


<p>KLM Technology Group</p> <p>Practical Engineering Guidelines for Processing Plant Solutions</p>	<div data-bbox="630 138 1112 237">  </div> <p>ENGINEERING SOLUTIONS</p> <p>www.klmtechgroup.com</p>	<p>Page : 1 of 92</p> <p>Rev: 02</p> <p>Rev 01 June 2011 Rev 02 June 2012</p>
<p>KLM Technology Group P. O. Box 281 Bandar Johor Bahru, 80000 Johor Bahru, Johor, West Malaysia</p>	<p>Kolmetz Handbook Of Process Equipment Design</p> <p>STORAGE TANK SELECTION, SIZING AND TROUBLESHOOTING</p> <p>(ENGINEERING DESIGN GUIDELINES)</p>	<p>Co Author:</p> <p>Rev 1 Karl Kolmetz Rev 2 Aprilia Jaya</p> <p>Editor / Author:</p> <p>Karl Kolmetz</p>

TABLE OF CONTENT

INTRODUCTION

Scope	5
General Design Considerations	6

TYPES OF TANKS

Fixed Roof Tanks	7
External floating roof tanks	11
Internal floating roof tanks	15
Domed external floating roof tanks	18
Horizontal tanks	20
Pressure tanks	22
Variable vapor space tanks	23

KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 2 of 92
		Rev: 02
		JUNE 2012

TANK SEALS AND FITTINGS	25
External and Domed External Floating Roof Rim Seals	25
External and Domed External Floating Roof Deck Fittings	32
DEFINITIONS	45
NOMENCLATURE	53
THEORY OF THE DESIGN	55
1. Tank Dimension	55
2. Atmospheric storage tank	59
3. Pressure Storage Tank	63
4. Refrigerated Storage	65
5. Emissions Losses	66
A. Total Losses from Fixed Roof Tanks	66
B. Total Losses from Floating Roof Tanks	69

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 3 of 92
		Rev: 02
		JUNE 2012

APPLICATION	75
Example 1: Dimension of tank calculation	75
Example 2: Fixed Roof Tank Emission (Cone Roof and Dome Roof)	78
Example 3: Floating Roof Emission Losses	81
REFERENCE	84

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 4 of 92
		Rev: 02
		JUNE 2012

LIST OF TABLE

Table 1: Maximum allowable stress value (f)	56
Table 2: Maximum allowable efficiencies for Arc and Gas welded joints	57
Table 3: Dimension of icr, rc, and sf	58
Table 4: Size of innage and outage of tank	61
Table 5: Nozzle service for tank	62
Table 6: Paint Factors for Fixed Roof Tanks	67
Table 7: Rim-seal loss factor	71
Table 8: Average Clingage Factors (C_s)	72
Table 9: Typical Number of Columns as a Function of Tank Diameter	72
Table 10: Deck-Fitting Loss Factors and Typical Number of Deck Fitting	78

LIST OF FIGURE

Figure 1: Fixed Roof Tanks	9
Figure 2: Fixed Roof Tanks 2	10
Figure 3: External Floating Roof Tanks	12
Figure 4: External Floating Roof Tanks 2	13
Figure 5: Typical List of Floating Roof Fittings	14
Figure 6: Internal Floating Roof	17
Figure 7: Dome External Floating Roof	19
Figure 8: Schematics of above-ground horizontal (a) and underground tanks (b)	21

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 5 of 92
		Rev: 02
		JUNE 2012

Figure 9: Scheme of Pressure Tank	22
Figure 10: Variable Vapor Space Tanks	24
Figure 11: Vapor mounted primary seals	26
Figure 12: Liquid-mounted and mechanical shoe primary seals	27
Figure 13: Secondary rim seals	29
Figure 14: Access Hatch	32
Figure 15: Gauge float	33
Figure 16: Sample ports	34
Figure 17: Rim vent	35
Figure 18: Deck drains	36
Figure 19: Deck leg	37
Figure 20: Slotted and unslotted guidepoles	38
Figure 21: Vacuum breaker	41
Figure 22: Fixed Roof Support Column	43
Figure 23: Ladder and well	44

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 6 of 92
		Rev: 02
		JUNE 2012

INTRODUCTION

Scope

This design guideline covers the sizing and selection methods of a storage tank system used in the typical process industries. It helps engineers understand the basic design of different types of storage tank systems and increases their knowledge in selection and sizing.

