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AN OVERVIEW OF STORAGE TANK TYPES

PREGLED TIPOVA SKLADIŠNIH REZERVOARA

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Keywords
• storage tanks
• classification
• fixed roof
• floating roof
• Horton's spheres
• water towers

Abstract

Tanks generally can be classified according to their position on the ground and underground. Based on this classification, the classification of ground storage tanks is usually made according to their shape, material, and type of roof. This paper shows the classification of ground storage tanks according to their construction and purpose and describes the main types of ground storage tanks, their construction, advantages and disadvantages.

Ključne reči
• skladišni rezervoari
• klasifikacija
• fiksni krov
• plivajući krov
• Hortonove sfere
• vodotornjevi

Izvod

Rezervoari se pre svega razvrstavaju prema svome položaju na nadzemne i podzemne. Dalje razvrstavanje rezervoara obuhvata njihovu klasifikaciju prema njihovom obliku, materijalima od kojih su izrađeni kao i tipu i načinu funkcionisanja njihovih krovova. U ovom radu prikazana je klasifikacija nadzemnih skladišnih rezervoara prema njihovoj konstrukciji i nameni, i opisani su tipovi skladišnih rezervoara, njihova konstrukcija, prednosti i nedostaci.

INTRODUCTION

Storage tanks store liquids such as crude oil, intermediate and refined products, gaseous chemicals, waste products and water/product mixtures. Storage tanks consist of internal gas and vapour spaces operating at pressures close to atmospheric pressure and are often referred to as atmospheric tanks. These tanks are usually made of carbon steel, alloy steel, aluminium or other metal depending on the purpose. Also, some tanks are made of non-metallic materials such as reinforced concrete, reinforced thermoset plastic and wood. Even today, some wooden tanks, some riveted tanks, and some bolted tanks can be found in use. Oil and gas storage tanks (petroleum industry) are usually used for liquids with (without this real) vapour pressure that is less than atmospheric pressure. Vapour pressure is the pressure on the surface of a closed liquid caused by evaporation of that liquid and increases with temperature. Crude oil, heavy oil, heating oil, gas oil, refined oil, gasoline and non-volatile chemicals are usually stored in atmospheric tanks. Most tanks are protected by pressure-vacuum vents which limit the pressure difference between the vapour space in the tank and the outside environment to a few ounces per square inch. Other branches of industry use atmospheric tanks including the storage of various chemicals and other substances operating in closed circuit systems without venting to the atmosphere and with pressure control and relief devices as needed. These tanks can be designed and used as storage tanks operating at low pressure. Additional uses of atmospheric storage tanks may include storage of liquids (both hydrocarbons and non-hydrocarbons) in horizontal vessels, storage of process fluids or granular solids in tanks supported on hollow skirts or on columns with raised conical bottoms (uneven bottoms) and process water/fluids in open top tanks /1/.

CLASSIFICATION OF GROUND STORAGE TANKS

In general, there are many classifications of tanks according to many criteria, such as their dimensions, shapes, operating parameters. One of the widespread classifications of tanks is according to their shape as well as the type and purpose of their roof, /1/. According to this classification, storage tanks can be classified into following categories:
- storage tanks with flat roofs;
- cone roof tanks;
- umbrella roof tanks;
- geodesic dome roof tanks;
- self-supporting dome roof tanks;
- storage tanks with breather type of roofs;
- storage tanks with vapour dome roofs;
- welded horizontal tanks supported on saddles;
- plain hemispheroid tanks;
- noded hemispheroid tanks;
- plain hemispheroid with knuckle radius;
- plain spheroid tanks;
- noded spheroid tanks;
- bullet tanks;
- Horton sphere pressure storage tanks;

- water towers;
- mushroom-shaped water towers /1-4/.

Storage tanks with flat roofs

Ground storage tanks with fixed flat roofs belong to the group of cylindrical storage tanks most often used for the storage of crude oil and water. The roofs of these tanks are most often made from aluminium (Fig. 1), /2, 3, 5/.

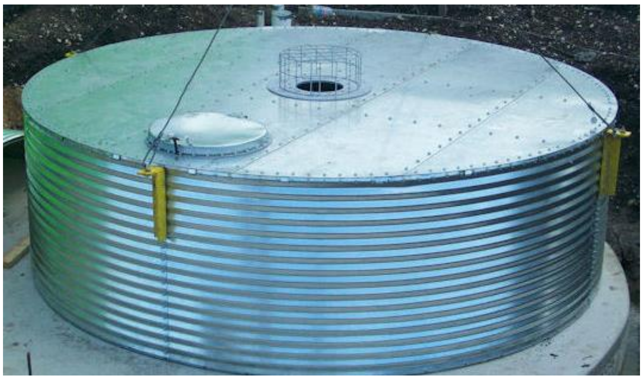

Figure 1. Storage tanks with flat roofs, /3/.

Cone roof tanks

Cone roof storage tanks are a type of aboveground storage tank typically used for storing liquids such as crude oil, gasoline, diesel, and chemicals. These tanks are characterised by their conical-shaped roofs which are either permanently attached to the tank shell or constructed as a separate dome that is mounted on top. The lines below list some key design features of these tanks.

