Title: Best Porcelain Enamel Tank in the World for Liquid Storage Tanks

CST Industries, Inc.
The Global Leader in Storage Tanks and Covers

BPE-WP-0614

Contents

History

CST Storage, formerly known as Engineered Storage Product Company (1996-2011), was originally part of the A.O. Smith Company. It was A.O. Smith's research, and later, development of coated welding rod that likely led them to a proprietary process of fusing glass to steel. The technology was initially used to manufacture large, single-piece, glass-lined brewery tanks, and soon after, to manufacture glass-lined, hot-water heaters. While other applications for glass-fused-to-steel were explored, years of experience with this technology eventually led to the design and manufacture of the first glass-fused-to-steel tank, which went into service in 1949 as the Harvestore® silo. This agricultural tank application for high-quality, feed storage has been widely used, and imitated, for over 65 years.

The first glass-fused-to-steel tank went into service in 1949 as a Harvestore® silo.

In the 1970's, A.O. Smith formed its Municipal and Industrial Division and subsequently launched porcelain enamel (glass-fused-to-steel) tanks for water, wastewater and other liquid storage uses. Since then, more than 100,000 glass-fused-to-steel tanks have been installed in over 70 countries around the world.

Introduction

CST Storage is the premier leader in the design and manufacture of glass-fused-to-steel storage tanks. Our success is evidenced by over 65 years of manufacturing experience and more than 100,000 installations worldwide. But time and experience alone do not qualify a company to be an industry leader. It is CST Storage's additional commitment to quality and customer service, and dedication to advancing product development through R&D and world-class manufacturing that sets it apart from other tank manufacturers and ensures continued success into the future. As a result, glass-fused-to-steel tanks are simply the best quality, lowest maintenance, and most flexible, storage tank option available.

Our success is evident by 65 years of manufacturing experience and more than 100,000 installations worldwide.

This paper contains detailed information on the items that make CST Storage glass-fused-to-steel tanks unique:

- Glass quality
- Our patented coating process known as Vitrium®
- Our custom, proprietary sheet edge coating process Edgecoat™
- Glass testing procedures
- Quality control
- Compliance with the American Recovery and Reinvestment Act of 2009
- Authorized dealer network

CST Storage applications range from the storage of livestock feed and manure to potable water and digesters. Our in-house engineering group, sales team, and authorized dealers work with our customers to design standard and custom tanks to meet their discriminating storage requirements.

CST Storage's glass-fused-to-steel tanks offer the longest product life and greatest value because of:

- **High Glass Quality**
  Our durable, field-tested, glass coatings have thicknesses in the range of 10 to 18 mils. This holiday-free glass coating thickness provides the lowest maintenance requirement over the life of the tank, and thus a greater lifetime value compared to alternative coating materials.

- **Patented Coating Process**
  Vitrium Glass combines the superior chemical resistance and outstanding physical properties of titanium dioxide-rich glass with process-optimized, ultra-fine bubble structure. This translates to longer tank life, durability at competitive pricing, maximum coating effectiveness without excess coating thickness, and 100% holiday-free sheets.

- **Exclusive Edgecoat Process**
  Edgecoat is a proprietary process developed in 1996 by A.O. Smith that is designed to reinforce and enhance the sheet edges by applying protective layers to the edge of shell and rectangular floor sheets.

- **Factory Glass Testing**
  CST Storage conducts voltage tests as high as 1500v to ensure ISO-conforming sheets are 100% holiday-free. Standard glass sheets are 100% 69.4v wet-tested for a holiday-free coating.

- **Product Quality Control**
  CST Storage has a state-of-the-art, in-house lab where the most technical, quality, performance, and validation related tests can be performed.

- **American Made Steel**
  CST Storage uses American-made iron and steel in our tanks and manufactured goods, American-made aluminum dome materials, and American-made glass frit to produce a glass-fused-to-steel tank that fully complies with Section 1605 of the American Recovery and Reinvestment Act of 2009.

Vitrium Glass combines the superior chemical resistance and outstanding physical properties of titanium dioxide rich glass with process-optimized, ultra-fine bubble structure.

- **Authorized Dealer Network**
  Our products are sold by authorized independent dealers. In addition to selling and erecting glass-fused-to-steel tanks, our dealers offer design and layout services, budget analysis, site preparation, concrete work, and more—for a complete turn-key solution. From the design phase through turn-key installation, CST Storage authorized dealers assure customers they have made the correct buying decision with the selection of a porcelain-enamel coated, glass-fused-to-steel tank manufactured by CST Storage.

