HIGH PERFORMANCE VINYL ESTER LINING SYSTEMS

AND THEIR USES

IN FGD (FLUE GAS DESULFURIZATION) SYSTEMS

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High Performance Vinyl Ester Linings have proven to be effective solutions for many corrosion and abrasion problems in Flue Gas Desulfurization (FGD) equipment. Vinyl Ester linings are available in a variety of different formulations, offering outstanding corrosion and abrasion resistance combined with the ability to withstand relatively high temperatures found in flue gas exhaust and other FGD environments. Typical FGD lining applications include:

1. Chimneys
2. Stacks
3. Ductwork
4. Scrubber modules
5. Precipitators
6. Baghouses
7. Limestone slurry tanks
8. Make-up water tanks
9. FGD system bleed tanks

Discussed herein are the various available types of Vinyl Ester linings and their unique properties and suitability for different FGD environments.

Most Vinyl Ester linings used within the Utility FGD market are based on one of two primary resin types: a) Bisphenol A Epoxy Vinyl Ester or b) Novolac Epoxy Vinyl Ester. Each of these resins exhibits various desirable properties; however, the primary differences are as follows:

Bisphenol A Epoxy Vinyl Esters offer good all around chemical resistance with excellent performance in both moderate acid and strong alkaline service. They are well suited for use in strong alkaline oxidizing agents such as sodium hypochlorite and caustic/chlorine solutions, as well as alkaline environments such as limestone slurry tanks and piping. Bisphenol A Epoxy Vinyl Esters can safely withstand temperatures up to 220^{o}F in most suitable chemical environments and slightly higher in dry heat or mild chemical service. Bisphenol A Epoxy Vinyl Esters offer only limited resistance to organic acids, solvents, strong oxidizing acids and high temperatures. These applications are better served using a Novolac Epoxy Vinyl Ester system.

Novolac Epoxy Vinyl Esters offer outstanding resistance to strong oxidizing acids, organic acids and solvents and acid/bleach solutions such as chlorine dioxide. Novolac Epoxy Vinyl Esters exhibit superior performance in high temperature acid environments such as those found in Flue Gas Desulfurization exhaust gas systems. Properly formulated linings based on these resins are capable of withstanding temperature extremes to 400^{o}F and higher in some instances. While Novolac Epoxy Vinyl Esters perform well in hot acid service and in oxidizing acids, they offer only limited resistance to strong alkaline solutions, particularly at elevated temperatures. These hot caustic applications are better served using Bisphenol A Epoxy Vinyl Esters as mentioned above.

Using either of the two above listed resin types, Vinyl Ester linings and coating systems can be broken down into two main system types:

1. Relatively thin film systems ranging from 20 to 70 mils, typically installed by spray, brush or roller in either one or two coats. These linings utilize various inert fillers based on either flake or abrasion resistant powders. Fillers include:
    a. surface treated flake glass
    b. mica
    c. iron oxide
    d. aluminum oxide
    e. silicon carbide
2. Thick film heavy-duty systems ranging from 70 to 150 mils, are usually trowel applied in multiple coats and are typically reinforced with inert flake glass, fillers, or sometimes fabrics, including:
    a. large diameter treated flake glass
    b. high purity silica
    c. aluminum oxide
    d. silicon carbide
    e. various fabric reinforcements i.e.: fiberglass, synthetic, graphite

Thin Film Vinyl Ester Linings are typically applied at thicknesses ranging from 20 to 70 mils and are best applied by spray, roller or brush in one or two coats. When spray applied, these materials are installed rapidly and cost effectively. The selection of base resins and filler combinations for thin film vinyl ester systems is based on the service requirements of each application. The benefits of these various fillers include exceptional corrosion resistance, low permeation rates, high temperature resistance and excellent resistance to wear and erosion.

