding up the wires are falling down due to corrosion. The good news is there is a proven method to ensure the long-term, cost effective protection of these structures. 50 year experience has proven the viability and benefits of formal maintenance painting programs for transmission structures. Utilities are being forced to see the necessity of implementing these programs, as well as the folly of abandoning them.

REFERENCES

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3. "Painting Galvanized Structural Steel", Zinc Institute, Inc., 292 Madison Avenue, New York, NY 10017 and American Hot Dip Galvanizers Association Inc., Suite 700, 1101 Connecticut Avenue, N.W., Washington D.C. 20036

4. "For Corrosion Protection Think Zinc", Zinc Institute, Inc., 292 Madison Avenue, New York, NY 10017

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CHARTS AND FIGURES

TABLE 1
QUANTITATIVE REQUIREMENTS FOR A HI-BUILD ZINC DUST TOWER PAINT

Test	Test Method	Required Results
Solids by Volume	Fed. Std. 141 Method 4311	89 ± 3%
Weight per gallon	ASTM D1475	16.0 ± .5 lbs.
Viscosity	ASTM D562	105 ± 5 Krebs Units
Anti-Sag	Lenetta Anti-Sag Meter (Form 7B - Draw Down Chart)	10 - Index
Flash Point	Pensky-Martens (ASTM D93)	103° ± 2° F
60 - Degree Specular Gloss	Fed. Std. 141 Method 6101 (ASTM D523)	15 - 20
Accelerated Weathering*	Q.U.V. (ASTM G-53)	2500 hours minimum

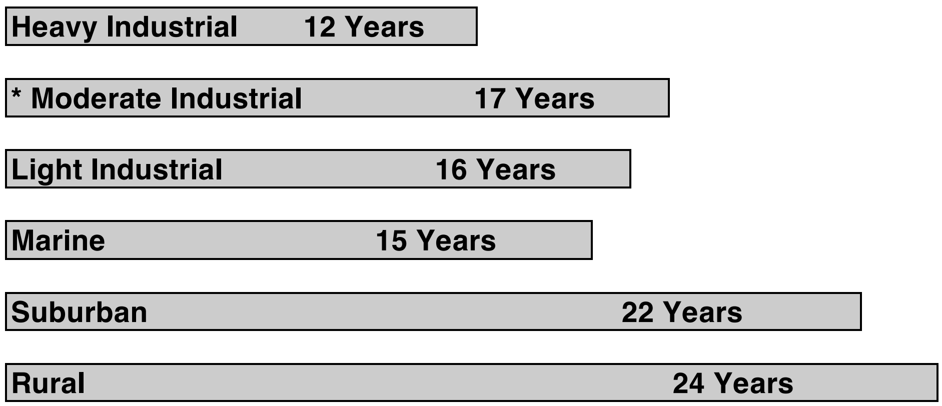
* Long term field tests are preferred as this test is inconclusive

FIGURE 1

HOW LONG DOES GALVANIZING LAST? [4]

The charts below show the **average** number of years before transmission towers and substations are first painted in the atmospheric conditions indicated. Averages are strictly arithmetic. Like other "averages" this gives the general idea of anticipated service life with many instances of longer or shorter lives.

TRANSMISSION TOWERS



* Longer service life for moderate over light industrial is due to varying interpretations of the words "light" and "moderate".

Figure 2: Average service life - years before first painting of Galvanized Transmission Towers , 75 Companies.

Figure 3: The figure shows a series of layers in hot dip galvanizing. Courtesy of the Zinc Institute, Inc.

FIGURE 4

COST PER SQUARE FOOT PER YEAR EVALUATION

HI-BUILD ZINC DUST TOWER PAINT

THE COST PER SQUARE FOOT PER YEAR is calculated based upon:

1. The net cost per gallon.
2. The percent solids by volume of the paint.
3. The documented protective life of the paint in years.

AN EXAMPLE USING THE **HI-BUILD ZINC DUST TOWER PAINT** IS AS FOLLOWS:

1. PRICE - $25.00 per gallon (approximate quantity price)
2. SOLIDS BY VOLUME - 92% (applied at 8.0 mils DFT)
3. LIFE EXPECTANCY - 24 years
4. CALCULATION -

a. The Square Foot Coverage of a Gallon of Liquid Spread 1 Wet Mil Thick:

1. There are 231 cubic inches in a gallon of any liquid.
2. 1 Mil equals 1/1000 inch.
3. There are 231,000 square inches in a gallon of any liquid spread 1 wet mil thick.
4. Converting square inches to square feet:
   (a) 231,000 ÷ 144 sq.in./sq.ft. = 1604 sq.ft. in a gallon of any liquid spread 1 wet mil thick.

b. 1604 mil sq.ft./gal x .92 (solids by volume) = 1476 mil square feet/gallon (dry film).

c. $\dfrac{\$25.00/\text{Gal.}}{1476 \text{ mil sq.ft./gal.}}$ = $.017 per mil square foot.

d. $.017 x 8.0 mils DFT = $.136 per square foot.

e. $\dfrac{\$.136}{24 \text{ Years}}$ = $.006 COST PER SQUARE FOOT PER YEAR for HI-BUILD ZINC DUST TOWER PAINT