The selection section contains the explanation for the suitability of types of tank system used in processing industries, which are based on the environmental regulations, location, and process materials involved.

All the important parameters used in this guideline are well explained in the definition section which helps the reader understand the meaning of the parameters and the terms used.

The theory section includes sizing theory and formulations for the tanking systems design.

In the application section, three cases examples are included by guiding the reader step by step to do tank sizing.

In the end of this guideline, example specification data sheets for the tank system are included which is created based on an industrial example. Calculation spreadsheet is included as well and to aid user more understand and to apply the theory for calculations.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 7 of 92
		Rev: 02
		JUNE 2012

General Design Considerations

Storage vessels containing organic and non organic liquids and vapors can be found in many industries, including;

- (1) petroleum producing and refining,
- (2) petrochemical and chemical manufacturing,
- (3) bulk storage and transfer operations, and
- (4) other industries consuming or producing liquids and vapors.

Liquids and vapors in the petroleum industry, usually called petroleum liquids or vapors, generally are mixtures of hydrocarbons having dissimilar true vapor pressures. Examples would include jet fuel, diesel, gasoline and crude oil.

Liquids and vapors in the chemical industry, usually called volatile organic liquids and vapor, are composed of pure chemicals or mixtures of chemicals with similar true vapor pressures. Examples would include benzene, styrene, and alcohols).

Liquids and vapors in the bulk storage and transfer operations can be organic or hydrocarbon in nature. Example would include all of the above including acids and bases.

All those chemical should keep in the right storage tank. Design and safety concern has come to a great concern as reported case of fires and explosion for the storage tank has been increasing over the years and these accident cause injuries and fatalities. Spills and tank fires not only causing environment pollution, there would also be severe financial consequences and significant impact on the future business due to the industry reputation.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 8 of 92
		Rev: 02
		JUNE 2012

TYPES OF STORAGE TANKS

Seven types of vessels are used to store volatile organic liquids:

1. Fixed-roof tanks;
2. External floating roof tanks;
3. Internal floating roof tanks;
4. Domed external floating roof tanks;
5. Horizontal tanks;
6. Pressure tanks; and
7. Variable vapor space tanks.

The first four tank types are cylindrical in shape with the axis oriented perpendicular to the foundation. These tanks are almost exclusively above ground. Horizontal tanks (i.e., with the axis parallel to the foundation) can be used above ground and below ground.

Pressure tanks often are horizontally oriented and "bullet" or spherically shaped to maintain structural integrity at high pressures. They are located above ground. Variable vapor space tanks can be cylindrical or spherical in shape.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 9 of 92
		Rev: 02
		JUNE 2012

1. Fixed-Roof Tanks

Of currently used tank designs, the fixed-roof tank is the least expensive to construct and is generally considered the minimum acceptable equipment for storing VOL's (volatile organic liquids). A typical fixed-roof tank, which is shown in Figure 1 below, consists of a cylindrical steel shell with a cone- or dome-shaped roof that is permanently affixed to the tank shell. Most recently built tanks are of all-welded construction and are designed to be both liquid- and vapor-tight. However, older tanks may be of riveted or bolted construction and may not be vapor-tight.

A breather valve (pressure-vacuum valve), which is commonly installed on many fixed-roof tanks, allows the tank to operate at a slight internal pressure or vacuum. Breather vents are typically set at 0.19 kPa (0.75 in. w.c.) on atmospheric pressure fixed-roof tanks. Because this valve prevents the release of vapors during only very small changes in temperature, barometric pressure, or liquid level, the emissions from a fixed-roof tank can be appreciable.

