From Floating Tops to Flat Bottoms

Chevron's Phil Myers discusses why an atmospheric AST isn't kept at atmospheric pressure, how tanks change from the refinery to the retail service station and other essential facts about large ASTs for the petroleum industry.

Large Aboveground Storage Tanks:
In this first of a series of articles on large aboveground storage tanks (ASTs), Chevron Products Co.'s Philip Myers lays the foundation for understanding the key environmental concerns associated with large ASTs and what can be done to mitigate them. This introductory article explains the role of ASTs in the petroleum distribution chain, the types of ASTs available and the different designs of AST roofs and bottoms. Future articles will tell how to prevent AST leaks and spills, use leak detection technology, comply with the Clean Air Act, inspect ASTs and follow the best practices regarding ASTs. A noted authority on the subject, Phil chairs the American Petroleum Institute's (API) Subcommittee for Tanks and Pressure Vessels. In covering this material, he will tell you about the issues and activities of current interest to API and the petroleum industry, and how states are addressing AST petroleum storage problems.

Large crude oil aboveground storage tanks, Photo courtesy of Chevron.

First, the basics. The most fundamental classification of storage tanks is based upon whether they are above or below ground. Aboveground tanks have most of their structure aboveground. The bottom of the tank is usually placed directly on an earthen or concrete foundation for containment purposes. Sometimes these tanks are placed on grillage, structures or heavy screen so that the bottoms of the tanks can be inspected on the underside and leaks can be more easily detected. The aboveground tank is usually easier to construct, costs less and can be built in far larger capacities than underground storage tanks (USTs).

While there are many types of ASTs (including, of course, those used for retail fueling), this article will focus on flat bottom aboveground petroleum storage tanks. This type of tank is most commonly used for ASTs with volumes of from 10,000 gallons to 25 million gallons or more.

Because there is no uniform regulation requiring registration of ASTs in the petroleum industry, the exact number in existence is unknown. However, approximately 10 years ago, the American Petroleum Institute (API) conducted a survey on the subject.

Table 1 shows that when the ASTs in all sectors of the petroleum industry are counted, the total comes to about 700,000. (Table 1 also provides the breakdown of numbers and capacities of tanks by sector.) However, the smallest capacity of tank surveyed was around 1,100 gallons; thus, the survey excluded very small tanks.

By way of comparison, EPA has estimated that there are 1.3 million regulated underground storage tanks, with an unknown number of exempt underground tanks used for home heating oil and farm fuel.

	Tank Capacity (Bbl)	Number	Est. Median Diameter (Ft)	Total Shell Capacity, MBbl
Marketing	26 to 500	64,793	10	
	500 to 1,000	4,417	15	
	1,000 to 10,000	7,434	25	
	10,000 to 100,000	11,469	70	
	100,000 or More	416	220	
	Tatal >	88,529		486,925
Refining	26 to 500	3,913	12	
	500 to 1,000	2,460	15	
	1,000 to 10,000	9,665	30	
	10,000 to 100,000	11,625	90	
	100,000 or More	2,060	220	
	Tatal >	29,727		945,092
Transportation	26 to 500	694	10	
	500 to 1,000	307	15	
	1,000 to 10,000	1,468	35	
	10,000 to 100,000	5,048	120	
	100,000 or More	1,680	220	
	Tatal >	9,197		556,183
Production	26 to 500	510,045	10	
	500 to 1,000	37,628	16	
	1,000 to 10,000	23,946	30	
	10,000 to 100,000	974	70	
	100,000 or More	27	200	
	Tatal >	572,620		280,595
All Sectors	26 to 500	579,445	--	
	500 to 1,000	44,812	--	
	1,000 to 10,000	42,513	--	
	10,000 to 100,000	29,120	--	
	100,000 or More	4,183	--	
	Tatal >	700,073		2,268,795

Table1: Summary of Petroleum Industry AST Survey

Source: Entropy Limited, "Aboveground Storage Tank Survey," April 1989; and Gruy Engineering Corporation, "Assessment of the Economic Impact of Certain Anticipated SPCC Regulations Pertaining to Aboveground Storage Tanks," September 1990.