Shell: the tank shell forms the cylindrical body of the storage tank and is typically constructed from welded steel plates. The thickness and grade of steel plates depend on factors such as the size of the tank, type of stored liquid, and environmental conditions. The shell is designed to withstand internal pressure from the stored liquid and external forces like wind and seismic loads.

Roof: the cone roof is the distinctive feature of these tanks. It can either be an integral part of the tank shell or a separate structure mounted on top. The roof is typically made from welded steel plates and is sloped to facilitate drainage of rainwater and snow. The slope directs water towards a central drain or scupper, preventing accumulation that could lead to corrosion or weight issues.

Roof supports: cone roof tanks are supported by internal columns and rafters that connect the roof structure to the tank shell. These supports provide stability and distribute the load of the roof evenly to the tank walls. The number and design of supports depend on the tank size and the roof configuration.

Accessories and fittings: cone roof tanks are equipped with various fittings and accessories depending on their specific application. These may include inlet and outlet nozzles for product transfer, overflow pipes, level gauges, temperature sensors, pressure relief devices, and venting systems to control vapour emissions.

Coatings and linings: to protect against corrosion and maintain the quality of the stored liquid, the interior surfaces of cone roof tanks are often coated or lined with materials compatible with the stored product. Common lining materials include epoxy, polyurethane, or special coatings designed for specific chemicals or corrosive substances.

Design standards: cone roof storage tanks are designed and constructed following industry standards and codes to ensure safety, durability, and compliance with environmental regulations. Standards such as API (American Petroleum Institute) 650 provide guidelines for the design, fabrication, erection, and inspection of welded steel tanks, including cone roof tanks.

Ventilation and emissions control: proper ventilation and emissions control systems are essential for cone roof tanks, especially when storing volatile liquids. Vent pipes and pressure relief valves are designed to safely manage vapour pressures and prevent over-pressurisation of the tank.

Overall, the design of cone roof storage tanks aims to provide a robust and reliable structure for the safe storage of liquids while minimising environmental impact and ensuring compliance with regulatory requirements. Specific design details may vary depending on factors such as tank size, location, stored product characteristics, and operational considerations.

Cone roof storage tanks offer several advantages over floating roof tanks, depending on the specific requirements of the stored liquid and operational conditions. Here are some key advantages of cone roof storage tanks compared to floating roof tanks:
- lower initial cost;
- simplicity of design;
- no maintenance of floating roof;
- suitability for heavy products;
- no risk of roof sinking;
- less sensitive to product level;
- easier to inspect.

Lower initial cost: cone roof tanks generally have a lower initial construction cost compared to floating roof tanks. This is because they do not require a complex floating roof mechanism, which includes pontoons, seals, and mechanisms for floating roof movement.

Simplicity of design: the design of cone roof tanks is simpler compared to floating roof tanks. They consist of a cylindrical shell and a conical roof, which are relatively easier to fabricate, erect, and maintain.

No maintenance of floating roof: floating roof tanks require regular maintenance of the floating roof seals, pontoons, and other moving parts to ensure proper functioning and to prevent leakage. Cone roof tanks, on the other hand, have a stationary roof structure that generally requires less maintenance over their lifetime.

Suitability for heavy products: cone roof tanks are often preferred for storing heavy products that do not easily evaporate and do not require the vapour control advantages offered by floating roof tanks. Heavy crude oils, for example, can be stored effectively in cone roof tanks without the need for a floating roof to minimise vapour space.

No risk of roof sinking: in floating roof tanks, there is a potential risk of the roof sinking or tilting due to factors such as uneven distribution of stored product or external environmental conditions. Cone roof tanks do not face this risk since their roof structure is fixed and supported directly by columns and rafters.

Less sensitive to product level: floating roof tanks require careful consideration of the product level to ensure the floating roof remains properly floated and to avoid mechanical issues. Cone roof tanks do not have this sensitivity, as the roof structure remains stationary regardless of the product level.

Easier to inspect: inspecting the interior of cone roof tanks is generally easier compared to floating roof tanks. There are no internal floating roof components obstructing the view or requiring access for inspection and maintenance.

While cone roof tanks offer these advantages, it is important to note that the choice between cone roof and floating roof tanks depends on factors such as the volatility of the stored product, environmental regulations, operational requirements, and overall lifecycle costs. Each tank type has its own set of applications and considerations based on the specific needs of the storage facility and the characteristics of stored liquids.

Cone roof tanks are primarily used to store volatile liquids or those that can degrade if exposed to the atmosphere. The conical shape of the roof allows rainwater and snow to easily drain off, preventing accumulation that could otherwise cause corrosion or contamination, /5-8/.

Figure 2. Storage tank cone roofs, /3/.

Umbrella roof tanks

Figure 3. Storage tank umbrella roofs, /9/.

The umbrella roof tank (Fig. 3) and geodesic dome roof tank are variations of fixed roof tank. Umbrella roof tanks are characterised by a flat roof that slopes towards the centre, resembling an umbrella.

