Aboveground storage tank liners for energy applications

Factory-fabricated bucket or tapered geomembrane liners in a variety of chemical compositions have become critical in the oil and gas industry for aboveground frac tanks. But which should be used?

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Over the past 20 years, hydraulic fracking rules and regulations have become increasingly stringent, and oil and gas (O&G) producers have become progressively more concerned with environmental stewardship. Quality, factory-fabricated geomembrane liners for the aboveground storage tank (AST) market have become a critical element of fracking infrastructure. As most O&G service companies and producers prefer not to field-fabricate frac tank liners, liner design and appropriate materials consideration ensure safe and compliant installation and the performance of the products. This article addresses the historical differences between a “bucket” liner and a “flat” or “tapered” liner, as well as the considerations of the appropriate liner material and the associated density; chemical-compatibility issues associated with AST and frac tanks in general have improved over years of collaborative efforts across the industry.

For hundreds, if not thousands of years, humans have been storing water in tanks, with most early tanks made from clays, cementitious products, hand-forged metals and soils. Around 1850, varying materials–such as copper, iron and wood (as seen in **Figure 1**)–began to be used in the O&G industry to store fluids such as petroleum products, condensates and brines.

Figure 1

In the United States in the late 1800s, in response to the need for a growing O&G industry, more companies built modern tanks that were iron, steel or concrete. Outside of the manufacturing and construction process, such as bolting and riveting or welding steel, very little has changed with these tanks since. Typically, all tanks contain a floor, sidewalls, and a cover or roof. While these tanks may vary in size, composition and requirements for chemical compatibility, they are time-consuming installations for often permanent storage needs.

The growth of the O&G industry and evolving standards, traditions and best practices created a need for more temporary and more rapid storage that minimized the footprint associated with permanent tanks. Based on this need, the O&G industry started using frac tanks and ASTs in the early 2000s.

AST tanks are unique because they are constructed only with wall sections as the primary method of containment designed into the structure. AST tanks in the O&G drilling segment of the industry are merely steel wall segments bolted together to create a ring. This ring is typically 12 to 14 feet (3.7 to 4.3 m) tall and between 60 and 260 feet (18.3 and 79.2 m) diameter (**Figure 2**). They require no floor, and they rely solely on the subgrade as their base. With the lack of a steel or concrete floor and only bolted sections and seams in the sidewalls, a compliant geomembrane lining system is the only way to hold the desired liquid (water or flowback chemicals) that result from drilling.

Figure 2

Bucket liners versus tapered liners

A traditional tank liner has two primary components consisting of a wall/skirt and a floor connected with a radial weld. This weld joins the sidewalls to the precut floor diameter or circle creating a single liner and is sometimes referred to as a bucket liner. Bucket liners work well in permanent applications when the tank's walls and the floor are fixed and support the liner in all directions. Typical installation requires hanging the wall sections or skirts, installing a floor piece built to the diameter of the tank and welding the two sections together via the radial weld around the perimeter of the floor, thereby attaching the two pieces to create a solid liner (**Figure 3**).

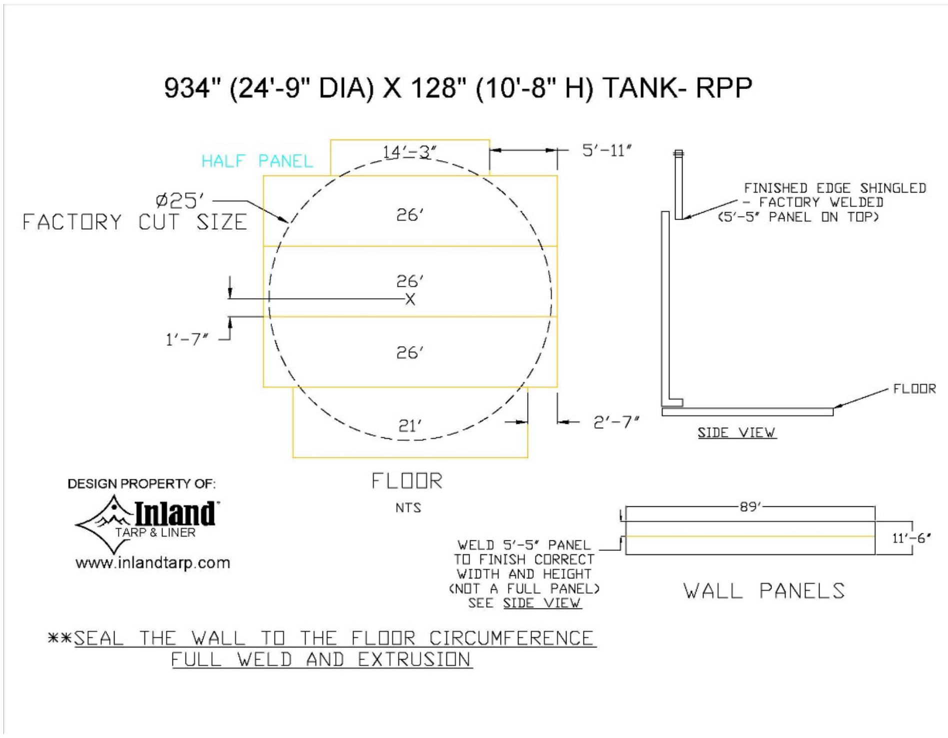

Figure 3

Based on the more permanent nature of the tank in this configuration, settling or movement of the tank and, subsequently, the liner is not as concerning. The most significant risk associated with this AST configuration is the radial weld. No voids between the liner and walls or floor of the tank are allowable. A load point or bridging at the edge of the tank can create a significant potential failure issue.