The distribution chain

Although exceptions exist, certain generalizations can be made concerning the sizes, distribution and the relative uses of USTs and ASTs in the petroleum distribution chain. For the most part, the size of the tank will diminish from the beginning of the chain (large tanks) to the point of end use (smaller tanks).

Again, while there are a number of notable exceptions, the following quotes describe the process. The quotes (italicized) are from the Aboveground Storage Tank Guide published by Thompson Publishing Group, Washington, D.C. 1994.

Summary of the beginning process—

"The economics of ASTs and USTs is best understood by visualizing the distribution chain involving most liquid products. Beginning at the production end, very large quantities of liquids are produced, and must be handled, stored, and transported to intermediate destinations in the manufacturing process and further downstream to the ultimate consumer. Depending on the liquid material involved, and the processes in which it is used, product storage can involve simple or complex operations. It is safe to say, however, that, as the liquid moves closer to the ultimate consumer, there is less need to store large quantities for long periods."

Summary of intermediate movements—

"Economics dictate that most intermediate movements in the distribution chain be of the largest volume that can be moved at one time. As the ultimate consumer usually requires very low volumes, the storage and movement of liquids at the wholesale and retail end can be in smaller quantities, occurring more frequently. Use of underground storage, with its smaller capacities, thus, becomes practical and feasible at this point. For example, let us follow the path of petroleum products from the oil well to the motorist.”

More ASTs are being used for retail fueling. Photo courtesy of Chevron

Description of pathway

- “Crude oil at the wellhead is produced in very large quantities, measured in thousands of gallons-or barrels—per day. Many wells are connected to pipelines that transport the production output directly to either a refinery or distribution terminal point, from which it can be transhipped to a refinery for processing. Systems for storing this output awaiting transport must be of large volume to accommodate the flow arriving daily. The tank size needed, therefore, precludes use of UST systems, and the storage terminals normally have adequate land area to accommodate the size of AST systems required. Moving the accumulated quantities efficiently and at lowest cost requires either pipeline or very large tankers.”

- “Receiving the cargoes from these vessels at the refinery, where the crude oil is processed into useful products, also requires large storage capacities. The finished products, in turn, must be stored temporarily until moved to the marketplace. Depending upon the methods and timing of transshipment—that is, by tanker, barge, railcar, pipeline, or truck—various types of ASTs are used. Generally, up to this point, the volumes handled are of such quantities as to preclude the use of UST facilities, due to their size and configuration limitations. Instead, AST systems are used almost universally.”

- “Because finished products sometimes are specialty materials produced in small quantities, some small tanks are needed for storage. Also, depending upon the distance to the consumer, deliveries can be made efficiently in smaller transport vessels. For gasoline, as an example, refinery output usually requires storage in very large AST systems, but it can be shipped in small barges or trucks to local distributors who have limited bulk storage. These facilities then, in turn, ship even smaller quantities more frequently to retail outlets by truck.”

“At this point in the distribution network, the UST becomes useful and efficient. Volumes handled at the retail level are relatively low, compared to earlier movements, and consumption by consumers occurs in even smaller volumes. Ideally, here the UST system suits the consumption need and offers safety for the volatile material, as well as a cost-effective use of often limited land space.”

Terminals and bulk plants—

For finished fuels distribution including motor gasolines, diesel, jet and aviation gasolines, refineries typically ship to wholesale marketing operations. This shipping is typically done using either barge or pipeline distribution systems. From these terminals, the fuel is usually trucked to retail service stations. Bulk plants are mini-terminals that are usually characterized by their remoteness from large suburban areas.

Tanks of certain sizes—
Although a small volume container, even as small as a coffee cup, can be considered a tank, most regulations and standards or codes have a lower minimum applicability cut-off. This cut-off is based upon a volume that has proven to be effective in screening out the myriad small containers that are not intended to be covered.

