WHITE PAPER

THE ENGINEERED APPROACH TO EDGE CORROSION WITH EDGECOAT II™

BY: WALT SKOVRON

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Edge corrosion on steel has a two-fold effect. It is not only aesthetically unpleasant, but more importantly, can affect product life. To address this issue, we need to consider the best form of material protection. When it comes to coatings, porcelain enamel (i.e. glass coated) over steel substrates has proven to be a top performer for long term durability and corrosion resistance. In order to understand porcelain enamel's superiority, we need to understand the history, how it is manufactured, and what makes it distinct vs other coatings.

History:

Porcelain enameling was believed to take form around the first century A.D. The primary types of enamel were cloisonné and champlevé, depending on the method of fabrication. As time progressed, enamels were applied to gold, then silver, bronze, copper and finally iron. It was on iron that enameling found its most practical use. Following the application to iron and steel, the next major achievement was the application of clay to keep the powdered enamel suspended in water, improving adherence to the metal before firing.

Present Day:

The 1940-50's was one of tremendous growth and increased usage as porcelain became heavily adopted by the appliance and hot water tank industries. Later, superb color properties led to the rise of architectural applications along with sinks and tables for its easy to clean and sanitary properties. Porcelain enameling markets include ovens and range tops in the appliance industry, interior hot water heaters, plumbing ware *and bolted storage tanks for water, municipal wastewater, manure slurry and animal feed silos.* Although many replacement coatings have been developed in the municipal water and wastewater markets, porcelain enamel's high performance characteristics simply outperforms all alternatives.

Porcelain Enamel Defined:

According to Porcelain Enamel Institute, porcelain enamel is defined *as "a substantially vitreous or glassy inorganic coating bonded to metal at a fusion temperature above 800°F."*

The key words are *vitreous* and *inorganic*. Most are familiar with the terms vitreous or glassy. These materials are encountered in everyday life in many different forms and applications. The uniqueness of the porcelain enamel material is that it is specifically designed and formulated to bond or fuse to the metal substrate. Much in same way glaze is formulated to adhere to a ceramic body. This unique formula requires ingredients that are not common in glass manufacturing like bottles or windows.

The other key word is *inorganic*. This is less familiar to most but actually sets porcelain enamel apart. Most inorganic compounds do not contain carbon and are derived from mineral sources. The raw materials used for porcelain enamels include minerals, rocks and clays as well as chemicals manufactured as products or by-products of the chemical industry. These "of the earth" materials are what contribute to porcelain enamels' superb corrosion resistant, physical, mechanical, electrical, sanitary and color stable properties desired for their end use applications and environments.

Another property that enamels exhibit is a lack of coating porosity on the surface. After firing the enamel forms an impervious moisture barrier. Most, if not all organic coatings have an amount of physical porosity that can ultimately allow water molecules to migrate to the metal substrate.

When it comes to coating performance, adhesion to the substrate is critical. While most organic coatings rely upon cross-linking during the curing process in which the cured coating attaches itself to the substrate, the porcelain enamel adhesion mechanism is more sophisticated and secure. During high temperature exposure, the enamel/steel interface undergoes a unique transformation. Iron oxide at the surface of the steel actually dissolves into the glass (see Figure 1), forming a layer where the steel and enamel or intertwined.

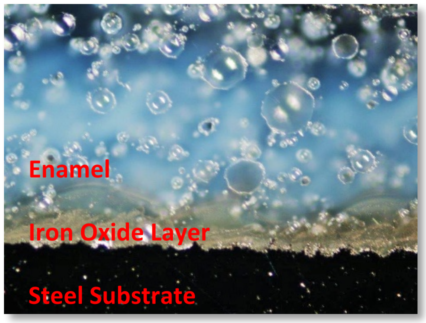


Figure 1

For corrosive environments like hot water tanks or liquid storage tanks, the enamel is specifically formulated for each application to perform. The glass frits are selected to promote the necessary adhesion while at the same time producing a durable surface for the application. The goal being, to prevent corrosion of the base metal substrate in a way that outperforms organic coatings.