These tanks are versatile and can be used for various applications, including water storage and chemical containment (Fig. 3). The design of umbrella roof tanks allows for efficient installation of accessories such as floating roofs or internal heating coils, enhancing their functionality in different industrial settings, /9/.

Geodesic dome roof tank

A geodesic dome roof, also known as a geodome, is a thin-shell structure based on a geodesic polyhedron. The elements of the dome are usually triangular shaped and are arranged in a pattern that, when completed, is structurally rigid and able to withstand relatively heavy loads compared to their low weight and size.

Geodesic dome roofs can be found on museums, libraries, art galleries, sports, entertainment facilities, and even homes. For industrial and manufacturing purposes, they are placed on top of a variety of containers and vessels, such as process vessels and aboveground storage tanks containing petroleum/fuel products or virtually any liquid or dry bulk chemical product.

The tanks are usually one of three types: general storage tanks, atmospheric storage tanks which operate at an internal pressure near atmospheric pressure, and low-pressure storage tanks which operate at an internal pressure between 18 kPa and 103 kPa, although in actual practice most dome roof tanks operate at less than 34.5 kPa.

These containers and vessels are commonly located at oil refineries, municipal water and wastewater treatment plants, chemical manufacturing plants and fuel storage terminals at truck, railroad and airport facilities. Geodesic domed roofs for the fuel storage industry have been around for over 50 years. Domes are typically constructed from aluminium, but the container's construction materials can also be alloyed steel, carbon steel, reinforced thermoset plastics or concrete.

Advantages of geodesic dome roofs

Geodesic dome roofs have a high strength to weight ratio and inherent structural integrity, thanks to their design characteristics which distributes structural stress equally throughout the structure.

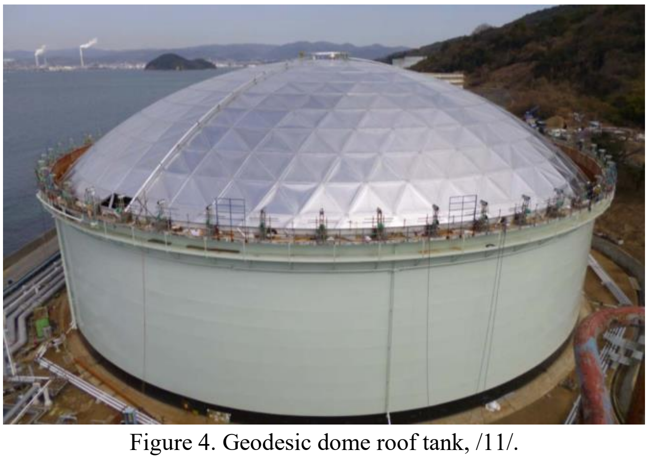

Figure 4. Geodesic dome roof tank, /11/.

The roof's primary purpose is to cover and protect the contents of the container by preventing rainwater and debris infiltration (Fig. 4). Geodesic dome roofs in particular can keep rain off a tank's external floating roof or allow an internal floating roof design to be used.

They also provide a way to comply with governmental regulations on vapour emissions. The geodesic clear span design not only eliminates the need for interior support beams but also reduces the number of holes through the structure where vapours could potentially leak. The roof blocks the wind flow to significantly reduce vapour emissions from the tank, /10, 11/.

Risks faced by geodesic dome roofs

Like any metallic structure, the roofs are susceptible to deformation, deterioration and corrosion. Roofs are usually constructed from aluminium for its corrosion-resistant properties, thus making failure due to uniform corrosion rare because the aluminium forms a passive oxide layer when exposed to the atmosphere. However, the possibility of localised corrosion remains due to stress corrosion cracking (SCC), contact with components (e.g., connectors, joints, attachments) made from dissimilar metals, hydrogen sulphide vapour, and highly alkaline or acidic environments.

Roofs contain a large number of triangular panels and joints mechanically sealed with fasteners that may corrode and eventually fail. Furthermore, daily thermal expansions and contractions create gaps between panels that can allow corrosive gas vapours and hazardous air pollutants to escape. Gaps can allow atmospheric rain and moisture (humidity), airborne chlorides and particulate matter to infiltrate the structure and contaminate the tank's valuable contents.

Due to the way these tank roofs are constructed, a flexible seal is required between each of the roof panel triangles. Over time this seal cracks and deteriorates. Once the seal is compromised, atmospheric rain can enter the tank and come in contact with the fuel or other material stored inside. Additionally, when dealing with gasoline tanks the domed roofs are designed to control regulated vapours from escaping into the atmosphere. When these roof seals are damaged, asset owners may receive strict fines due to release of gas vapours and incur the economic loss of the product stored within the tank. Leaks also make tanks with interior floating-roof seals more susceptible to damage and corrosion.