An example of the petroleum industry's definition is found in API 2610, Design, Construcion, Operation, Maintainance and Inspection of Terminal and Tank Facilities, which defines a tank as having a volume exceeding 1,100 gallons. The largest tanks have diameters of up to 500 to 600 feet, but this is a rare occurrence. In fact, it has only occurred once—as a unique construction built specifically for crude oil in Saudi Arabia. Large tanks in the US are also designed for crude oil, but they typically do not exceed 330 feet in diameter by about 56 to 64 feet high.

Some codes limit the maximum capacity of tanks in their definitions or scope. Underwriter's Laboratories (UL) tank standards, for example, apply only to tanks larger than 60 gallons but less than 10,000 to 50,000 gallons, depending on the type of tank.

Tank types—
To understand atmospheric tanks in context, it is important to know how they fit into the major categories of large liquid storage containers (for ASTs). These major categories are described below:

- Atmospheric tanks—Most tanks for petroleum storage are called atmospheric tanks and are built to API Standard 650. By far, this is the most common type of tank. Although called atmospheric, these tanks are usually operated at internal pressures slightly above atmospheric pressure, perhaps up to H inch of water column. With special design provisions, the pressure may be increased to higher pressures. The fire codes define an atmospheric tank as operating from atmospheric pressure up to one pound per square inch (psi) above atmospheric pressure.

- Low pressure tanks—Low pressure tanks are considered in between atmospheric tanks and pressure vessels. They are used to store relatively volatile liquids such as refrigerated LPGs and various petrochemicals. Ironically, low pressure in the context of tanks means tanks designed for a higher pressure than atmospheric tanks. In other words, these are relatively high pressure tanks. They are designed to operate from atmospheric pressure up to 15 psig.

Low pressure tanks are characterized by rounded tops called domes. Sometimes they are built to spherical or elliptical shapes. These shapes are more appropriate for large structures where the internal pressure is greater than a few inches of water column.

- Pressure vessels (high pressure tanks)— Since high pressure tanks (vessels operating above 15 psig) are really pressure vessels, the term "high pressure tank" is not used in the terminology of those working with tanks. Pressure vessels are a specialized form of container and are treated separately from tanks by all codes, standards and regulations. Therefore, we will not cover them in any detail here. However, a few words are in order to clarify the relationship between pressure vessels and tanks.

When the internal design pressure of a container exceeds 15 psig, it is called a pressure vessel. The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code is one of the primary standards used throughout the world to ensure safe storage vessels for high pressure liquids or gases.

Various substances, such as ammonia and hydrocarbons, are frequently stored in spherically shaped vessels, which are often referred to as tanks. Most often, the design pressure of these so-called tanks is 15 psig or above, and they are really spherical pressure vessels that fall under the rules of the ASME Boiler and Pressure Vessel Code.

Most pressure vessels are small. However, there are some very large pressure vessels found typically in refineries. These include spheres or reactors.

Internal floating roof tanks, including some with geodesic domes (in the background) Photo courtesy of Chevron

Types of atmospheric tanks

Other than Liquid Petroleum Gas (LPG) and Liquid Natural Gas (LNG), most fuels are stored in atmospheric storage tanks. The roof shape of a tank may be used to classify the type of tank and is instantly self-explanatory to tank fabricators and erectors. These roof shapes are summarized below:

Fixed roof tanks—

The fixed roof tank is the simplest of all tanks. Fixed roof tanks are cylindrical shells with a vertical axis of symmetry. The roof is usually made of steel, conical in shape and supported by beams or rafters, as well as columns. Another common name for a fixed roof tank is a cone roof tank. Some fixed roofs are self-supporting. The bottom is usually flat and the top is made in the form of a shallow cone.

These are the most widely used tanks for storage of relatively large quantities of fluid, mainly because: (1) they are economical to build and (2) the field supports a number of contractors capable of building them. These tanks can be shop-fabricated in small sizes but are most often field-erected. Cone roof tanks typically have roof rafters and support columns, except in very small diameter tanks.

Aluminum geodesic dome roof tanks—

These are essentially the same as cone roof tanks except for the roof, which is constructed of aluminum. They offer superior corrosion resistance for a wide range of conditions and are clear span structures not requiring internal supports. They can also be built to essentially any required diameter.