For fixed-roof tanks, the nominal capacity is the geometric volume from the bottom of the tank up to the curb angle, which is a metallic angle that is welded along the periphery at the top of the cylindrical portion of the tank.

Additionally, gauge hatches/sample wells, float gauges, and roof manholes provide accessibility to these tanks and also serve as potential sources of volatile emissions. Breather vents may be called conservation vents, although hardly any conservation of vapors occurs at such low pressure settings. Generally, the term conservation vent is used to describe a pressure setting of 17 kPa (67 in. w.c.) or less. Vents with settings greater than 17 kPa (67 in. w.c.) are commonly called 'pressure' vents.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 10 of 92
		Rev: 02
		JUNE 2012

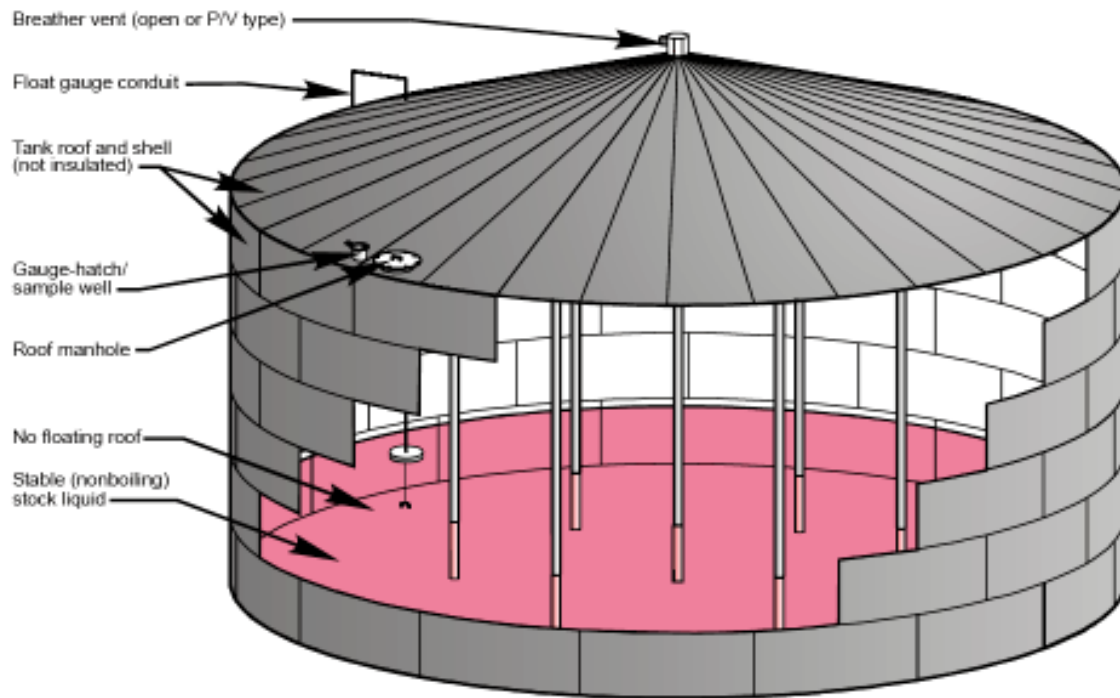


Figure 1: Fixed Roof Tanks 1.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 11 of 92
		Rev: 02
		JUNE 2012