Thick Film Vinyl Ester Linings are typically applied at thicknesses ranging from 70 to 150 mils and are usually trowel applied in two or more coats. Heavy-duty systems are installed in areas requiring low permeation rates, exceptional corrosion resistance and, often times, resistance to constant wear and erosion. System selection, including base resin, filler and lining type for thick film vinyl esters is based on the service requirements of each application. Thick film trowel applied systems include flake glass reinforcement, high filler loads and are often fabric reinforced to improve physical properties, high temperature resistance and resistance to wear and erosion. While thick film, trowel applied linings are more costly than thinner, spray applied systems, many harsh environments require their use.

Various FGD applications and suitable lining systems are listed below.

Chimneys, Stacks, Scrubber Modules and Outlet Ductwork in most FGD units, operate at relatively low temperatures (below 200^{o}F), extremely low pH and often under positive pressure due to high velocity and limited exhaust volumes. In these cool, wet and highly acidic conditions flake glass and other flake type fillers offer enhanced permeation resistance and extended service life. The configuration of these flake type fillers creates a very lengthy path for any corrosive media to make its way to the substrate. Surface treatment of many fillers provides a tenacious bond of the resin to the flake filler minimizing the ability of acid solutions to permeate the lining, as illustrated in Fig. 1 and compared on Fig. 2, both found on Pg. 6. The overlapping of the flake shaped fillers creates a film cross section that is highly resistant to strong acid vapors, even under positive pressure and constant flow. (Photos 1 & 2 on Pg. 5)

Scrubber Inlet Ductwork and Bypass Ducts handle the continuous flow of gasses that are typically unscrubbed, acidic, particulate containing and at relatively high temperatures. In many FGD systems these areas in the units operate at temperatures between 275^{o}F and 375^{o}F. As the gasses in these areas have not yet been scrubbed they are highly acidic and may contain some flyash or other particulate matter. In these areas the fillers of choice are usually surface treated flake glass or aluminum oxide. Properly formulated Vinyl Ester linings based on the appropriate resin and filler combinations are able to withstand thermal extremes up to 410^{o}F, along with the corrosion, wear and erosion associated with these unscrubbed acidic gasses. (Photos 3 & 4 on Pg. 5)

Precipitator and Baghouse conditions are very similar to Scrubber Inlet and Bypass Ducts. In addition, these units also include the possibility of the formation of acid condensate at various times throughout the year. As ambient temperatures in many geographic locations fall below freezing in the winter months, many precipitators and baghouses experience what is known as cold wall corrosion. This phenomenon usually occurs only on one or two walls of the unit, usually the walls with a northern exposure or constant shade. As the outside temperature pushes the wall temperature below the dew point, the interior surfaces are exposed to considerable amounts of strong acid condensate. This unique set of conditions creates the need for high temperature resistance throughout most of the year, as well as low permeation rates and good corrosion resistance when the temperatures fall below the dew point. Surface treated flake glass and iron oxide fillers offer the necessary properties for good performance in this environment. (Photos 5 & 6 on Pg. 5)

FGD System Tanks; Limestone Slurry, Make Up & FGD Bleed Tanks are not subject to the high temperatures typically associated with flue gas exhaust systems. There are, however, many corrosion and abrasion requirements in these tanks. FGD system tanks are typically used for storage, mixing, make up and recirculation of a highly alkaline, limestone slurry used for neutralization of the acidic gasses passing through the FGD system. Constant flow of limestone slurry and recycled FGD effluent poses a significant abrasion problem as well as the potential for substrate corrosion if not properly protected. This combination of constant erosion and wear, combined with both alkaline and acidic solutions requires the use of aluminum oxide, silicon carbide or flake glass fillers. In addition, many slurry impact areas, high velocity flow areas and tank bottoms require the added protection of a double layer, fabric reinforced lining system. In most of these double layer linings, high purity silica fillers are used for the first layer with abrasion resistant aluminum oxide or other ceramic powders used for the topcoat, or working surface of the lining. (Photos 7, 8, 9 & 10 on Pg. 6)

