

INTRODUCTORY GUIDE TO GLASS-LINED STEEL EQUIPMENT

Glass Lining Properties

Glass-lined steel is not a new technology; it has existed for centuries. The first glass-lined cast iron vessel was produced by De Dietrich in the 1800's in Zinswiller, France. Manufacturing practices and glassing technology have certainly improved in the past three centuries, but the fundamental characteristics of this unique type of equipment have remained intact and continue to make glass lining a valuable component in the chemical process industry.

Glass-lined steel equipment features unique characteristics that make it mandatory for use in processes when service conditions are particularly difficult. This is the case for applications involving products that exceed the resistance limitations for corrosion, abrasion, mechanical and thermal shocks. Chemical and pharmaceutical companies are continually extending the limits of their processes in order to increase productivity or succeed in new developments, calling for higher temperatures, lower temperatures, higher pressures, and higher concentrations. The capability to extend standard limitations is possible only if the equipment in use can withstand these progressive operating requirements.

Through continuous research and development of various glass, De Dietrich Process Systems has created a glass formulation referred to as "3009 glass" which has proven to offer the most optimum properties including:

- Chemical resistance to acidic and alkaline mediums
- Mechanical resistance to shocks and abrasion
- Thermal allowance for variant temperatures

The subsequent pages will provide you with additional information on the chemical, mechanical and thermal properties of 3009 Glass as well as a general overview of the glass lining fabrication process. Understanding the properties of glass lining will help you determine if glass-lined equipment is a viable option for your company. You can also visit us online at www.ddpsinc.com for more information or to contact us about specific questions involving your process.

Glass-Lined Steel Benefits

Glass-lined steel's composite metal/glass material of construction provides the best of both worlds of each of the primary components. The external steel construction provides strength while the internal glass lining gives nearly universal corrosion protection and a smooth non-contaminating surface. Additionally, companies choose to use glass-lined equipment for the various other benefits it offers, including:

- Anti-Stick Many substances will not stick to glass, but will stick to metal.
- Purity Glass has high quality standards for food and drug applications.
- Flexibility Glass can handle a diverse range of chemical conditions. Drastic changes in process involve no added investment for new equipment.
- Ease of Cleaning Fire polish lends itself to quick, easy cleaning and sterilization.
- Absence of Catalytic Effect Eliminates the possibility of catalytic effect.
- Economy Glass-lined steel equipment is the most corrosion resistant material. The cost is comparable to stainless and most alloys.



Glass Lining Fabrication

The manufacturing of glass-lined steel equipment is a three step process, consisting of glass production, steel fabrication, and combining of the glass and steel. Today, our raw glass material is still produced at our worldwide headquarters in Zinswiller, ensuring universal quality. The vessel and glass lining are manufactured at our production facility in Corpus Christi, Texas. The glass production and glassing process are outlined below.

Glass Production

Each batch of enamel is comprised of carefully selected and rigidly controlled raw materials, which are melted in a rotary furnace at approximately 1,400°C.The melted glass is then poured into water. This sudden tempering breaks the enamel into grains called "glass frit", which are dried and milled into powder. The powder is then shipped to DDPS sites throughout the world. To prevent any contamination, each batch is processed separately, between each operation, in closed containers. During the preparation of each batch of 3009 glass, numerous tests are performed and rigorous control measures are set to assure a perfect and reproducible quality.

Glassing Process

A suspension called "slip" is prepared with enamel powder and emulsifying agents are sprayed like a paint on the surfaces to be glass-lined. After this coat is air dried the equipment is charged into a furnace and fired at temperatures that affect fusion between glass particles. The vessel/parts are then transferred to a cooling oven and allowed to cool. The coat is then submitted to various controls including thickness, spark testing, and visual inspection.

The process is then repeated; the item is sprayed with another coat that will be air dried, fired, and Q.C. tested. These cycles are always performed by the same technician who will adjust and complete his/her work, until obtaining perfect glass lining. To facilitate visual inspection of a process the glass is available in blue or white, both having identical chemical and mechanical properties.



Chemical Properties

Isocorrosion Curves

Our isocorrosion curves are established for most current products. They illustrate product concentrations in relation to temperatures at which the weight losses correspond to 0.1 and 0.2mm/year.



The use of glass is not advisable

Care must be taken of the advance of corrosion

Glass can be used without problems

All the tests have been performed in Tantalum-lined reactors and using a ratio volume of product/surface of enamel (V/S) > 20 to avoid the inhibition of the attack by dissolved silica.

Resistance to Acids

Generally, 3009 glass has a high degree of resistance to acids whatever their concentration, up to relatively high temperatures. For most of the inorganic acids, the resistance of the glass passes through a minimum for a concentration of 20-30% weight, then increases with the acid concentration.

For example, the 0.1 mm/year rate is found at 128°C in H_2SO_4 30% and at 180°C in H_2SO_4 60%. The exception to this is phosphoric acid, in which the speed of attack increases with the concentration: 0.1 mm/year at 163°C for 10% concentration and at 112°C for 70% concentration.

Hydrofluoric acid completely and quickly dissolves the glass whatever the temperature is. Its concentration in the product must not exceed 0.002% (20 ppm).









