The Development Of Fiberglass USTs

In 1961, a major oil executive challenged Owens Corning Fiberglas to develop a non-corroding tank. John M. Clark, P.E. tells how the manufacturers met the challenge.

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Fiberglass reinforced plastic (FRP) underground storage tanks (USTs) have been used widely since their introduction in the mid 1960s. Owens Corning Fiberglas (OCF), now known as Fluid Containment, Inc., was the first company to receive a UL Listing for its FRP buried tanks. In late 1976, I joined OCF and, for the last 20 years, I have been closely involved in the research, design, product development and testing of FRP underground storage tanks – first as an employee of OCF and now, as president of my own consulting engineering company.

This article is about how FRP buried tanks were developed, from their initial prototypes into the popular product lines of today.

Initial development
In 1961 a major oil executive challenged OCF to develop a non-corroding tank. OCF met this challenge and dedicated 50 percent of its tank production to supply one company's needs.

When OCF started the initial product development of the first FRP USTs, one important issue became quickly apparent–existing steel tank specifications were material not performance specifications. Therefore, major changes were required to replace steel with a less stiff corrosion resistant material.

The first tanks, the Model A, had tapered shells that allowed them to be nested (i.e., stored like paper cups) for shipping to other locations for assembly. The walls of the tanks were smooth and about 1/4 inch thick. The thinking at the time was that a 1/4 inch shell wall, with the added support provided by the backfill, would be sufficient without making the tank with ribs. This assumption proved to be incorrect, indicating how little we understood about the interaction between soil and large underground structures.

The prototype Model A was installed at OCF's Granville, Ohio Technical Center laboratory and subjected to a flooding condition to duplicate the pressures of high groundwater.

Like a submarine, a tank must be strong enough to resist the external hydrostatic pressure. During the test, the tank developed small, localized buckling on the bottom that was visible through an inspection port. Local buckles are football-shaped dimples that can form in a cylinder that is subjected to an external pressure and are a function of thickness, radius and material stiffness.

The second prototype, Model B, included stiffening ribs to prevent localized buckling and to stiffen the tank in the circumferential direction. Rib feet were added to Model B to increase rib bond strength; and this new design, Model C, became the first commercially available underground fiberglass tank for fuel storage in 1963.

Owen's Corning met the challenge to design a non-corroding tank. Here the Model C-2 tanks are installed for a major oil company (1968).

How specifications were developed

OCF aimed to provide a tank that would not leak, even under severe pressure. Therefore, with input from Underwriters Laboratories (UL), OCF pressurized each tank to 5 pounds per square inch (psi) and sprayed a soapy solution over them to detect bubbles from leakage. Tanks also had to withstand a 25 psi internal test for ultimate strength. Here we found that flat end caps would not work, and hemispherical end caps were used instead. Other requirements were also established for surface loads, uneven support, dropping and external pressure resistance.

The UST group at the OCF Tech Center worked closely with UL to develop the FRP performance specifications and test methods. We then went about developing a tank that would meet these specifications, the Model C. This was the first FRP tank with UL and Factory Mutual (FM) approval. The majority of these specifications have remained unchanged, and UL has added specifications for new products, such as double wall tanks.

Once that the initial tanks were UL tested, OCF started to develop longer, higher volume tanks. The UL test series were based on the largest volume tank of a given diameter, since the diameter controls the design criteria for buckle resistance. Lower volume tanks of the same diameter and design were Listed by this testing.

OCF improved its installation practices and overall performance in the late 1960s and early 1970s through incremental design and manufacturing changes and by requiring pea gravel as backfill material. Pea gravel is a naturally rounded, uniformly graded, self compacting aggregate that flows easily. Today, pea gravel remains the preferred backfill material of the industry.

OCF extended its product line to a 10 foot diameter tank in the early 1970s and to 12 foot diameters in the mid 1970s. The 6, 8 and 10 foot tanks all used a 16.5 inch rib spacing for the optimum design. For the 12 foot diameter tank, however, 12 inch spacing was needed to maintain the same relationship for pipe stiffness and to keep the shell wall thickness reasonable.

OCF's Model G tank was introduced in 1979 and had new, conical-hemispherical shaped end caps (a patented OCF feature and a redesigned rib with a lower height). The new end cap design helped to ensure that backfill would flow easily underneath the curve of the endcap. The change in the ribs provided greater flexibility and lower in-service stress. The desired stiffness for stability was maintained by increasing the bending strength-to-stiffness ratio.

OCF also started using straight wall collapsible molds to manufacture tank shells to simplify tank calibration. A tapered shell has a variable area along the tank length, complicating measurement of the tank contents.

New product demands

In the early 1980s, the industry faced new challenges with the increased use of methanol and ethanol fuel mixtures; and, in the mid-1980s, there was increased interest in double wall tanks. Existing laminates were not 100 percent compatible with alcohol fuels, so new methods for laminate construction, processing and curing were needed. Double wall tanks are more difficult to construct, so new designs and manufacturing processes had to be developed.

Significant material testing and product development efforts were launched to verify that existing products would meet low level alcohol environments and to develop new products to handle up to 100 percent alcohol. These developments are ongoing to create the chemically resistant tank laminate and to improve manufacturing processes.

Alcohol performance criteria

The controling design criteria for adequate performance was local buckling, which could possibly occur when a nearly empty tank was subjected to a hydrostatic pressure. Thus, the wall thickness for tanks storing alcohol fuel blends had to be thick enough between ribs to safely resist this buckling.

We conducted a carefully designed test series of eight full scale buckling tests on 8 foot diameter, 10,000 gallon tanks with an underwater video camera mounted inside the tanks. Tanks made of any material will buckle if subjected to a sufficient vacuum and external hydrostatic pressure. When conducting a structural test, it was important to take the test tank to failure to help the design engineer establish accurate safety factors. This was done for this test series.