From the design phase through turn-key installation, CST Storage authorized dealers assure customers they have made the correct buying decision.

Design Life Statement

Life Cycle Cost (LCC) analysis is used by federal, state, and local governments, and world-class industries throughout the globe. In accordance with a 2008 University of Washington study, 91% of US states and Canadian provinces that responded to their survey indicated that they use LCC analysis for major construction projects.

The National Institute of Building Sciences states that "LCC is especially useful when project alternatives fulfill the same performance requirements, but differ with respect to initial costs and operating costs." LCC analysis, as a part of the evaluation process, is a valid component in the total purchase decision of a municipal or industrial storage tank. It is important when conducting an LCC analysis that the data used to perform the calculations be as accurate as possible. The Office of Government Commerce (UK) offers the following hierarchal list of methods for determining these values with the clear emphasis on actual data having more probability of accuracy than opinions.

- "Known factors or rates" are inputs to the LCC analysis which have a known accuracy.
- "Cost estimating relationships (CERs)" are derived from historical or empirical data.
- "Expert opinion," although open to debate, is often the only method available when real data is unobtainable. When expert opinion is used in an LCC analysis, it should include the assumptions and rationale that support the opinion.

CST Storage designed an LCC analysis to assist anyone attempting to determine lifetime value of various types of water storage tanks. When conducting the glass

tank portion of the LCC analysis, it needs to be clearly stated that the longevity of CST's glass-fused-to-steel tanks is yet to be finally determined by actual field data. That is because among the thousands of glass-fused-to-steel tanks in municipal water, wastewater, and leachate service around the world, there are very few tanks available that have been removed from service for CST to gather data to definitively determine the actual end of service life. Not surprisingly, most of them are still in service today.

There have been very few tanks that have been removed from service for CST to gather data to definitively determine the actual end of service life. Most of them are still in service today.

Glass Quality

Over our 65-year history, we have built 100,000+ installations around the world. These structures have been built using glass coatings with thicknesses of 10 to 18 mils. The holiday-free glass coating thickness is one of the specification details that provide confidence, the lowest maintenance requirements, greater lifetime value, and an allowable service range to 140 F at pH 3 to 11, depending on specific product stored. It isn't the coating thickness that makes our product unique, it's the proprietary chemistry of the glass (porcelain enamel coating) combined with the special processes needed to fuse it to the steel. The end result is a high-performance, glass-fused-to-steel technology also known as porcelain enamel-coated steel.

The end result is a high-performance, glass-fused-to-steel technology, also known as porcelain enamel coated steel.

High-performance, titanium dioxide (TiO_2)-rich glass formulations provide:

- Longer tank life
- Maximum coating effectiveness, without requiring excess coating thickness, in order to provide the needed durability at competitive pricing
- Proprietary process technologies and voltage testing provide factory certified 100% holiday free sheets.

With over 65 years of experience, and over 100,000 structures successfully installed around the world, this combination of glass quality and glass thickness will continue with each and every new structure installed.

Titanium Dioxide

In 1998, CST Storage launched an R&D project to develop a process for the direct application of our patented, titanium dioxide (TiO_2)-rich glass. Through this research the goal of increasing value by providing a three-coat-two-fire (3c2f)

coating performance with a single pass through the furnace was achieved. The result was a totally new, patented "three-coat-one-fire" (3c1f) process for applying TiO_2-rich glass. The patented process and coating has been trademarked as Vitrium (from Vitreous and Titanium).

TiO_2 is a very common ingredient used by many coating manufacturers for various reasons:

- It is considered inert, and at high levels in porcelain enamel, gives unique properties.
- In the case of the interior coating, Vitrium, with its higher percentage of TiO_2 in the final white layer, allows CST Storage to provide an exceptional enamel surface.
- During firing, the white layer's higher viscosity has the effect of controlling bubble structure, in addition to making the top TiO_2 rich layer harder, more chemical resistant and the bubble structure finer. This high TiO_2 content is unique to glass-fused-to-steel and provides exceptional properties to fit colder conditions common to the North American market.

During firing, the white layer's higher viscosity has the effect of controlling bubble structure, in addition to making the top TiO_2 rich layer harder, more chemical resistant, and the bubble structure finer.

As a result of using higher amounts of TiO_2 in the final white layer, a unique visual marker on the glass known as "Vitrium threading" becomes apparent. This is caused by thicker areas of the top white layer interspersed with thinner areas allowing the underlying bluecoat to rise through because of its lower specific gravity. This immediately identifies the coating as Vitrium.