Resistance to Organic Substances

Chemical attack is very low in organic substances. If water is given off during the reaction, the rate of attack will depend on the amount of water in the solution. In the case of 0.1N sodium hydroxide in anhydrous alcohol at 80°C, the rate of attack is virtually nil. In methanol, there has to be more than 10% water before the loss of weight can be measured, whereas in ethanol with 5% water, the weight loss is already half of what it is in aqueous solution.



Resistance to Alkalis

Here the permissible temperature limits are lower than for acids. At pH = 13 (NaOH 0.1N) this maximum is 70°C. Therefore, it is important to be cautious when using hot alkalis. Temperature must be controlled, as an increase of 10°C doubles the rate of attack of the glass. Care must be taken for the introduction of alkalis into a vessel. Avoid the flow of alkalis along the warm vessel wall by using a dip pipe.

Resistance to Water Vapor

Resistance to water is excellent. The behavior of glass in neutral solutions depends on each individual case but in general is very satisfactory.







Corrosion Inhibition

Chemical reactions are sometimes so severe they cause a rapid wear on the enamel surface. The use of additives to the reacting substance can inhibit this corrosion permitting the use of glass-lined equipment. When using acids, several tens or several hundreds ppm of silica protect the enamel and considerably reduce the rate of corrosion during the liquid phase. The same result can be obtained at the vapor stage by adding silicon oils. Generally speaking, the higher the temperature, the greater the quantity of silica required, and more the acid is concentrated, the more the amount of silica can be reduced. In presence of fluorine, silica also has a favorable influence. We always recommend a pre-test as each reaction is different. An attack inhibitor can be useful in one case and non-effective in another.

	Pure Product	500 ppm CaCO ₃	300 ppm SiO ₂	Silicon Oil 2 ml/l
NaOH 1N 80 °C	0.18 mm/year	0.09 mm/year		
Buffer pH= 1 ; $100^{\circ}C$ + HF 430 ppm	1.5 mm/year		0.42 mm/year	
HCI 20 % vapor 110 °C	0.036 mm/year			< 0.005 mm/year





Mechanical Properties

Glass-lined equipment features the qualities of glass as well as its main weaknesses, which are brittleness and low tensile strength. Since the resistance of glass to compression is well above its tensile strength, one of the solutions to improve the mechanical resistance is to put the glazed layer under compressive prestress. This is achieved during controlled cooling after each firing. During mechanical work (deformation, mechanical or thermal shock) the compressive stress must first be offset by an equivalent tensile before the glass could be put under dangerous tensile stress.

Flammable Solvent Vapors

The different experimental arrangements used for measuring mechanical shock resistance produce incomparable results, making it virtually impossible to give intrinsic values for resistance. The only way to compare different glasses is to use the same method and the same criteria.

In our method, a 1 kg mass equipped with a 15 mm ball is dropped onto a glass-lined plate (glass

thickness: 1.5 mm). This plate is locked onto a magnetic base, making it thicker and increasing the shock efficiency (no energy absorption through steel vibrations). The plate is electrically grounded, and the electric current going through an electrolyte deposited at the shock location is used as assessment criteria. When tested to this procedure, which is close to the real service conditions, the mechanical shock resistance of the De Dietrich 3009 glass is about 80% greater than that of the former glass.

Abrasion

The abrasion test is far from the actual working conditions of a glass-lined reactor where the effects of the chemical attack enhance those of abrasion. Nevertheless, it allows a comparison between glasses, showing 3009 glass advantageously. Statistically, it has been shown that in practice the cases of destruction by abrasion are negligible. However, should any doubt arise when an abrasive substance is being used, only a comparative test performed with that product could lead to a conclusion.

	Units	DD 3009 GLASS		
HCI – Vapor – DIN 51157 - ISO 2743	mm/year	0.036		
HCI – 20 % 140 °C – V/S = 20	mm/year	0.2		
NaOH 1N 80 °C - DIN 51158 - ISO 2745	mm/year	0.19		
NaOH 1N 80 °C – V/S = 20	mm/year	0.35		
NaOH 0.1 N 80 °C – V/S = 20	mm/year	0.18		
H ₂ O - Vapor - DIN 51165 - ISO 2744	mm/year	0.017		
Thermal shocks – Statiflux surface cracks	С°	220		
Abrasion – DIN 51152	mg/cm²/h	2.35		
Abrasion – DIN 51152	Improvement against former glass: 80 %			

Thermal Properties

The large majority of glass-lined process equipment is designed with a system that enables the heating and cooling of their contents. Heat transfer can cause considerable damage to the glass lining if proper precautions aren't taken when introducing variant temperatures to the process. The limits set in the chart below should be followed when working with standard equipment; In the case of customized equipment that is built specifically for extreme temperature and pressure ratings, contact DDPS for operating limitations.

Thermal Shock vs. Thermal Stress

Glass-lined equipment is sensitive to thermal shocks and thermal stresses, depending on their geometrical or structural characteristics. It is important to clearly define the terms "thermal shock" and "thermal stress" in order to make the distinction between these events.

