

Corrosion Protection

FOR COOLING TOWERS

The forces of corrosion (as the term is being used in this paper) are those elements or compounds whose natural tendency is to chemically or electrolytically react with a metal, given the opportunity and a proper set of circumstances. Principal among these is oxygen, which happens to be the most prevalent element on earth. "Oxidation" refers to its interaction with other elements or compounds, and "rust" relates to its particular reaction with iron — which is the primary ingredient of the carbon steel typically utilized for various cooling tower components.

In varying degrees, corrosion has always been a primary concern in the use of carbon steel. Where atmospheres tend to be dry and cool, the concern can be relatively minor. Where atmospheres are warm and humid, however, the potential for corrosion increases dramatically, and must be addressed at the outset.

Similarly, the constituents of that atmosphere have their effect upon corrosion — trending toward its acceleration, rather than its reduction. Years ago, when the air was relatively "fresh", coatings which would be considered rudimentary by current standards proved adequate. Today, the asymptotic increase in industrialization, and the gaseous by-products thereby generated, has created a changed (and ever changing) typically corrosive atmosphere. Obviously, this evolutionary acceleration of the potential for corrosion requires ongoing research and development on the part of coating manufacturers, and evidence would indicate that they have kept up with the problem of *atmospheric* corrosion admirably.

However, add to this an oxygen-containing vehicle (such as water), in which atmospheric gases can be absorbed and concentrated; cause it to come into intimate contact with the steel; provide continuous aeration — along with heat — and you will have increased the opportunity for corrosion markedly. You will also have begun to simulate the environment in which the steel components of a cooling tower are required to operate.

To complete the simulation, the aspects of *flow* and *evaporation* must be introduced. In stagnant water, steel usually has the opportunity to form a somewhat self-protecting surface film of oxidation which tends to reduce the rate of corrosion. Under flow conditions, however, this protective film can erode away as quickly as it forms, continuously exposing new material to deterioration. With evaporation (as occurs in a cooling tower), pure water vapor leaves the system — concentrating the remainder into a highly aggressive bath which tends to accelerate the corrosion within an already susceptible system.

Obviously, if one were to seek a torture chamber in which to assess the effects of corrosion, one would need to look no further than a cooling tower. It should come as no surprise, therefore, that reputable cooling tower manufacturers are considered among the most knowledgeable on the subject of the prevention or control of carbon steel corrosion under conditions of flow and evaporation. What is surprising is that, given equal circumstances under which to test, apparently conflicting conclusions are reached by different manufacturers. Depending upon whose standard specifications one reads, various coating systems are described in rather glowing terms — sometimes to the point of confusion.

In some cases, there is a common denominator. That common denominator is *galvanization*, in support of which this paper is written.

Barrier Coatings

As applied to cooling towers, protective coatings can be categorized into two basic types; namely, barrier type and sacrificial type. Both are used extensively throughout the cooling tower industry, occasionally in concert.

Barrier type paint coatings, as the designation implies, are intended to form a protective barrier between the steel and the agent of corrosion. Most are applied in liquid form by brush, roller, or spray. Some are applied in powder form, by electrostatic deposition, with subsequent application of heat to promote bonding.

Although the materials used for barrier type coatings in the cooling tower industry are normally unaffected by the environment typically encountered, the reader must understand that *all* protective coatings are permeable (porous) to a greater or lesser degree. Some have greater porosity than others, and permeability can be decreased by increasing the applied thickness. Nevertheless, *in no commercial formulation or applied thickness can barrier type coatings be classified as impervious to the intrusion of moisture and/or atmospheric gases.*

Accordingly, it is but a matter of time before the barrier layer is penetrated, exposing the substrate metal to elemental corrosion. At that time, the integrity of the bond between coating and substrate metal becomes decisive, and this bond is only as good as vigilant quality control can make it. Precise preparation of the substrate is required, as is the controlled application of the coating. Being familiar with the precautions necessary for liquid-applied coatings,

typical users will find nothing new in this statement. However, being hopeful of new technology, they may find it disconcerting to discover that some of the newer “miracle” coatings are among the most sensitive in this regard.