Historical methods for protecting geodesic dome roofs

While relatively low maintenance, geodesic dome roofs must be regularly inspected for loss of containment, corrosion and deterioration from wind, weather and wildlife damage, and then repaired as needed. Historically there have been two alternatives:

1. Remove each roof panel and replace the seals between the panels. This is a very costly and labour-intensive operation. Sometimes this is not possible due to the configuration of the tank and safety considerations. Additionally, some manufactures of older tanks no longer produce the seals, thus making them difficult to replace.
2. Apply tape over the seals. Tape can also be expensive. More importantly, the adhesion of the tape is always going to be questionable due to the tape being applied to an irregular surface.

Depending on the tank's design and contents, it may be necessary to take the asset out of service during operation.

Beside to the previously described tanks with an aluminium dome, the steel dome tanks shown (Figs. 5 and 6) are often used. Roof plates are usually formed with joints of curved segments to be self-supporting, /12/.

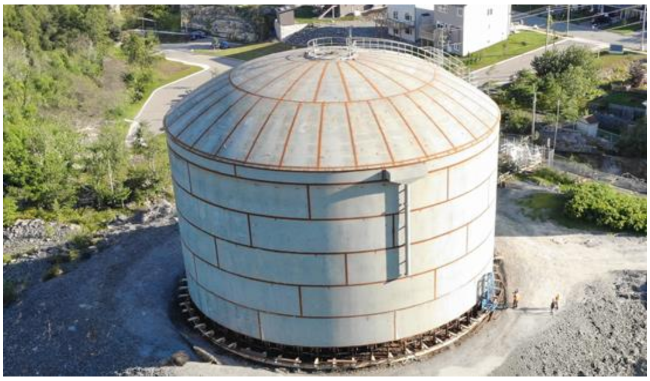

Figure 5. Tank with carbon steel dome roof, /12/.

Figure 6. Tank with carbon steel self supporting roof, /12/.

Storage tanks with floating roof

In addition to previously mentioned tanks with a fixed roof, tanks with floating roofs represent another common type of atmospheric tank. A floating roof tank is designed to minimise filling and venting losses by eliminating or minimising the vapour space above the stored liquid. The shell and bottom of this type of tank are similar to those of a tank with a fixed roof, but in this case the roof is designed to float on the surface of the stored liquid. Older floating roof designs include single steel deck details without ring pontoons as shown in Fig. 7, /1/.

Figure 7. Tank with floating roof with single deck, /1/.

Newer designs of storage tanks include annular-ponton floating-roof tank (Fig. 8) and double-deck floating-roof tank (Fig. 9), /1, 13/.

Figure 8. Annular-pontoon floating-roof tank, /13/.

Figure 9. Double-deck floating-roof tank, /13/.

When constructing the aforementioned tanks, special attention should be directed to the selection of adequate equipment for sealing the space between the roof rim and cylindrical shell, in terms of ensuring excellent sealing performance, suitable for assembly and maintenance, /13/.

Storage tanks with internal floating roofs

In addition to previously mentioned constructions with floating roofs, tanks with floating roofs are often used in industrial plants having a fixed conical roof above them with accompanying venting devices (Fig. 10), /14/. These types of storage tanks are commonly referred to as internal floating roof tanks. The fixed roof is usually a supported cone or dome (of steel or aluminium). The internal floating roof can be constructed of steel, aluminium, or other material. Such tanks are usually built to alleviate weather-related concerns about floatation of an external floating roof, to reduce vapour emissions, or prevent product contamination. An existing fixed roof tank often can be modified by the installation of an internal floating roof. Cone roofs with an internal floating roof supported by cables suspended from the fixed cone roof are a newer design that is being used, /1/. API 650, Appendix H classifies internal floating roofs into the following types:
- metallic internal floating roofs,
- metallic open top bulk-headed internal floating roofs,
- metallic pontoon internal floating roofs,
- metallic double-deck internal floating roofs;
- metallic internal floating roofs on floats /1/.

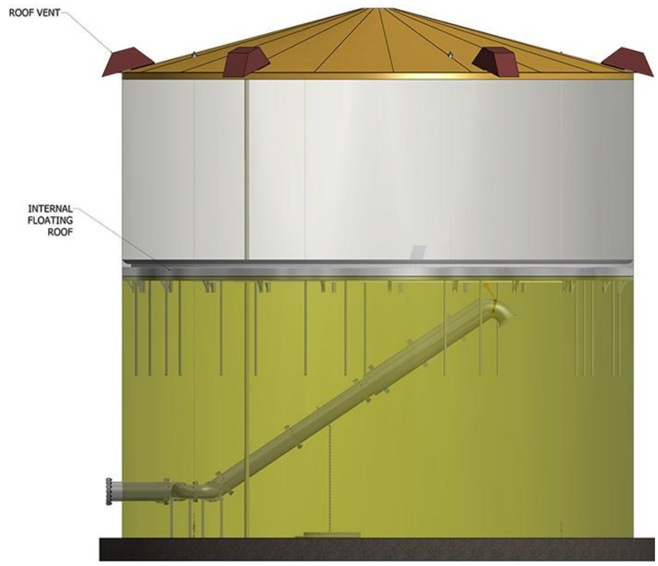

Figure 10. Storage tank with internal floating-roof tank, /14/.