While studying the effects of applying a vacuum on reduced thickness tanks (used to model the effect of lower material properties), we were able to verify the local buckling equation used today for design. Using the test data, along with plant QC data for thickness (t) and modulus for elasticity (E), we developed a statistical model for analyzing the risk of local buckling.

We also developed a global building equation that improved upon the predictor for large diameter tanks with shallow bury depths, the American Water Works Association’s AWWA-C 950 method used at the time. There is a significant body of data available to confirm this result, and I continue to work on this relationship to add data points for different types and materials of USTs.

Today, the buckling problem has been solved with alcohol blends of fuel. FRP UST manufacturers now regularly sell tanks for methanol and other alcohol blends of fuels, and provide 30 year warranties for laminate performance.

Rotational molding

Xerxes (formerly Century Fiberglass) has made significant contributions to the state of the art technology, using a manufacturing process called rotational molding. Century Fiberglass developed its tank design between 1969 and 1972; and, in 1972, secured a UL Listing for its 8 foot FRP tanks up to 12,000 gallons. These 8 foot diameter tanks are the most prevelant diameters in use today.

The Xerxes female rotating mold concept permitted the ribs to be integrally molded to form a monocoque structure, which requires no secondary bonding of the half-shells other than rib caps.

Xerxes acquired Century in 1979 and expanded the product line to include 4, 6, 10 and 12 foot diameter tanks. This gave Xerxes the market opportunities to make small diameter waste oil tanks at one extreme, and huge sprinkler and potable water tanks at the other.

The first UL Listed FRP double wall tank was developed by Xerxes in 1984.

Double wall tanks

In 1984, Xerxes developed the first UL Listed FRP double wall tank in the marketplace. It was essentially a single tank on which a second shell was constructed. In 1989, the company introduced the first reduced annulus (interstice) tank that utilized advanced “sandwich design.” It was less costly, and reduced the capacity of the annulus. Reducing the annulus capacity reduced the weight of brine and allowed it to be installed at the factory annulus with brine in all but the largest models. This eliminated a difficult and critical step in the installation in the field.

The main issue in the development of double wall tanks was how to make a double wall tank that performed well and would be cost effective – not just how to provide an outer wall. Manufacturing process development was the key, and many innovative methods were developed to make double walled tanks.

The performance criteria for the first double wall tank included:

a) containing a leak for the inner wall;
b) detecting both an inner and an outer wall leak; and
c) detecting a leak with high groundwater pressure.

The latter is accomplished by creating a small gap of about 1/8 inch between two shells, and filling this gap with a fluid of specific gravity of 1.4 (brine), up to and into a reservoir mounted on the top of the tank shell, creating a constant pressure head on the annulus (interstice). The level of brine in the annulus is continuously monitored .

If the inner wall was breached, the brine will flow into the inner tank and the reservoir level will drop, signaling a problem. Likewise, if the outer wall was breached, the brine will flow outward for low groundwater conditions, signaling trouble. In high groundwater conditions, groundwater will flow into the tank, raising the level in the reservoir and signaling a problem.

While the first OCF double wall tank (DWT-1) worked well, it was expensive and did not meet an EPA requirement that the interstice volume must have 10 percent of the tank volume. DWT-2 was the next step.

Here, we made a sandwich shell with ribs as the core and the walls bonded to the ribs. The walls were separated by about 1 inch, so there was a much greater amount of brine required to fill the gaps. This led to the development of outer walls that conformed to the inner wall over the ribs, then to a model with the shells bonded to the rib tops and finally, to the latest model with the outer wall in close contact with the inner wall over and between the ribs.

Single wall versus double wall

After double wall tanks (DWT) first became available in 1984, they soon become required in certain localities such as Dade County, FL., San Antonio, TX., Orange County, CA., and New York City. Within the next few years, some of the major oil companies started specifying DWTs for all regions of the country.

Although single wall tanks are still made, the market is switching to double wall because of the added protection it provides against leaks and quick leak detection.

Currently, major FRP underground storage tank manufacturers have complete product lines of both single wall and double wall tanks. The double wall tanks may include continuous self-testing and leak detection.

I believe current models of FRP tanks are the best that have ever been made. This is a tribute to continual product development, testing and a better understanding of soil-tank behavior. To give you a few examples:

“Super-long” tanks require stiffer ribs to meet above ground vacuum testing requirements. Now 8 foot diameter tanks can be manufactureed 45 feet long. They can require special handling and shipping considerations as well as increased care in installation to ensure a smooth bedding along the tank length.

The FRP industry also has developed steel encased aboveground double walled FRP tanks. One of the performance criteria for these tanks is to withstand an impact from a truck weighing 12,500 lbs. traveling at 10 mph.

Tank technology continues to advance. The introduction of advanced designs of oil/water separators by both Xerxes and Fluid Containment is expanding tank utilization in storm water run-off applications.

FRP tanks tomorrow

The future will most likely be controlled by government regulations, manufacturing costs and, of course, the needs of the people who use the equipment. Other countries are starting to enjoy the benefits of FRP USTs. Most of these countries have long been dominated by government subsidized steel manufacturing that has supported barriers to the FRP industry. Through engineering and marketing efforts and persistence, these barriers are being overcome.

In the United Kingdom, approval required that ribs be stiffened. In Japan, all seismic tolerance issues had to be resolved. In New Zealand, where premium unleaded gasoline is just now being introduced, corrosion and longevity questions have been addressed. In short, opportunities abound from Venezuela to Russia, and across the U.S., the market for fiberglass underground storage tanks is expanding.

The advanced designs of oil/water separators has expanded the ways in which tanks can be used to include storm water applications.

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