Powdered epoxy coatings (electrostatically applied), for example, achieve a proper bond only under the most stringent quality assurance procedures. Not only is the metal preparation super critical as regards the temperature, concentration, and application time of the cleaner; but repelling electrical charges, which naturally form in corners and angles, virtually preclude the application of a uniform coating thickness. Hangers, normally re-used in successive coating applications, provide progressively reduced grounding capability, and ultimately, bonding of the applied coating depends upon the curing which takes place within a period of time in an oven at a specific temperature. Obviously, multi-step processes such as this, in which each step is subject to precise control, introduce considerable margin for error.

Questioning the probability of achieving suitable coverage, however, is academic. Even if it were possible to achieve consistently uniform film thickness — along with an ideal bond — the problem of permeability would remain unresolved. Corrosion, fed by oxygen entering through the coating’s natural porosity, gradually undermines the coating and gains increasing access to the metal. Unfortunately, such corrosion often goes undetected until too late to make proper repairs. Although telltale “blisters” usually tend to give this condition away, the apparent integrity of the coating sometimes disguises it, permitting concentrated corrosion to proceed unchecked.

Consequently, barrier type coatings alone are considered inadequate for proper corrosion protection in cooling towers.

Sacrificial Coatings (Galvanizing)

In recognition of the above, concerned cooling tower manufacturers make use of a *sacrificial* type coating, such as galvanizing. In the galvanizing process, steel is submerged in a bath of molten zinc at approximately 850°F. It emerges from this bath with several layers of iron/zinc alloy, topped by a coating of pure zinc; with the effective thickness of the coating being governed by the time in the bath. In a physical sense, therefore, galvanizing results in what would appear to be a barrier type coating. As regards its ability to protect steel against corrosion, however, there is no similarity.

Although oxygen will combine with virtually all known elements, it has a distinct order of preference. Given an equal opportunity to react with either iron (carbon steel) or zinc, for example, it will avoid the iron in favor of the zinc. Therefore, as regards corrosion, zinc is considered sacrificial with respect to carbon steel. It does not have to form an impenetrable barrier — it merely has to be nearby! Barrier type coatings may permit steel corrosion to begin shortly after contact with water — galvanizing, by nature, will not. As long as zinc exists in proximity to steel, and is allowed to freely contact the water, the steel is protected against progressive corrosion.

Major changes have occurred in the basic method of galvanizing which subtly affect the manner in which the applied zinc protects the substrate metal. During the 1950s, a number of galvanizing companies existed. They maintained huge vats of molten zinc into which large steel items could be dipped. This enabled manufacturers to complete sizable components of a product out of bare steel, then hot-dip galvanize them after fabrication by total immersion in the vat. Although this process tended to warp many of the components, this difficulty was considered to be offset by the fact that all surfaces of the finished product were obviously coated with zinc.

In the 1960s, rising costs caused many of these companies to discontinue operations until, by 1970, all but the most efficient had virtually disappeared. Those which remain are utilized for Marley cooling towers to galvanize structural shapes and weldments which fall outside the sheet metal classification.

Recognizing its value, the galvanizing of sheet metal is now performed by the steel-producing companies themselves. Accordingly, it is currently referred to as “mill galvanizing” — yet it is no less a hot-dip process than it ever was. Continuous sheet steel (previously rolled to gauge) is annealed in the galvanizing line, and conducted through a bath of molten zinc. It then proceeds through wiping dies, steam jets, or air jets which establish the required zinc thickness and uniformity. Experience has been that the resultant galvanized sheet will undergo considerable fabrication forming and bending with no loss in the integrity of the zinc coating.

This is not to say that there is no difference between a product that is hot-dip galvanized after fabrication, and one that is fabricated of mill galvanized steel. For example, when mill galvanized sheets are sheared to size for fabrication, the edge is essentially exposed (the ductility of zinc causes a certain amount to re-coat the edge, but it can be considered negligible). As a result, relatively new galvanized cooling towers may show thin lines of red (rust) on these exposed edges. Areas such as these, however, merely serve to prove the sacrificial nature of zinc. Years later, the exposed edge will be just as red — and just as sound.