Breather type roof-storage tanks

Storage tanks with breather roof type are relatively new constructions of storage tanks where the elastic characteristics of roof material are used for vapour expansion above the stored liquid. In general, with these types of tanks several methods are used to provide space for vapour expansion without using a loose movable outer roof. The most common constructions of these tanks include cylindrical tanks with a flat metal roof which is essentially a flexible steel membrane that can move (oscillate) up and down within fairly narrow limits (Fig. 11). This amplification depends primarily on the filling/emptying of the tank as well as on the changing temperature of the working fluid in the tank.

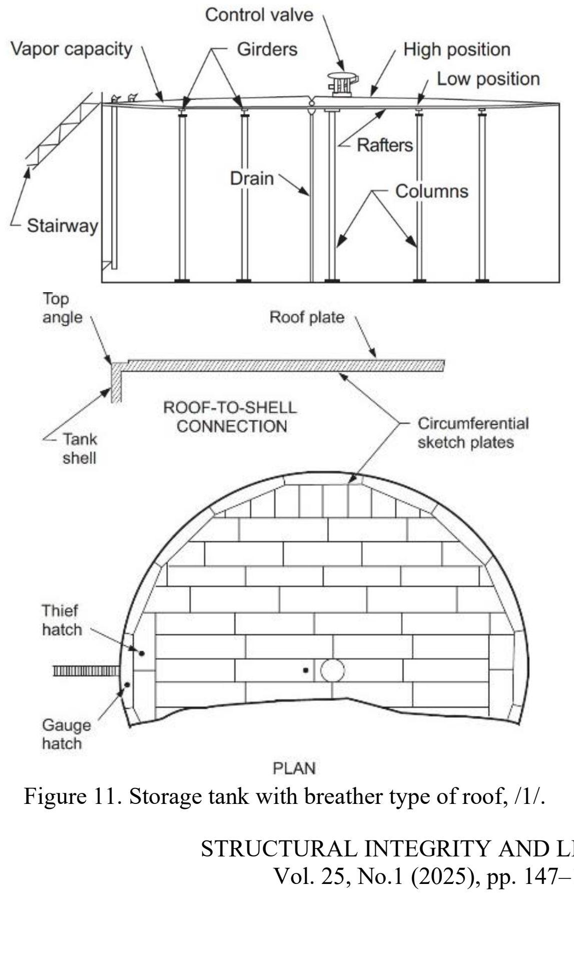

Figure 11. Storage tank with breather type of roof, /1/.

Balloon-type roof is a modification of the plain breather-type of roof that is capable of a greater change of volume.

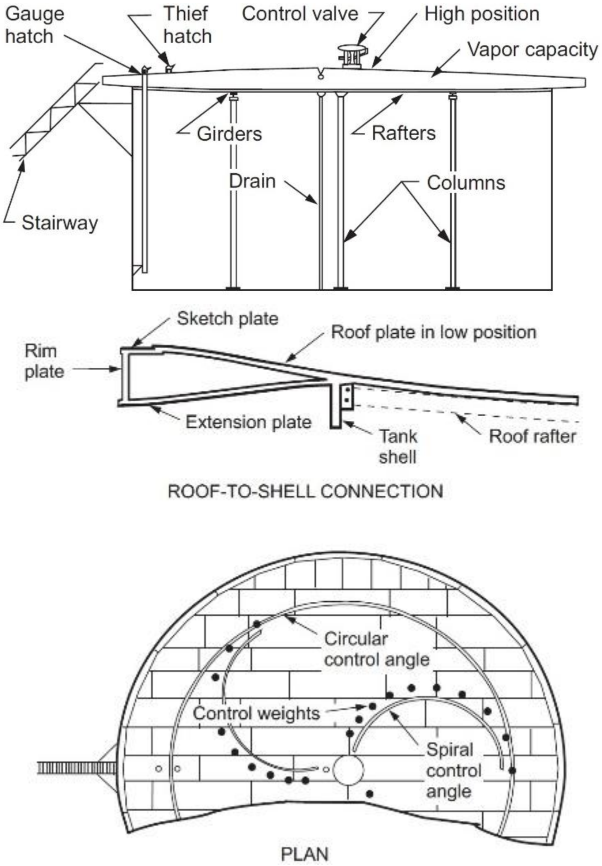

Figure 12. Storage tank with breather type of roof, /1/.

Storage tanks with a vapour dome roof

A tank with a vapour-dome roof uses an added fixed dome with a flexible membrane attached to the walls and is free to move up and down, Fig. 13, /1/.

This type of vapour roof may be designed to provide any desired change in volume. Vapour recovery systems may use this type of tank. Vapour recovery systems can be provided on several types of tanks such as fixed cone roof, umbrella roofs, and vapour dome roofs. Adjustment in relieve value settings will be required to accommodate the operating parameters for the vapour recovery system, /1, 15/.