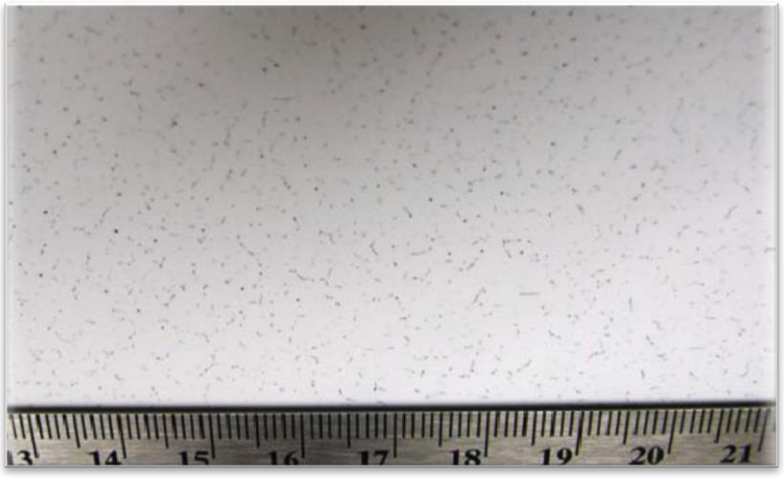

Figure 1 - Vitrium Threading. Opaqueness of whitecoat to show underlying Vitrium bluecoat

What should be emphasized is the incredible effectiveness of the white glass layer in containing the blue layer even with the variation in white coat thickness. Figures 2 and 3 show cross-sections of the glass-steel interface at 100X magnification. Note the glass bubble structure and how the top, white layer displays an ultra-fine bubble structure at the surface of the glass. This is the real value of the TiO2–rich, white glass.

Figure 2 is a typical cross-section of a "two-coat-one-fire" (2c1f) process that does not contain a final layer of TiO_2 rich porcelain. Comparing this cross-section to Vitrium (3c1f) in Figure 3, one can see significant differences. First, the bubble structure for Vitrium is very fine which allows flexibility yet provides a hard, impermeable coating. The 2c1f process without TiO_2 results in larger bubble structure allowing a potential direct path for corrosion. Second, by its very nature, a 2c1f process cannot have the thickness of a 3c1f enamel. Utilizing a 2c1f process for an interior coating could potentially make the coating less resistant to liquids.

The 2c1f process without TiO_2 results in larger bubble structure, allowing a potential direct path for corrosion.

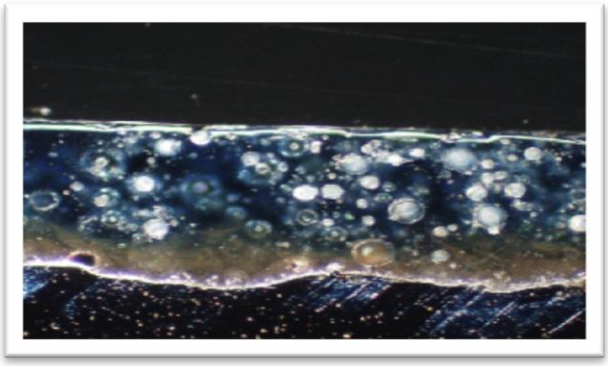

Figure 2- 100X magnification showing a Two-Coat-One-Fire (2c1f) without titanium dioxide

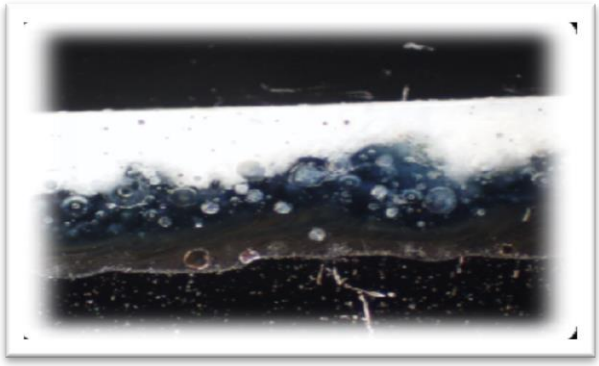

Figure 3- 100X magnification showing the Three-Coat-One-Fire (3c1f) with titanium dioxide (Vitrium)

Edgecoat

The Edgecoat process was originally developed in 1996 and continues to be refined to this day. Edgecoat is a machine-sanded and arc-sprayed, sheet-edge treatment, and is an excellent example of CST Storage's attention to detail and innovation. The CST Storage Edgecoat process is another benefit and advantage of glass-fused-to-steel tanks, and is hard to beat.