Since galvanizing protects steel sacrificially, it follows that protection longevity is directly related to the thickness of zinc applied in the galvanizing process. The greater the amount of zinc applied, the more years will be required for it to totally react with the elements of corrosion. But thickness is not the only determinant of galvanizing’s ability to retard corrosion. Galvanizing also offers the unique property of protecting substrate metal by sacrificial reaction which radiates in all directions from the point of initial corrosive attack. Any agent that impedes this effect, such as the imposition of a barrier coating on top of the galvanizing, may actually reduce the time necessary for corrosive activity to fully penetrate through the zinc to the substrate metal.

Marley cooling towers had been utilizing G-210 galvanizing as the standard coating for steel 20 gauge and heavier, since 1957. Since 1996 G-235 has become the standard. This yields an average zinc thickness of 2.1 mils which, to the best of our knowledge, is unsurpassed in the cooling tower industry.

The Value of Combined Coatings

For a significant addition to the base cooling tower price, some cooling tower manufacturers are currently offering galvanizing, topped with an overlay of electrostatically-applied epoxy paint. In one such instance, this combined coating has been described as a “cost-effective alternative to stainless steel”. Since this is quite a thought-provoking description, we feel that some background information on this coating system is in order — along with some logical conclusions.

This is a coating system that was developed primarily for the automobile industry and, in view of the fact that its exposure there will be considerably more benevolent than would be encountered in cooling tower operation, it should serve automobiles quite well. The galvanizing utilized will offer good protection in normal atmospheric conditions, and the epoxy overlay will provide a base to which a final paint finish will readily adhere.

As indicated on page 90 of the September 1983, issue of *Iron Age Magazine*, if corrosion protection were the sole criterion to be considered in the automobile industry (as it *should* be in the cooling tower industry), unadorned galvanizing would be their first choice. As far as barrier type (paint) coatings are concerned, they consider them to be only marginally better than bare steel. However, in that industry, galvanizing presents some problems with which the cooling tower industry has, historically, been unaffected:

First is cost: unlike cooling tower users, purchasers of cars are not usually looking for a piece of equipment that will last an extraordinary length of time (why would they seek to increase the price of something that they fully intend to trade in three to five years?).

Secondly, except to the appreciative and understanding eye of an engineer, galvanizing cannot be classified as an attractive finish. It is comparatively rough – often spangled in appearance – and over a period of time, forms a protective patina of oxidation that gives it a whitish appearance. (Owners of older cooling towers often say, “the whiter – the better.”)

Finally, because of galvanizing’s propensity for early oxidation, it will not accept paint readily. Without stringent measures for surface preparation, the paint adheres to the patina – rather than the base metal – and ultimately flakes off. (Presumably, the early electrostatic application of an epoxy coating – under good quality assurance procedures – will alleviate this problem for the automobile industry.)

Intuition would lead the layman to believe that covering a sacrificial coating with a barrier coating should result in a coating system of unparalleled excellence. Unfortunately, intuition does not always lead one to the correct conclusion. However, such a conclusion may have been the motivation for premature acceptance of this coating system by some cooling tower manufacturers and users. That, plus the evidence of its having withstood a reported 6000 hours exposure to a 5% salt solution spray.

First, let’s consider the value of this test. In June of 1951, at the **ASTM 25th Edgar Marburg Lecture**, F. L. LaQue presented a paper entitled *Corrosion Testing* in which he demonstrated the misleading nature of salt spray tests. The following are excerpts from that paper:

“When it is known that a certain composition of brine is most corrosive towards a particular material, and the object of the test is to achieve maximum destruction in minimum time, this concentration of brine is indicated in preference to some other one. But it must be remembered that this composition of brine may be less corrosive than another one towards some other material and that no single brine composition can be used to rate materials in any general order of corrodibility that will apply to other environments, including even marine atmospheres.”