While these liners provide a uniform and clean fit to the tank, the liners must be installed by qualified technicians, as the radial weld, extrusion and subsequent cap patching and testing are crucial to quality and compliant installation.

This brings us to tapered liners. A tapered liner is a flat sheet made with staggered liner panels to create a diameter large enough to fit an AST floor, wall and overlap (**Figure 4**).

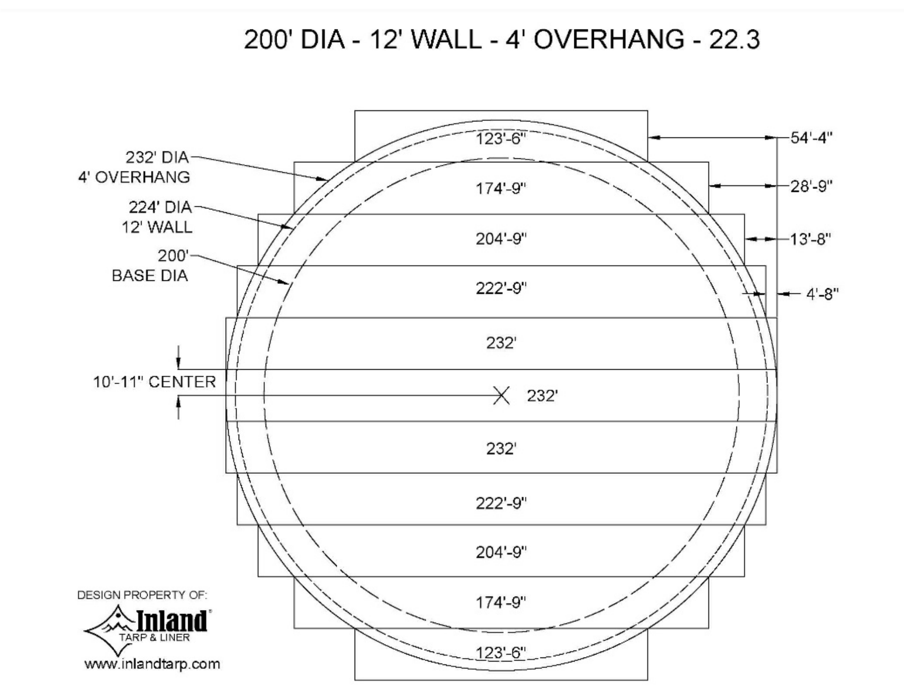

Figure 4

In the above example, a 12 foot (3.7 m) tall, 200 foot (61.0 m) diameter tank requires a tapered liner of 232 feet (70.7 m). This is 200 feet (61.0 m) for the floor, 24 feet (7.3 m) total for the two walls and 8 feet (2.4 m) excess to allow 4 feet (1.2 m) over the back of the tank all around to terminate and hold the liner outside the tank.

A typical installation requires the liner to be stretched out on the ground and folded back in on itself to allow the AST walls to be installed and secured around the liner. The liner is then unfolded back up and over the AST walls allowing the excess material to be draped along the walls vertically and evenly around the inside of the tank. In many applications, clamps are put on the top ring of the tank to secure the liner and the excess material, then secured below the top edge with straps or a thick cable. The most significant advantage of these liners is there is no one single radial field weld, a potential point of failure, as the liners are factory-welded and folded into one single piece, considerably reducing risks associated with field fabrication. However, challenges and careful considerations remain.

During the installation of the tapered liner, the wrinkles along the walls must be installed uniformly around the interior of the tank. Also, with a typical AST containing no hard tank bottom, the tapered tank liner's integrity is contingent on a properly prepared and compacted subgrade. With the tapered liner being anchored at the top, any movement of the liner or settling of the subgrade can lead to failures of the liner at the point of the wall transition to the ground, or failure load point, as shown in **Figure 5**.