To date this Edgecoat process is the only such process in the world.

Milled or sheared edges are the most difficult areas to coat with glass. The custom-built, proprietary process is designed to reinforce and enhance the sheet edges with the same robust and inert coating that protects the rest of the panel.

To date, this Edgecoat process is the only such process in the world, and consists of several proprietary operations, resulting in complete encapsulation of the sheet edge with porcelain enamel.

Once the tank is assembled, all full height shell sheets and rectangular floor sheets are coated with a sealant to provide one more layer of edge protection.

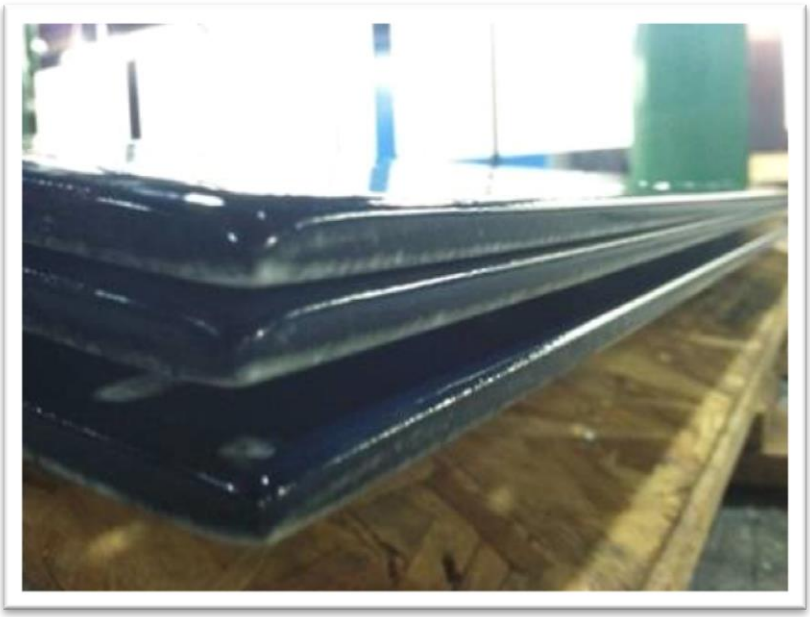

Figure 4 – Thermally applied proprietary protective layers/coating

Holiday Testing

Holiday testing, as it is commonly called, is known more accurately as discontinuity detection. Its purpose is to test for the presence and location of discontinuities, voids, and/or thin spots in an otherwise non-conductive surface. Holiday testing is separate from a coating thickness test; however, both tests are used to confirm quality of the final porcelain enamel coating.

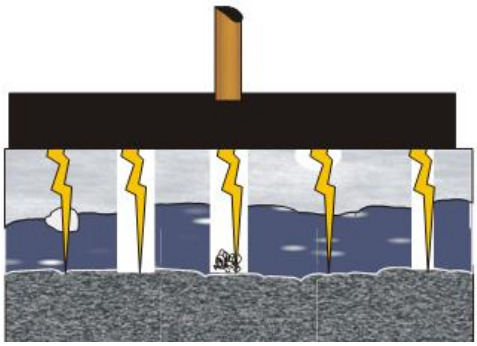

Figure 5– Test Sheet with Defects

1 – Current passes through defect below surface
2- Current passes through pin hole
3- Current passes through grease
4-Current passes through thin spot
5- Current passes through small pin hole

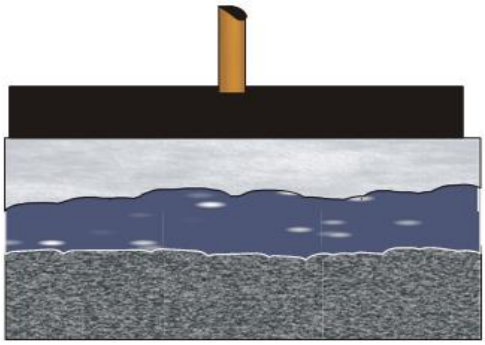

Figure 6- Test sheet with No Defects Current DOES NOT pass through a uniform, continuous, quality coating.

Holiday testing is performed by generating a DC voltage potential or difference between the glass surface and the steel substrate, and then detecting any current flow that occurs between the two surfaces. When testing Vitrium, CST applies a voltage to the dry glass surface while monitoring for any return signal that may be detected on the steel substrate. This circuit must be recreated for each and every sheet tested. Any sheet that is found with interior holidays is re-blasted and recoated.