A major advantage of the aluminum dome over the conventional steel dome is that it is a free span structure that requires no internal columns to support the roof. This is important because the columns tend to accelerate corrosion pitting under their bases, and it is difficult to inspect for leaks under columns. Also, the aluminum corrosion resistance is inherently better than for steel or even coated steel roofs. Another advantage is that an aluminum dome may be retrofitted on an existing tank with no hotwork; this is not possible with normally for steel roofs.

Spherical pressure vessel built to ASME Boiler and Pressure Vessel Code
Photo courtesy of Chevron

Floating roof tanks—

The floating roof tank is probably the single most important tank type for the petroleum business. It represents an evolutionary step forward in the safety of storing combustible and flammable petroleum liquids. The function of the cover or roof is to reduce evaporation losses and air pollution by reducing the surface area of liquid that is exposed to the atmosphere.

All floating roof tanks have vertical, cylindrical shells just like a fixed cone roof tank. They are different from a fixed roof tank in that they have a cover that floats on the surface of the liquid. The floating cover or roof is a disk structure with sufficient buoyancy to ensure that the roof floats under all expected conditions, even if leaks in the roof develop. The floating roof is built with approximately a four- to 12-inch gap between the roof and the shell so that it does not bind as the roof moves up and down with the liquid level. The clearance between the floating roof and the shell is sealed by a device called a rim seal. The floating roof may be one of any number of designs, as described later.

The tank shell and bottom are similar to those of an ordinary vertical cylindrical fixed roof tank. The two categories of floating roof tanks are:

- External Floating Roof (EFR)
- Internal Floating Roof (IFR)

If the tank is open on top, it is called an EFR tank. If the floating roof is covered by a fixed roof on top of the tank, it is called an IFR tank. (see Photo "Roof Tank")

Note that fixed roof tanks can easily be converted to internal floating roof tanks by simply installing a floating roof inside the fixed roof tank. Conversely, external floating roof tanks can be easily converted to internal floating roof tanks simply by covering the tank with a fixed roof. A popular method is to use a geodesic dome that can be built in-situ over the existing external floating roof tank to convert it to an IFR.

EFR tanks have no vapor space pressure associated with them and operate strictly at atmospheric pressure. IFR tanks, like fixed roof tanks, can operate at or above atmospheric pressure in the space between the floating roof and the fixed roof.

The fundamental requirements for floating roofs depend upon whether the roof has been designed for an internal or an external application. The design conditions of the external floating roof are more demanding in that the roof must handle rainfall, wind, deadload and liveload conditions, comparable to and at least as severe as those handled by building roofs.

Details of floating roofs—

Let's take a look at the floating roof in more detail. The floating roof is nothing but a cover, as mentioned previously. However, "the devil is in the details." Old designs were literally pans floating on the liquid. If a single hole from corrosion penetrated the deck, the entire roof would sink! Modern designs are detailed in API Standard 650 Appendix C and H. Fundamentally, these include pontoons so that if any single pontoon is punctured, the roof will not sink.

Aluminum dome being put into place
Photo courtesy of Chevron

Fixed roof tank
Courtesy of Chevron

Designs: There are many designs, but the two most common are:

1. Annular pontoon— These pontoons are common for floating roofs from approximately 30 to 150 feet in diameter. The roof is simply a steel or aluminum deck with an annular compartment that provides buoyancy. The annular section is segmented or bulkheaded to provide the stability in case the pontoons leak.

2. Double deck roofs— Double decks are suitable for very small floating roofs—up to about 30 feet—but may also be used on diameters that exceed 150 feet. They are very strong and durable because of the double deck.

A number of manufacturers build aluminum floating roofs. These are not as durable as steel roofs but are permitted in IFRs (those tanks which are protected by the weather with a fixed steel roof over them). The aluminum has certain advantages that often result in lower retrofit costs than a steel roof, and so aluminum floating roofs maintain a share of the IFR market.

The floating roof is usually sealed to the shell by a primary and a secondary seal. The seals are flexible structures with many design variations. The most common seal is the shoe seal.

Internal floating roof tank Courtesy of Chevron

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