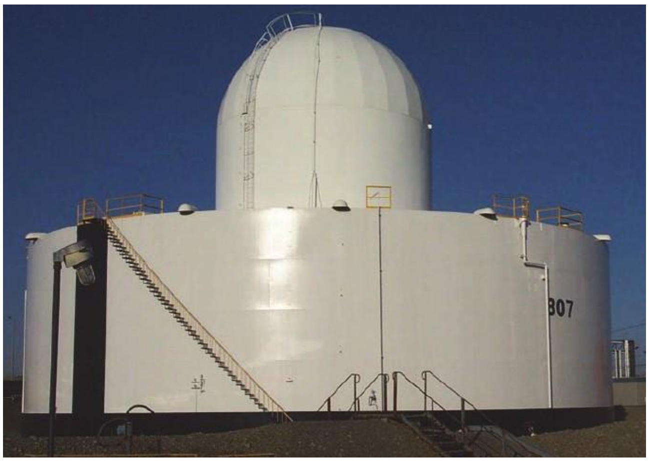

Figure 13. Storage tank with vapour-dome roof, /1/.

Horizontal storage tanks supported on saddles

Horizontal tanks are a great choice when floor space is not an issue and head room is at a minimum. The horizontal tank ends are ASME flanged and dished for added strength and capacity. Horizontal tanks come standard with a minimum of two primed carbon steel support saddles which provide a standard 12″ under-clearance from the tank bottom to the bottom of the saddles (Fig. 14), /15/.

Figure 14. Storage tank supported on saddles, /15/.

Horizontal tanks with heating coils are normally used to heat and store liquid AC, but can be used for other materials, such as heavy fuel oil. They come in eleven different sizes with capacities from 5,000 to 40,000 gallons. Tanks for stationary HMA plants are mounted on steel skids that bolt to concrete foundations. Tanks for relocatable plants have built-in steel foundations that rest directly on the ground, /15/.

The storage tank has serpentine heating coils. Liquid asphalt in the tank is indirectly heated by hot thermal oil flowing through the coils. The coils are formed into three layers, each with ten coils. Coils are made from rugged 2-inch scheduled 40 seamless pipes and run the full length of the tank or compartments.

Storage tanks are made from 1/4-inch A-36 steel plates. Tank heads are also 1/4-inch steel, flanged and reinforced with channel stiffeners. Lifting lugs are provided on both ends of the tank. Skids are made from steel channels and have expansion joints to compensate for changes in temperature. Unlike many competitive tanks, tanks have saddles along their length for added strength. The skids have tie-down lugs for shipping. A manway is located in the top of each compartment. An access ladder is provided on the outside of the tank and inside each compartment. Each compartment also has a combination vent and overflow pipe. A 3-inch valve in the bottom of each compartment allows the tank to be completely drained.

Hemispheroid storage tanks

Plain hemisphere tanks belong to a group of cylindrical storage tanks used to store various substances at moderate pressures (Fig. 15), /1, 16/. Beside to this, noded hemispheroid tanks present one modification of the storage tank with the hemispheroid roof (Fig. 16), /1/.

Nowadays, one more design of the hemispheroid tank exists - a hemispheroid tank with knuckle radius, Fig. 17 /1/.

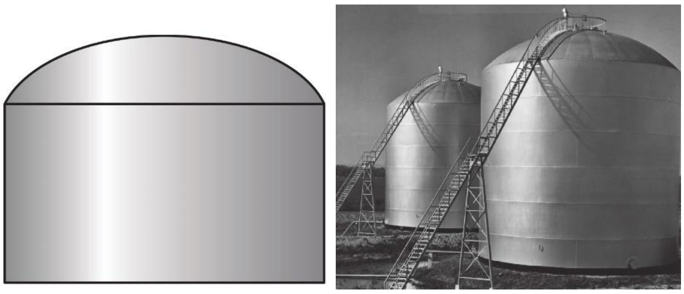

Figure 15. Storage tank with hemispheroid roof, /16/.

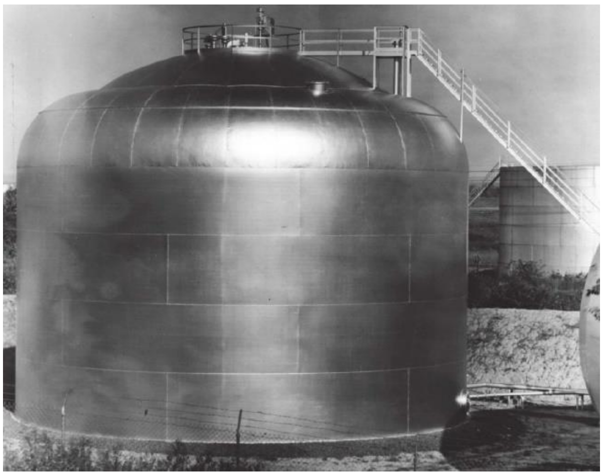

Figure 16. Noded hemispheroid tank, /1/.