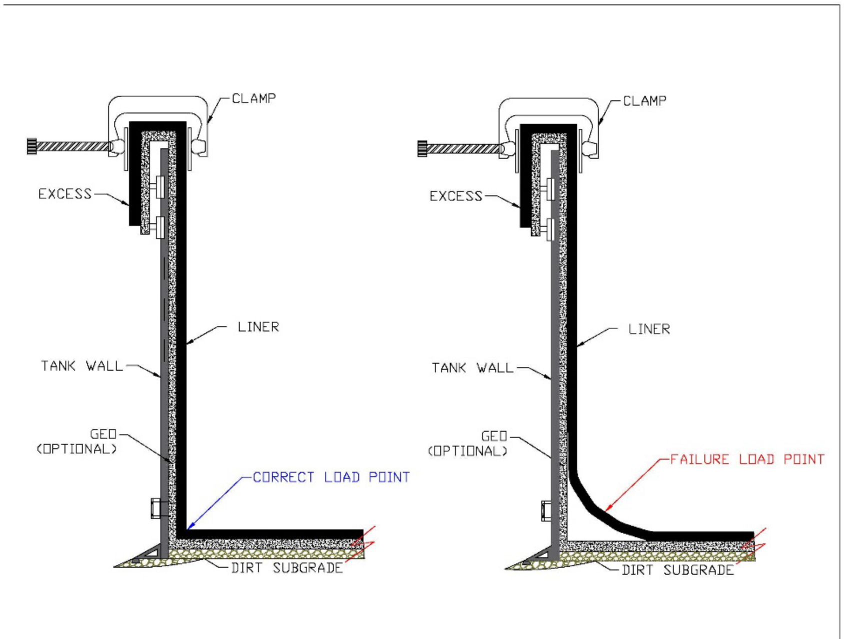

Figure 5

To minimize the risk of a failure load point, after unfolding the tapered liner inside the AST, 1 to 2 feet (0.3 to 0.6 m) of water is added to achieve the correct load point before clamping at the top of the tank. Lessons learned also include the necessity for filling the lined AST with the intended liquid within a short time. Empty tanks are susceptible to shifting of the liner due to wind, thermal expansion and contraction. The shifting is rarely realigned before introducing product or fluids, leading to increased risk to liner and project integrity. Fortunately, years of trial and error have led most producers and installers to enact procedures combatting these risks. Primarily, by putting product in the tank prior to any clamping or locking of the liner, failures from tension to the liner have become almost nonexistent.

Material choices and chemical compatibility

When designing a liner for an AST, engineers consider the strength of the products, chemical compatibility, potability, color, lifespan desired and disposal/recyclability. Modern liners have evolved over the past 50 years in reinforced and nonreinforced variants. Polymers can range from polyvinyl chloride (PVC) and polyethylene (PE) to bitumen materials and various other polymers in-between, including tripolymer for specialty applications.

Dating back 35 years, the most commonly used product in the geomembrane liner industry is high-density polyethylene (HDPE). Available as a nonreinforced polyolefin sheet, it is typically found in the range of 20 to 120 mil (0.5 to 3.0 mm) thicknesses, and it is used extensively today in the landfill market and many other industrial applications. HDPE has excellent chemical resistance, UV stabilization and considerable strength characteristics for a nonreinforced material. While cost-effective, the most concerning aspect of HDPE products are their limited flexibility, stress crack resistance and workability in colder climates. As a result, most HDPE products are strictly field-fabricated and lend themselves best to large-scale, flat square-footage projects.

Many cost-effective reinforced hybrid materials, such as reinforced polyethylene (RPE), have overcome these challenges and can be factory welded. However, many lack the long-term chemical and or UV resistance required of largescale projects based partially on the coating that can range anywhere from 1 to 6 mils (0.03 to 0.15 mm) thick.

The higher end of reinforced materials, such as reinforced PVC or multipolymer blends, have excellent chemical resistance, strength and UV characteristics, also allowing for factory welding. While suitable for primary containment of crude oil during the recent storage crisis in the O&G industry, for short-term solutions, using this material in ASTs can be largely cost-prohibitive.

This brings us to linear low-density polyethylene (LLDPE), which presents the most compliant, workable and cost-effective material for temporary AST industrial applications. In the 1980s, a need arose for more flexible materials for industrial applications. Expanding on the benefits of HDPE successes, resin and sheet manufacturers worked to improve the compounds involved in manufacturing polyolefin sheets. In short, the idea was to retain the high chemical resistance characteristics of HDPE and create a cost-effective nonreinforced material that could be factory welded and fabricated. By adjusting the polymers and additives involved and decreasing the density, LLDPE showed high stress crack resistance and excellent elongation, flexibility, extreme cold weather durability and workability. These characteristics make LLDPE ideal for AST liner applications.

While clean water poses no concerns for chemical compatibility, flowback water from drilling operations contains chemicals, hydrocarbons and additives that can harm the liner. The proprietary nature of many drilling fluids makes obtaining information and safety data sheets on the liquids for continued study challenging. While many states have mandated chemical disclosures, many have not, leaving the need for a liner compatible with a broad spectrum of chemical and hydrocarbon tolerances. With the high chemical resistance of LLDPE, as well as its suitability for factory welding/fabrication and testing, it will continue to be the most compliant and cost-effective solution now and in the immediate future of these applications.

Conclusion

While the AST market has significantly evolved over the last 20 years, it is partnerships between the O&G producers, tank installers, factory liner fabricators and field liner manufacturers working together that has made fracking containment the safe and environmentally sound application it is today. By eliminating the need for field fabrication, solving field and weather issues, and simplifying the design to allow for factory-fabricated and tested tapered liners to go in round tanks, significant strides in safety have been made. Increased vetting of the chemical compatibility of short-term containment liners is needed. With the advent of higher-quality LLDPE resins, as well as increased training of installers on proper procedures, the industry has done an excellent job of providing a safe and sound frac tank containment solution.