Cost engineered Hybrid Vinyl Ester Linings are ideally suited to retrofit existing FGD Equipment. After years of service, in many cases existing FGD Equipment reaches critical stages of deterioration due to harsh conditions. Often the equipment was either unlined or previously installed linings, left in a state of disrepair, no longer provided protection to steel substrates. Hybrid Trowel/Spray applied linings are available which offer substantial cost savings over steel replacement and costly metal fabrication expense. These linings are suitable for use in areas with significant steel corrosion, pitting and compromised substrates. By the use of a heavy duty, trowel applied basecoat to fill voids and a low cost spray applied topcoat, much of the steel replacement, welding and patching is minimized. While these hybrid lining systems cannot restore structural integrity to failing steel vessels, they can minimize or eliminate steel replacement or welding to fill pitted steel and can provide a cost effective lining for areas exposed to harsh chemistry, wear and erosion. **

The use of a heavy-duty trowel applied mortar or flake glass basecoat fills voids in pitted steel and creates a sound smooth surface for the spray application of the topcoat system. These systems can also be fabric reinforced to offer additional integrity to the lining. These systems can be based on Flake Glass, Aluminum Oxide, ceramic powders or other appropriate fillers for specific applications. (Photos 8 & 9 on Pg. 6)

Due to their unique ability to withstand strong acid and alkali solutions, as well as relatively high temperatures, Vinyl Ester linings have proven to be viable solutions for many problems associated with harsh operating conditions found in today's Flue Gas Desulfurization systems. Continuing advances in resin technology, formulating concepts, and engineering design allow higher performance standards to be reached utilizing these polymer systems. Further data on permeation resistance, perm rates and other information is included in Fig.1 and Fig. 2 on Pg. 6.

Photo 1 **
FGD Outlet Ductwork and Chimney

Photo 2
FGD Outlet Ducts and Breeching

Photo 3
Scrubber Bypass Duct

Photo 4
Scrubber Inlet Duct

Photo 5
Precipitator Outlet Duct/Breeching

Photo 6 **
Precipitator Corrosion

Photo 7
FGD System Bleed Tank

Photo 8 **
Deteriorated Baffle Limestone Slurry Tank

Photo 9 **
Severely Pitted Tank Interior

Photo 10 **
Exterior Corrosion on Slurry Feed Tank

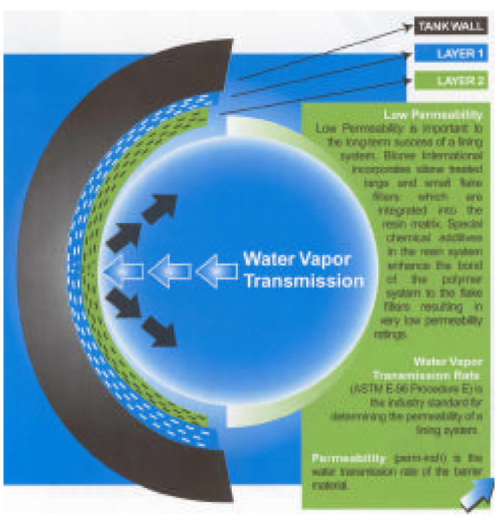

Figure 1
Flake Fillers Reduce Perm Rates

Comparison of several commercially available systems:

System	Permeability (Perm-inch)
Blome TL-220	0.0002
Blome TL-280	0.0005
Blome TL-220S	0.0009
Blome TL-220S-AR	0.0006
Flake Glass Polyester Lining: spray	0.0016
Fiberglass Mat Laminate hand lay-up epoxy or polyester	0.0078
Flake Filled Epoxy Coating: spray / 2 coats	0.00157

Figure 2
Permeability Measured by Perm-inch

** Photos and supplemental text by Andrew K. Bernard – Corrosion Protection Services; St. Louis, MO