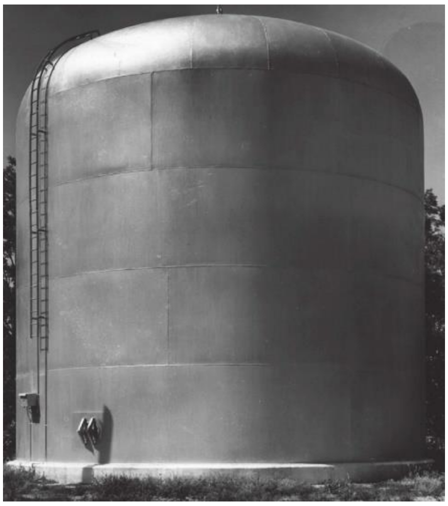

Figure 17. Hemispheroid tank with knuckle radius, /1/.

Spheroid storage tanks

Figure 18. Smooth spheroid tanks, /17/.

Storage tanks that most often resemble pumpkins or flattened spheres are called spheroidal tanks. In the period roughly between 1930 and 1960, a large number of these types of tanks were manufactured by the Chicago Bridge & Iron-CBI company after they patented this design. CBI produced these tanks in two forms, in the form of smooth spheroids and segmented spheroids, Figs. 17-18, /1, 17/.

Figure 19. Segmented spheroid tanks, /18/.

Figure 19 presents segmented spheroid tanks, /18/.

The original purpose of the spheroid was a pressure container used for storage of volatile liquids. It was particularly intended for the storage of hydrocarbons ranging in volatility from motor gasoline to natural gasoline.

The principle of operation for the spheroid was originally to prevent evaporation losses from volatile liquid by making use of the simple fact that no loss can occur unless vapour escapes. The spheroid is designed to eliminate losses due to:

- *breathing, resulting from daily temperature change*: the spheroid was equipped with a relief vent set to open at a predetermined pressure. The air-vapour mixture could not expand when temperature rose, and pressure was built up instead;
- *boiling*: the spheroid was designed to minimise surface boiling of higher vapour pressure liquids at ambient storage temperatures by allowing the pressure to build to a level sufficient to stop the boiling;
- *filling*: spheroids were designed to either reduce filling losses or eliminate them completely, depending on the vapour pressure of the stored liquid and pressure and vacuum settings of the relief valves.

An economical vessel capable of being built in large capacities was made available with the invention and introduction of the spheroid. Plain or smooth spheroids were built in standard capacities ranging from 2,500 to 30,000 US barrels and for gauge pressures as high as 170 kPa. Noded spheroids were built in standard capacities ranging from 2,500 to 30,000 US barrels and for gauge pressures as high as 107 kPa. Noded spheroids are distinguished by one or more discontinuities in the curved surface of the shell.

Today, most of these vessels have been retired from pressure service or dismantled. Of remaining, many have been de-rated to lower pressure or to atmospheric pressure service. The unique geometry of vessels was intended to make the most efficient use of steel shell plates by balancing the latitudinal and longitudinal membrane stresses. This unique geometry presents a challenge to those responsible for inspecting and evaluating the structural integrity of these vessels. Tank Industry Consultants (TIC) has developed the analysis tools necessary to evaluate these unusual vessels.

One can inspect and evaluate them in accordance with API Standard 653, API Standard 510, or ASME B&PV Code criteria, to determine remaining life, inspection intervals and other necessary information for owner/operator, /19/.

Bullet storage tanks

Storage tanks in the form of bullets (bullet tanks -horizontal pressure tanks) are practically pressure vessels used to store fluids under high pressure. The heads of these above ground storage tanks are usually elliptical or hemispherical in shape. Hemispherical heads of these tanks are used when it is necessary to store fluids at higher pressures, /3/. Often, these types of storage tanks are used to store liquid petroleum gas, Fig. 20, /3, 20/.

Figure 20. Bullet storage tanks, /20/.

Horton sphere storage tanks

The Horton sphere is named after Horace Ebenezer Horton (1843-1912), founder and financier of a bridge design and construction firm in about 1860, merged to form the Chicago Bridge & Iron Company (CB&I) in 1889 as a bridge building firm and constructed the first bulk liquid storage tanks in the late nineteenth and early twentieth centuries. CB&I built the first field-erected spherical pressure vessels in the world at Port Arthur Texas refinery in 1923 and subsequently claimed 'Horton sphere' as a registered trademark, /21/.

Initially, Horton spheres were made by riveting separate wrought iron or steel plates, but from the 1940s, were of welded construction. The plates are formed in roller plants and cut to patterns. Today, spherical tanks are designed to codes such as ASME VIII, PD 5500, or EN 13445.

The spherical geometry minimises both the mechanical stress imposed on the tank walls by internal pressure and the heat transfer through the walls. This makes spherical tanks the optimal solution for the storage of large amounts of liquefied gases, where liquefaction is achieved by pressurisation, cryogenic refrigeration, or a combination thereof. Minimisation of heat transfer is due to the sphere being the solid figure with minimum surface area per unit volume. This is an advantage because it reduces the production of boil-off gas from both pressurised and refrigerated liquefied gases.