LaQue goes on to say: “Any notion or statement that so many hours exposure in a salt spray chamber is equivalent in general to so many days, weeks, months, or years in a natural environment (including marine environments) is obviously nonsensical.”

To date, as far as cooling towers are concerned, time in actual operation is the only test on which it has been possible to base accurate conclusions. The possible combinations of corrosive elements, concentrations, temperatures and degree of aeration, which can exist in the water circulated over a cooling tower are infinite. Small wonder that conditions even approaching similarity cannot be duplicated in the laboratory.

Not too long ago, zinc-chromatized aluminum paint was represented to have withstood 4700 hours of 20% salt spray under laboratory conditions. Yet time proved that it was unable to survive actual cooling tower operation. Therefore, the ability of a current coating system to withstand 6000 hours of 5% salt spray is insufficient reason to begin comparing it to stainless steel. Proponents of galvanizing do not presume to make such a comparison; and their history of success exceeds a quarter of a century.

SPX Cooling Technologies has not always been skeptical of the promise of laboratory test results. We succumbed to the apparent superiority of a specialized barrier-type coating in 1955. “Marclad” was a spray-applied, baked-on epoxy coating which withstood testing beautifully, which produced a very attractive finish, and which gave every indication of being virtually impenetrable. Unfortunately, this highly advanced coating proved unable to survive in the real world of cooling towers. Consequently, we dismantled and discarded the expensive booths and ovens, and standardized on time-proven heavy galvanizing.

Although SPX Cooling Technologies continues to test various coatings under laboratory conditions, the ultimate test always involves placement of promising material or coating samples in operating cooling towers for extended evaluation. To date, we have found no cost-effective coating system capable of dislodging uncoated galvanizing from its position of supremacy.

Because laboratory testing alone is too self-limiting to warrant meaningful conclusions with respect to cooling towers – and because the vagaries of field testing prevent accurate laboratory analysis – the reason why no advantage appears to be gained by coating galvanizing with a barrier layer is, of necessity, conjectural. A possible explanation may be that the normal variations in barrier layer porosity will promote localized acceleration of corrosion, while neighboring areas of greater barrier integrity might tend to restrict the underlying zinc’s ability to respond as required. Decreasing the availability (or mobility) of zinc, therefore, would increase the response of the steel – allowing localized progressive corrosion to occur rapidly.

Logical Alternatives

The condition of these two installations – operating under widely disparate qualities of water and atmosphere – is typical of the majority of existing Marley galvanized steel cooling towers of similar vintage. And, in most of those cases, the evidence would seem to point to many more years of useful service life before major recoating becomes necessary. On the other hand, a few such cooling towers have been subjected to an operating environment so severe that they have required major repairs within a relatively short period of time.

Generally, those failures can be traced to inadequate maintenance or inappropriate water treatment – but not always. Occasionally, local atmospheric conditions, or circulating water contaminated by particular processes, are sufficiently aggressive to make even the most diligent attempts at maintenance and treatment ineffective. In such cases (most of which are quite predictable on the basis of a typical water analysis or past experience), concerned users are well-advised to consider other materials of construction as alternatives to the prospect of abnormal maintenance costs.

A thorough exposition of the available materials of cooling tower construction, along with indications for their application and guidelines for specifiers, appears in *Corrosion Resistant Materials for Cooling Towers*. The following is a brief overview of the more common materials used either in conjunction with or in lieu of galvanized steel.

Plastics – In this era of increasing petrochemical technology, plastics tend to spring most quickly to the modern mind – and many of them have found their way into the cooling tower industry. For the most part, they are impervious to all of the elements and water qualities normally encountered in cooling tower operation (except, of course, for the rare combination of circumstances that causes a solvent solution to result).

Fiberglass structure cooling towers are gaining increasing popularity for particularly aggressive environments. They can also offer advantages where cooling tower aesthetics are a concern, often providing an economical alternative to costly cooling tower enclosures. Polyvinyl chloride (PVC), polypropylene, glass reinforced nylon and glass reinforced polyesters and epoxies also provide major advantages in many cooling tower components.

