How a Single Wall Storage Tank Gets a New DoubleWass

In less time and with less money, a new technology promises to deliver effective corrosion protection for tanks. Engineers report from ICI Devoe Coatings, Para-beam, CSI Coating Systems, ZCL-USA and Parabeam Distribution NA.

Lining Technology:
Today’s emphasis on secondary containment and leak detection has made double-wall tanks and piping popular choices for new installations. With the relatively new product discussed in this article (3D glass fabric-epoxy system), tank owners can now get double-wall containment and continuous leak detection without replacing their single-wall steel or fiberglass underground storage tanks or reworking their aboveground storage tank floors. To acquaint PE&T readers with the technology, the above authors prepared this article from a considerably longer feature that appeared in the March 1999 issue of the Journal of Protective Coatings & Linings (“Reinforced Glass Fabric Epoxy Linings with Leak Detection for Storage Tanks,” p. 24, by Mike O’Donoghue, PhD, Ron Garrett and V. J. Datta, ICI Devoe Coatings Company; Kees Swinkles, Parabeam Industrie, Holland; and Pierre Crevolin, PEng, CSI Coating Systems, Inc.).
Until recently, tank owners in the United States who opted either to line their storage tanks rather than replace them (or to replace them with less expensive single-wall tanks) had to accept an important fact: Neither course of action would give them the added assurance that would have come from installing tanks with secondary containment and continuous leak detection—that is, double-wall tanks.

Now, tank owners in the United States can transform their existing single-wall tanks into double-wall tanks with secondary containment and continuous leak detection by using the 3D glass fabric/epoxy technology already embraced in Austria, Germany, the Netherlands, Sweden, Switzerland and the United Kingdom (and recently field tested in the United States and Canada). Deploying this technology in an existing double-wall tank will create a new triple-wall tank.

What is this technology and how does it work?

3D glass fabric and epoxy
The tank conversion technology, known as the Phoenix System for USTs and Devmat 3D Plus for ASTs, is a composite matrix of 100 percent solids epoxy and three-dimensional (3D) glass fabric that is bonded to the inside wall of a UST or, in the case of an AST, the tank floor. The matrix is then top-

coated with a 100 mil (nominal) layer of 100 percent solids epoxy. The fabric in the matrix, which is referred to as glass yarn 3D glass fabric and trademarked as Parabeam worldwide, was developed in Europe in 1989.

Parabeam, the 3D glass fabric, consists of two identical parallel fabric decks (upper and lower planes) woven integrally and mechanically together by means of vertical pile threads. There is a pre-set interstitial space between the two deck surfaces or planes. The 3D glass fabric is available in interstitial space thicknesses ranging from three to seventeen millimeters (0.12 to 0.67 inches). The three-millimeter thick fabric is the most commonly used type of Parabeam for tank linings and conversions.

Figure 1: End and side view of a section of the 3D glass fabric.

All surfaces of the 3D glass fabric have a silane sizing that makes them compatible with the specially formulated epoxy resin system and allows the resin system to saturate the fabric. During the wetting-out process, the fabric has an inherent rebounding property, called spring resilience, that forces the upper deck to spring back from the lower deck to a height dictated by the length of the vertical pile threads. The vertical pile threads look like a multiple series of miniature I-beams. Figure 1 shows the end and side view of a section of the fabric.

The spring resilience and compressive strength of the 3D glass fabric is derived from four factors:

- over 45,000 vertical pile threads per square foot;
- capillary forces during and after impregnation with a resin system;
- firmness with which the vertical piles are woven into the fabric planes; and
- E-glass composition of the fabric.

Figure 2:
Schematic of leak detection system that monitors interstitial space.

When the glass fabric is impregnated with this epoxy and begins to cure, a continuous cavity is formed between the upper and lower decks of the laminate. A cross-sectional view of the cured fabric/resin matrix looks somewhat like that of corrugated cardboard. While the lower deck is tightly adhered to the tank wall or floor, the upper deck is flooded with epoxy. This process leaves an interstitial space, which can be continually monitored by a number of standard leak-detection systems. See Figures 2, 3 and 4.

The upper and lower decks of this system are impermeable. In the event of a cargo leak resulting from mechanical damage to the interior surface of the laminate, the interstice will contain the product, allowing the monitor to detect the leak and sound an alarm. Similarly, water entering the interstitial space from outside the tank will be contained inside the space so that it can be detected and appropriate steps taken.

In USTs, the technology provides a 360-degree double wall with an “interstitial sandwich” system that combines high strength and the appropriate degree of bending stiffness. The 3D glass fabric/epoxy laminate is entirely non-corrosive.

Leak-detection options

Many permanent leak-detection techniques can be applied with this composite laminate to provide continuous leak detection. Several combinations of techniques are possible, which can increase detection reliability. In practice, the leak-detection techniques that can be employed with the lining include: hydrostatic, pressure, vacuum or liquid sensing.

Based on a theoretical model, the appropriate laminate construction can be calculated. In practice, with the proper glass content, a continuous pressure load of up to 10 psi on the interstitial space of the UST is possible.

Figure 3:
Interstitial space monitoring attachment.

Figure 4:
3D glass fabric-AHC epoxy laminate at the critical zone of an AST.

Mechanical properties

Besides its leak detection capabilities, the fast-curing sandwich structure of the 3D glass fabric has several properties not found in standard fiberglass mat laminates. These include the following:

- The majority of the E-glass is at the extreme surfaces of the 3D laminate, which is separated by the capillary support beams, or pseudo-I-beams, giving the laminate high tensile strength and flexural modulus.