Spherical tanks are used extensively for LPG and associated gases, such as propane, propylene, butane, and butadiene. They can be used for cryogenic storage of LNG, methane, ethane, ethylene, hydrogen, oxygen, nitrogen, etc. Support is usually provided by the use of legs attached to the sphere at its equator. Legs are typically braced together with diagonal rods to provide lateral support against wind and seismic loads. Legs are fireproofed if the material is flammable.

Pressure relief valves are installed at the top, from where level instrumentation is also accessed. Liquid inlet and outlet connections are at the bottom of the sphere. Bunds are usually provided around the tanks or tank clusters to contain potential leakage. However, if the gas is prone to boiling liquid vapour expanding explosions (BLEVE), spills should be directed away from the leaking tank.

Other uses have been applied to the Horton sphere including space-, hyperbaric-, and environmental chambers, vacuum-, process-, test-, containment-, and surge vessels (Fig. 21), /22/.

Figure 21. Horton sphere tanks, /22/.

Beside straight Horton sphere tanks, designs of Horton elliptic tanks also exist which are practically modifications of the straight Horton sphere tanks (Figs. 22 and 23), /23/.

Figure 22. Elliptic tanks with a longer vertical axis, /23/.

Figure 23. Elliptic tanks with a longer horizontal axis, /23/.

Water towers

Storage tanks placed at a height are most often used for water storage and are therefore often called water towers. Here it is also necessary to mention that the first written data on the construction of water towers appear in prospects of the Chicago Bridge & Iron-CBI company from 1912.

A water tower is an elevated structure /1/ supporting a water tank constructed at a height sufficient to pressurise a distribution system for potable water, and to provide emergency storage for fire protection. Water towers often operate in conjunction with underground or surface service reservoirs which store treated water close to where it will be used. Other types of water towers may only store raw (non-potable) water for fire protection or industrial purposes and may not necessarily be connected to a public water supply.

Water towers are able to supply water even during power outages, because they rely on hydrostatic pressure produced by elevation of water (due to gravity) to push the water into domestic and industrial water distribution systems; however, they cannot supply the water for a long time without power, because a pump is typically required to refill the tower. A water tower also serves as a reservoir to help with water needs during peak usage times. The water level in the tower typically falls during the peak usage hours of the day, and then a pump fills it back up during the night. This process also keeps the water from freezing in cold weather, since the tower is constantly being drained and refilled, /24/.

Figure 24 shows the water tower system in downtown Kuwait City. These water towers are designed by famous Danish/Sweden architects and designers Malene Bjorn and her husband Sune Lindstrom, /25/. Constructions of these towers are performed by RAD Holding company from Belgrade-Yugoslavia. Towers were put in service on Feb. 26, 1977, while restaurants were opened for public on March 1, 1979 /26/.

Figure 24. Main water towers in Kuwait city, /27/.

This water tower system consists of 3 towers. The main tower is 187 m high and consists of two spheres. The lower sphere holds a water tank with a capacity of 4,500 cubic meters at the bottom of its half. On the upper half there is a restaurant for 90 people, a cafe, a rest area and a reception hall. The upper sphere rises 123 m above sea level and there is an observation deck that describes a full circle every 30 minutes. The second tower is 147 m high and serves as a water tower. In the third tower is the equipment for controlling the current flow and illuminates the two higher towers. Together, the towers store 9,000 cubic meters of water. Unfortunately, these towers were damaged during the Iraq-White War in 1991, and luckily the greatest damage was done to the electrical installations, /27/.

Mushroom-shaped water towers

Storage tanks for liquids with a mushroom-shaped roof (mushroom-shaped water tower) represent a modification of classic water towers, where the purpose of these tanks is the same as that of the previously described water towers. These tanks are usually fabricated from steels, concrete, or a combination of both. Figure 25 shows the carbon steel storage tank.

Figure 25. Carbon steel mushroom shaped water tower, /27/.

Figure 26 shows the Roihuvuori water tower (in Eastern Helsinki, Finland) which is fabricated from concrete.

Figure 26. Concrete mushroom-shaped water tower, /28/.

The mentioned tower is built in 1976-1977 and designed by architect Simo Lumme. It is 52 m high and can hold around 12,000 cubic metres of water.

CONCLUSION

The paper describes the main types of above-ground storage tanks. Their classification is performed according to their shape, materials, and type and functionality of their roofing. Special attention during this classification is directed to cylindrical tanks with cone roofs as storage tanks which are the most represented tanks in industrial plants and the storage tanks with floating roofs. Also mentioned are the storage tanks practically near to their final disappearing, such as smooth spheroid tanks and segmented spheroid tanks, whose inspection and examination have practically ended.

Horton sphere storage tanks (their design modification) also are briefly described as a category of storage tanks working under low and high pressure and are usually used for storing liquid petroleum gas.

Besides previously mentioned, water towers are presented as a special category, as systems for distributing water which are specially used in dry and rural environments and whose shapes are and still amazing. Among them, the water tower system in Kuwait stands out in particular, constructed by Yugoslav companies in the mid 70s.

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