Thermal Shock

Thermal shock occurs when there is an abrupt change in temperature applied either to the surface of the enamel when a new product is introduced to the vessel (e.g. reagent, cleaning water), or to the steel (such as jacket nozzle location when introducing, for example, super-heated steam).

Thermal Stresses

Thermal stresses are mechanical stresses related to temperature gradients which appear temporarily in the steel during phases of temperature changes. These are related to the design of equipment and may generate stresses in the enamel, which may cause its rupture, and/or result in fissuring of the passivation layer in the jacket coils. If the latter occurs it can foster the development of corrosion under stresses, which may lead to the appearance of transverse cracks.

Example A

If the product and the glass-lined wall are at 170° C, the fluid temperature should be between +30°C and +200°C.

Example B

If the glass-lined wall and the thermal fluid are at 20°C, products between -25°C and +165°C may be safely introduced.

GENERAL CASE OF STANDARD VESSELS CALCULATED FROM -25°C TO +200°C EN 15159 NORM

WHEN INTRODUCING THE THERMAL FLUID IN THE JACKET				WHEN LOADING Product Into the vessel			
	— A	4		da	B		
₽ Ţ Ţ	T [°] not t T [°] mini -25 -25 -25 -25 -25	T ^o maxi 120 125 135 145	Product and wall T° -25 -20 -10 0	Pro not 7° mini -25 -25 -25 -25 -25	T° maxi 125 130 140 150	Thermal fluid and wall T° -25 -20 -10 0	
	-25 -25 -25 -25 -25 -25 -25 -25 -25 -25	155 165 170 175 180 185 190 195 200 200 200	10 20 30 40 50 60 70 80 90 100 110	-25 -25 -25 -25 -25 -25 -25 -25 -25 -25	157 165 175 180 190 200 200 200 200 200 200 200	10 20 30 40 50 60 70 80 90 100 110	
	-20 -10 0 10 20 30 40 50 60	200 200 200 200 200 200 200 200 200	120 130 140 150 160 170 180 190 200	-25 -25 -5 5 20 30 45 60 75	200 200 200 200 200 200 200 200 200	120 130 140 150 160 170 180 190 200	

Note: The maximum ΔT values given in these tables MUST be respected. They are limit values which must not be exceeded.

Glass Lining FAQS

Q: Why is glass-lined equipment used?

A: Glass-lined steel is a material of construction for chemical and pharmaceutical processing where service conditions of the process are particularly difficult and corrosion resistance, inertness and cleanability are key concerns. The 3009 glass formulation withstands lower and higher temperatures, pressures, and product concentrations and offers superior corrosion resistance over a broad range of chemical applications.

Q: What are the properties of glass-lined steel equipment?

A: 3009 glass offers excellent resistance to corrosion, abrasion, mechanical and thermal shocks, making it suitable for highly corrosive processes. The formulation of this multipurpose glass is adapted to cGMP requirements and its anti-adhesive properties are ideal for cleaning, cleanliness, and sterilization. Furthermore, the glass surface is impervious to catalytic effects and contamination.

Q: How is De Dietrich glass lining fabricated?

A: 3009 glass starts out as enamel comprised of carefully selected and rigidly controlled raw materials. The enamel is melted in a rotary furnace and then poured into water. This sudden tempering breaks the enamel into particles called frit. The frit is then dried, ground and screened into a powder.

Next, the powder is mixed with emulsifying agents and the glass suspension is sprayed on the prepared steel. The item is moved into an electric furnace to "fuse" the glass to the steel. The item is then transferred to a controlled cooling booth that helps to reduce built-in stresses in the glass. This cycle is repeated until the desired glass thickness is obtained. Quality control spark and thickness tests between coats are performed to ensure the highest quality of the finished lining. The result is an impermeable, smooth coating of glass that is ideal for pharmaceutical and chemical applications.

Q: Where is De Dietrich glass lining manufactured?

A: The raw glass material is produced at our worldwide headquarters in Zinswiller, France, ensuring universal quality. The vessel and the glass lining are manufactured at our state-of-the-art manufacturing plant located in Corpus Christi, Texas.

Q: What are the main benefits of glass-lined steel equipment?

A: Benefits to glass lining include:

- Excellent resistance to corrosion
- Mechanical resistance to shocks and abrasion
- Smooth, non-stick properties
- Non-catalytic inertness
- Multipurpose material for versatility

- Meets cGMP requirements for cleaning, cleanliness and sterilization
- Customization upon specification
- Suitable for high pressure and full vacuum at elevated temperatures

010

De Dietrich PROCESS SYSTEMS

De Dietrich Process Systems is a leading provider of Process Equipment, Integrated Systems, and Engineered Solutions to the bulk chemical, fine chemical, and pharmaceutical industries. Our experience enables us to offer a wide range of high-quality solutions, products, and services for a variety of manufacturing processes. Specializing in glass-lined steel, we provide corrosion-resistant equipment that can handle severe service conditions.

How can we help you meet your business's chemical processing needs? To find out more, contact us:

Visit - www.ddpsinc.com Call - 908-317-2585 Email - sales@ddpsinc.com