Below are examples of the properties a porcelain enamel glass must pass in order to be approved for storage tank specifications:

1. **ISO28706-2:2011 Clause 10**. Boiling Citric Acid (2.5 hours)
2. **ISO28706-2:2011 Clause 12**. Boiling Hydrochloric Acid – vapor phase (7days)
3. **ISO28706-22011 Clause 13**. Boiling distilled Water. 48 hours
4. **ISO28706-2:2011 Clause 9**. Standard Detergent Solution 24 hours
5. **ISO28706-2:2011 Clause 8**. Hot Sodium Hydroxide. 24 hours
6. **ISO 6370-2** Abrasion Resistance

Proper selection of the glass frits, clays, refractories, opacifiers, coloring oxides and electrolytes are essential for the specific application and the responsibility of the supplier and coating manufacturer.

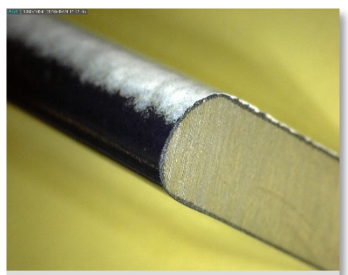
By now it should be clear that porcelain enamel is the coating of choice for ultimate performance in these conditions. The challenge becomes how to uniformly apply and adhere this coating to all the surfaces of a metal substrate. We will now focus our attention to where corrosion becomes most susceptible – *the steel edges*.

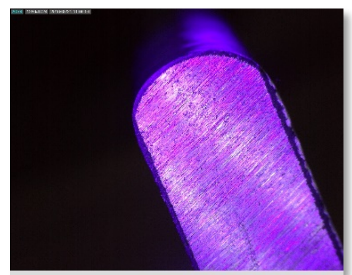
Edge corrosion is not a new phenomenon. Whether the coating is organic based (i.e. paint/epoxy/urethanes etc.) or inorganic based (i.e. porcelain enamel, ceramic) the challenge lies in providing an adequate film of protection on a surface that is not exactly conducive to accepting a coating.

Any thermosetting (organic) or thermoplastic (inorganic) coating must proceed through a melt phase as it heats to the temperature at which it can crosslink or fuse to its substrate. During this phase, the film has an opportunity to flow and level itself, ideally resulting in a smooth and attractive film which is aesthetically appealing and corrosion resistant. The Porcelain Enamel Institute recommends that when designing parts for enameling that certain radii criteria are maintained for the enamel to successfully adhere. Depending upon the post-fire enamel thickness, different radii are recommended. Thinner thicknesses can tolerate a tighter radius, heavier thicknesses (12 mils +) require larger radii.

Engineered Approach:

The engineered approach combines the superior adhesion and performance of porcelain enamel, along with a properly configured metal substrate geometries. CST has accomplished this by engineering the metal edge and applying the glass in a suitable yet consistent thickness range for maximum corrosion resistance.





End result, the steel panel is now completely encapsulated in glass on all six sides. Driving innovative improvements in the areas that are most susceptible to environmental attack is what CST considers to be the "*Edgecoat II.*"

In memory of Walt Skovron (1957-2016) - Director of Coating Technology at CST Industries and responsible for Glass quality and continuous improvement. Walt earned his BS degree in Ceramic Engineering from Alfred University and had over 32 years of experience in porcelain enamel, metal pretreatment and powder coatings. He was a certified Six Sigma Black Belt from GE Appliances where he also earned the title of Manufacturing Principal Engineer for Coatings. Walt is the co-author of one patent, one patent pending and was an active board member of the Porcelain Enamel Institute where he taught and presented technical subject matter on porcelain enamel. He has co-authored two technical manuals on porcelain enamel processing for the institute. He will be missed.