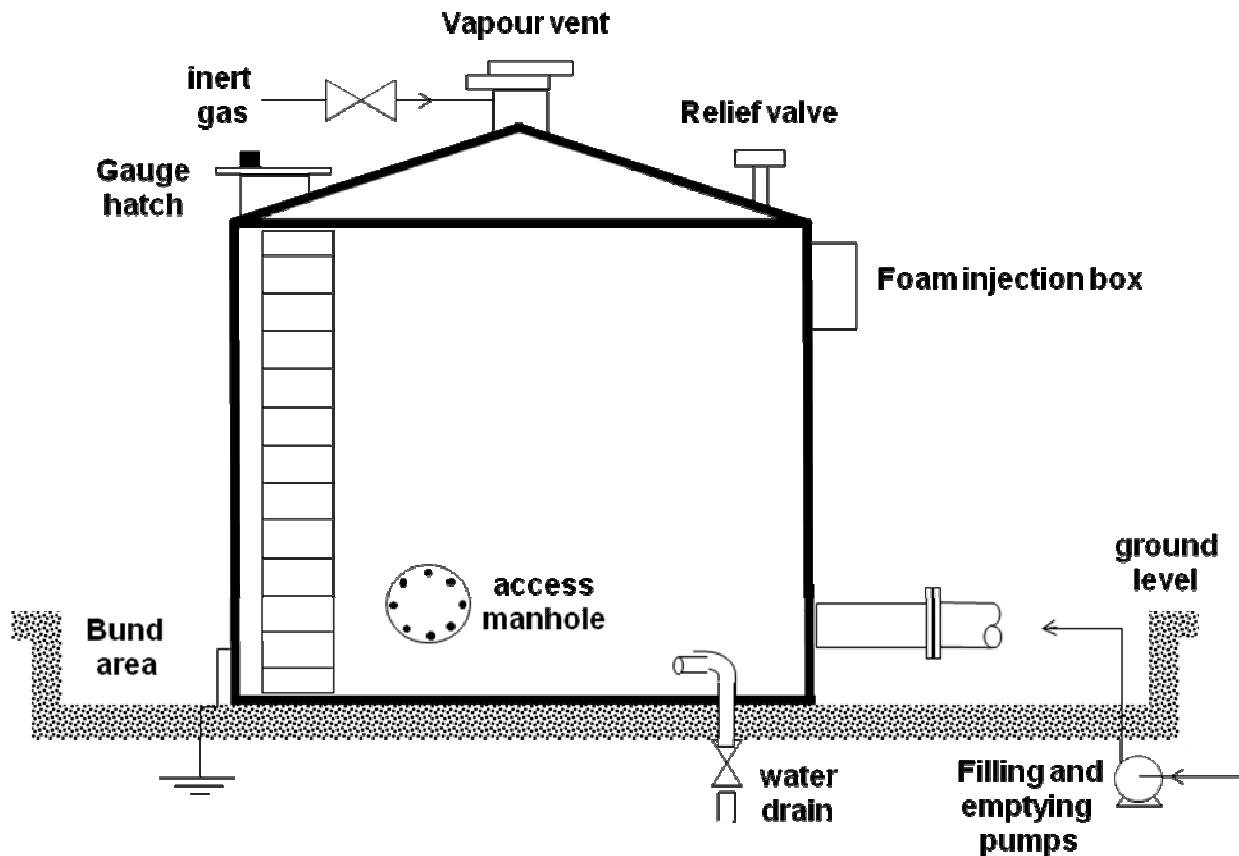


Figure 2: Fixed Roof Tanks 2

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 12 of 92
		Rev: 02
		JUNE 2012

2. External Floating Roof Tanks

A typical external floating roof tank consists of an open-topped cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid, rising and falling with the liquid level. The floating roof is comprised of a deck, fittings, and rim seal system. Floating roof decks are constructed of welded steel plates and are of three general types: pan, pontoon, and double deck.

Although numerous pan-type decks are currently in use, the present trend is toward pontoon and double-deck type floating roofs. The two most common types of external floating-roof tanks are shown in Figures 3 and 4.

Manufacturers supply various versions of these basic types of floating decks, which are tailored to emphasize particular features, such as full liquid contact, load-carrying capacity, roof stability, or pontoon arrangement. The liquid surface is covered by the floating deck, except in the small annular space between the deck and the shell; the deck may contact the liquid or float directly above the surface on pontoons.