Any sheet that is found with interior holidays is re-blasted and recoated.

Quality Control

The stringent testing of CST Storage coatings is an extensive process and covers all aspects of the ISO-certified plant. Analysis of the steel, steel surface, frit, slip, slip application, firing, color, consistency, coating thickness, and coating defects are combined to provide a coating that is specified to be holiday-free.

All steel that enters the CST Storage plant undergoes external and internal inspections prior to the application of the enamel coating:

- All incoming steel is accompanied by a steel batch report confirming composition and yield strength
- Sheet tolerances, thickness, and squareness are confirmed.
- Once the sheets pass inspection, they are blasted and the surface roughness is measured. The surface is blasted to a NACE (National Association of Corrosion Engineers) specification of least SP-10, near white metal, that is checked against a visual NACE comparator.

All of the porcelain enamel surfaces, Vitrium as well as 3c2f processes, adhere to the requirements of International Standard EN15282:2007/ISO 28765 and to AWWA D103. Furthermore, CST Storage complies with its own published

standards that have been formed from over 65 years of experience in dealing with many different liquids and field conditions throughout the world.

The testing methodology employed by CST Storage is proprietary and takes into account the exceptional material properties that fit the colder conditions common to the North American market. The glass-fused-to-steel product is subjected to several critical tests that go beyond AWWA D103 as well as the requirements of any international standard. Cross-sectional photomicrography is primarily used to confirm the quality of the coating and is performed on both Vitrium and 3c2f products. Each sheet is stamped with a serial number that is traceable back to its original steel coil ID. This numbering system allows CST Storage to track and trace every sheet through the manufacturing, testing, shipping, and erection processes.

The testing methodology employed by CST Storage is proprietary and takes into account the exceptional material properties that fit the colder conditions common to North America.

Bubble Structure Testing

In order to confirm an ultra-fine bubble structure that is so critical to porcelain enamel, cross-sectioning and microphotography are utilized. Bubble structure cannot be left up to field evaluation to determine success. CST Storage incorporates photomicrography into its testing regime in order to confirm bubble structure and consistency.

Impact Testing

Impact testing is done to check coating bond strength with the steel and is critical in evaluating high quality porcelain enamel. A sheet fails if underlying steel is exposed after the test is performed.

International standards only require testing monthly or a per-batch basis. The intent of the international standard (ISO) is to check the surface coating resistance to impacts and does not fully consider bond strength. CST Storage's testing is performed hundreds of times a year and intensity is varied based upon the sheet thickness.

Factory Testing of Glass

Over the last decade, significant improvements have been made in the factory testing equipment for glass coatings. Currently there are several pieces of equipment on the market that can routinely test glass with dependable and repeatable results without damaging the glass coating. The dry test conducted in CST Storage's factory provides assurance of a 100% holiday-free glass-fused-to-steel sheet with no damage to the glass coating.

The dry test conducted in CST Storage's factory provides assurance of a 100% holiday free glass-fused-to-steel sheet with no damage to the glass coating.

Packaging

Finally, each sheet is carefully packaged on specially designed pallets with paper between each sheet to protect them during shipment. The packaging guarantees the tank is delivered defect and holiday free, and guarantees that exact replacement sheets can be manufactured if any were damaged in the field.

American Made Steel

Today's customers are more aware than at any time in recent history of the importance of buying American-made products to keep our economy strong. CST Storage prides itself on producing products that comply with the American Recovery and Reinvestment Act of 2009.

Today's customers are more aware than any time in recent history of the importance of buying American made products to keep our economy strong.

All of the following steel, glass, and aluminum components make for a glass-fused-to-steel tank with an aluminum dome that is made in the United States of America:

- Glass frit used for our premier coatings
- Sidewall, roof, steel floor material
- Aluminum dome material
- Structural steel material
- Other miscellaneous components

Since 1949 CST Storage has been manufacturing glass-fused-to-steel (porcelain enamel coated) storage tanks. The discoveries and refinements of our dedicated research are incorporated into our manufacturing processes. With over 100,000 storage tanks installed worldwide, our glass-fused-to-steel tank is backed by CST Storage's history and proven integrity. For more information, please visit our website at www.cst-storage.com. For an estimate on a CST Storage porcelain enamel coated (glass-fused-to-steel) tank, please visit our website and request a quote.