- The interstitial space also safely absorbs impacts, which would cause fractures or holidays in standard tank linings.

- Another important distinction is that the 3D glass fabric/epoxy eliminates osmotic pressure pockets or corrosion cells that can otherwise result from fluid wicking when tank linings are damaged by mechanical impact. With the 3D lining system, if any fluid finds a path through the primary containment membrane, it will be contained in the interstice.

Getting the right resin

Until recently, 3D glass fabrics were used primarily in conjunction with isophthalic polyester and vinyl ester resins rather than epoxy resins. However, it is widely known, and demonstrated by immersion test data, that certain epoxies are capable of delivering equal or better corrosion resistance and structural performance compared to the polyester and vinyl ester resins.

Though epoxies are, in general, more expensive than polyesters and vinyl esters, they provide the advantage of having a very low VOC emissions rate. This makes them more desirable when applying resins within closed spaces, such as inside an UST. The Phoenix System utilizes an epoxy resin system to reduce the risk to personnel and the environment while working in a non-factory location.

While an epoxy system would solve these problems conceptually, it was not so easy in actuality to develop a suitable material for this purpose. But recent research and molecular engineering have led to the development of a new class of solventless epoxies.

The new epoxies are described as advanced hybrid cycloaliphatic (AHC) amine-epoxies. Refinements in this technology have enabled a critical balance to be achieved among viscosity control, thixotropy, wetting, reaction rate, chemical resistance, thermal resistance and recoatability. At the same time, a clear resin system is produced; this is necessary for visual inspection as the resin wets out glass fabrics.

Using AHC epoxy chemistry with 3D glass fabrics offers significant performance and application advantages compared to polyester, vinyl ester and standard epoxy-based laminates.

AHC epoxy advantages

With AHC technology, coatings are available that provide: excellent compatibility with 3D glass fabrics; great penetration; a high degree of wet and dry adhesion; rapid curing without accelerators; self-priming; excellent water and chemical resistance; and excellent high temperature resistance.

Rapid cure AHC epoxy coatings are 100 percent solids by volume and, when not used in conjunction with 3D glass fabrics (and depending on service requirements), they can be spray-applied to create an ultra-thick, one-coat film of from 20 to 125 mils, without runs or sags and without compromising performance.

Careful modifications of some of these AHC epoxies enable them to thoroughly impregnate, and be reinforced by, 3D glass fabrics. After installation of a 3D glass fabric-AHC composite laminate (and depending on project specifics), a tank could be returned to service in as little as 12 to 24 hours after application.

AHC epoxy systems were developed in the 1990s. The benchmark chosen for optimum chemical resistance for the systems was satisfactory long-term immersion in methanol and other aggressive, petroleum-based chemicals.

Formulations with single converters have limited effectiveness, whereas properly formulated multi-converter AHC epoxies can withstand constant immersion in methanol and a whole range of solvents, fatty acids and mineral acids (e.g., glacial acetic, hydrochloric and concentrated sulfuric acids).

The particular AHC epoxy developed for use in USTs meets API 1631 Section 1.3.4 criteria in independent third party tests.

Figure 5:
“Butt” edges of installed glass fabric and seal with stitch-mat.

Converting to a double-wall tank

Before applying any lining, a tank's condition and integrity must be carefully determined and the tank must be cleaned and prepared according to applicable codes and standards. This work and the lining application itself must be performed only by qualified applicators.

When AHC epoxies are applied in conjunction with 3D glass fabric, the initial application of the clear AHC epoxy is 20 to 30 mils WFT. It is immediately followed by placing the three-millimeter 3D glass fabric into the wet epoxy. The epoxy must be worked up into the 3D glass fabric and any air trapped beneath the lower deck should be removed and wrinkles eliminated.

The 3D glass fabric is laid down in parallel courses with edges butted together and not overlapping (see Figure 5). After each parallel course is rolled out, a specially-designed seam cover material known as Phoenix Tape is applied, uniformly wetted, and rolled out over the butted seams of the glass fabric (see Figure 5). This material is required to seal off the joints of the 3D glass fabric. Additional epoxy is applied on this first layer as required.

The application then needs sufficient time to cure so that it can be inspected. Then, any anomalies, protruding strands, rough edges, seams, clips and projections are either ground or sanded smooth, preparing the surface for the next step. The entire surface of the tank is swept clean and vacuumed.

After all prep work and touch-up is complete the top coat can be applied. The top coat is also a 100 percent solids epoxy resin formulated to be compatible with the cargo stored in the tank. This top coat is applied to a nominal thickness of 100 mils.

The final stage of the installation is a pressure test of the interstitial space using the air and soap bubble method. The contractor will then reconnect the piping, install the leak detection system and run a precision test on the tank to verify its tightness. Quality assurance guidelines are followed at every step of the installation process and are reviewed completely prior to putting the tank into service again.

USTs and ASTs

In the Northeastern United States, USTs with such cargoes as gasoline and fuel oil have been converted into double-wall tanks using the Phoenix System, and ASTs have been converted into double-floor tanks using the Devmat 3D Plus System. In addition, two major oil companies are finalizing plans for long-term national programs to upgrade their USTs and ASTs using the 3D glass fabric/epoxy resin technology.

ICI Devoe Coatings sells the Devmat 3D Plus System, a 3D glass fabric/epoxy technology for creating double-floors in aboveground storage tanks. ZCL-USA, Inc., markets the Phoenix System, a 3D glass fabric/epoxy technology for converting single-wall underground storage tanks to double-wall.

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