Wood – Wood (particularly pressure-treated Douglas fir) is very forgiving of a wide range of water and air qualities, but often, specifiers will avoid wood cooling towers on the assumption that they are fire hazards, and will require the added expenditure and maintenance associated with a fire protection sprinkler system. For the most part, these fears are groundless. Only where local building codes specifically prohibit wood cooling towers should they be considered out of contention! (Almost without exception, those codes were enacted when fill, drift eliminators, and fan cylinders were still being manufactured of wood.)

Today, those components are routinely manufactured of fire-retardant plastics – as are casings, louvers and a multitude of components previously mentioned. As a result, governing authorities for fire underwriters usually grant blanket approval of selected, predesigned wood cooling tower models, without the need for a sprinkler system – and *without* any increase in insurance premiums. Where requirements exceed normal routine, additional features can be added—such as FRC (fiber-reinforced cement board) overlays on all decking, “firewall” partitions between cells, and the like. (See pages 95 and 96 in *Cooling Tower Fundamentals*, or discuss the situation with your Marley sales representative.)

Stainless Steel – Occasionally, either through personal preference, or because of a restrictive building code, specifiers will exhibit a preference for steel cooling towers, regardless of the conditions under which they will operate. Although Marley steel cooling towers are designed such that all of the major components normally manufactured of galvanized steel can be provided in stainless, experienced users often take a selective approach to the specification of those components. Many will tend to limit their requirements to a stainless steel basin and/or structure, recognizing that all other primary components are relatively easy to replace.

Where cooling towers of “all stainless steel” construction are specified, all cooling tower components are provided in stainless steel except for motors, Geareducer® units, ladders, handrails, fans, fan guards, fill, drift eliminators, valves, nozzles, castings and the like. The components excluded are those which do not

lend themselves to stainless steel construction, or are naturally impervious to corrosion (as are all of the plastic components). The result, of course, is a cooling tower whose service life far exceeds that expected with standard construction – even heavily galvanized steel.

Conclusions and Recommendations

The purpose of this paper has been to give the specifier and user a perspective on which to base judgment of the various types of coating systems applied to carbon steel cooling towers today, apart from the hype and hoopla of promotional language. The points made are summarized as follows:

1. The constant processes of aeration, evaporation and air-washing which occur in a cooling tower, along with water of dubious quality – combine to produce a unique potential for corrosion. Apparent successes registered by coating systems utilized in other industries (where success may be measured by an altogether different yardstick) are, historically, not transferable to the aggressive environment of cooling towers.
2. There are no laboratories which can anticipate and reproduce the highly variable operating environment which a cooling tower is required to withstand as a matter of routine. Therefore, the only measure of a coating's success is its exhibited longevity (in real time) under actual operating circumstances.
3. To date, barrier type (paint) coatings, however applied, have been totally unsuccessful in cooling tower application. Furthermore, considering their natural porosity, and dependence upon stringent quality control measures, there is no present anticipation of a “major breakthrough”.
4. Galvanization is a sacrificial type coating, whose effectiveness is relatively independent of the perfection of its application, but whose capacity for protection is directly related to the applied thickness of zinc and to the accessibility of the zinc surface. Marley cooling tower's standard application is G-235 (2.1 mils average thickness), and specifiers should insist upon nothing less! Galvanizing's history of success in actual operation speaks for itself.
5. The marginal value of “combined” coating systems over and above the value of galvanizing alone is questionable. Since the true protection must be provided by the galvanizing, and since the barrier coating may inhibit the zinc's sacrificial nature, there is valid reason to anticipate that these coating systems are unlikely to live up to their advance billing.
6. Where users are seeking corrosion protection beyond that which even heavy galvanizing might be expected to assure, alternate materials of construction should be considered. Currently, the principal choices are fiberglass, wood and stainless steel. Specifiers and purchasers are well advised to selectively apply these alternate materials to meet individual requirements of environment or application.

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