External floating roof tanks are equipped with a rim seal system, which is attached to the roof perimeter and contacts the tank wall. The rim seal system slides against the tank wall as the roof is raised and lowered. The floating deck is also equipped with fittings that penetrate the deck and serve operational functions. The external floating roof design is such that evaporative losses from the stored liquid are limited to losses from the rim seal system and deck fittings (standing storage loss) and any exposed liquid on the tank walls (withdrawal loss).

In external floating roof design, the roof is made to rest on the stored liquid and is free to move with the level of the liquid. These tanks reduce evaporation losses and control breathing losses while filling. They are preferred for storage of petroleum products with a true vapor pressure of 10.3 to 76.5 kPa absolute.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 13 of 92
		Rev: 02
		JUNE 2012

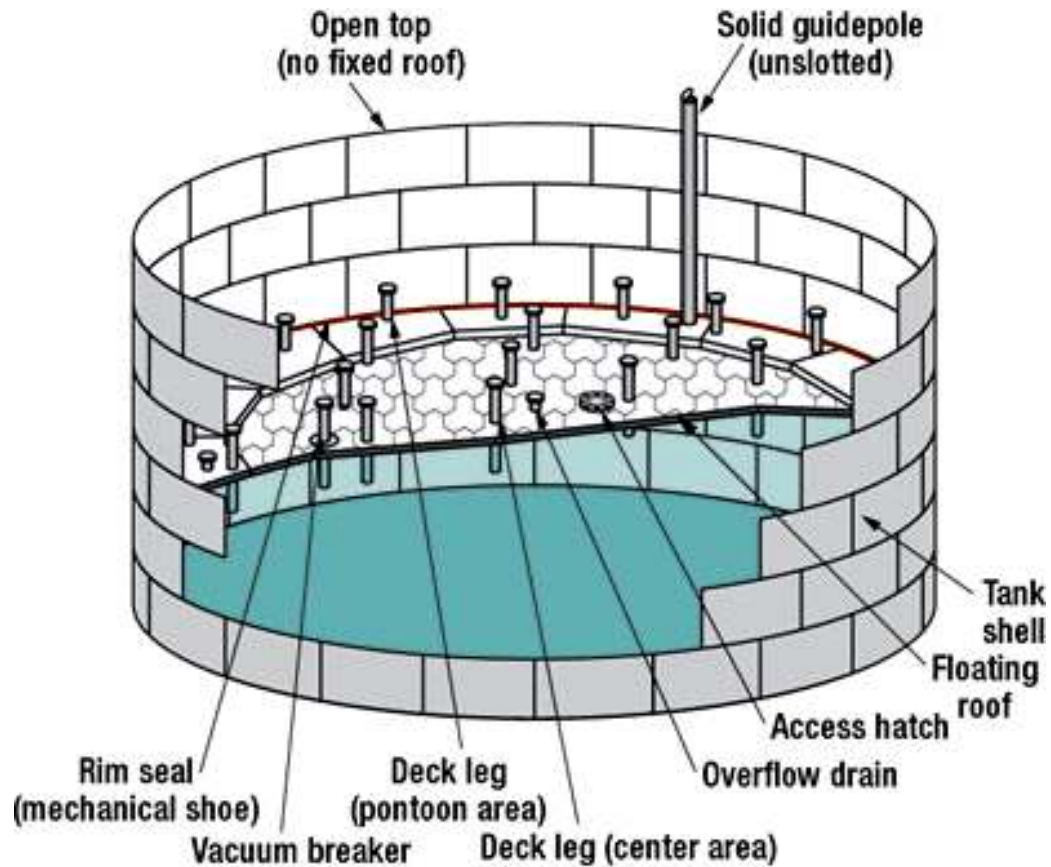


Figure 3: External Floating Roof Tanks 1

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		Rev: 02
		JUNE 2012

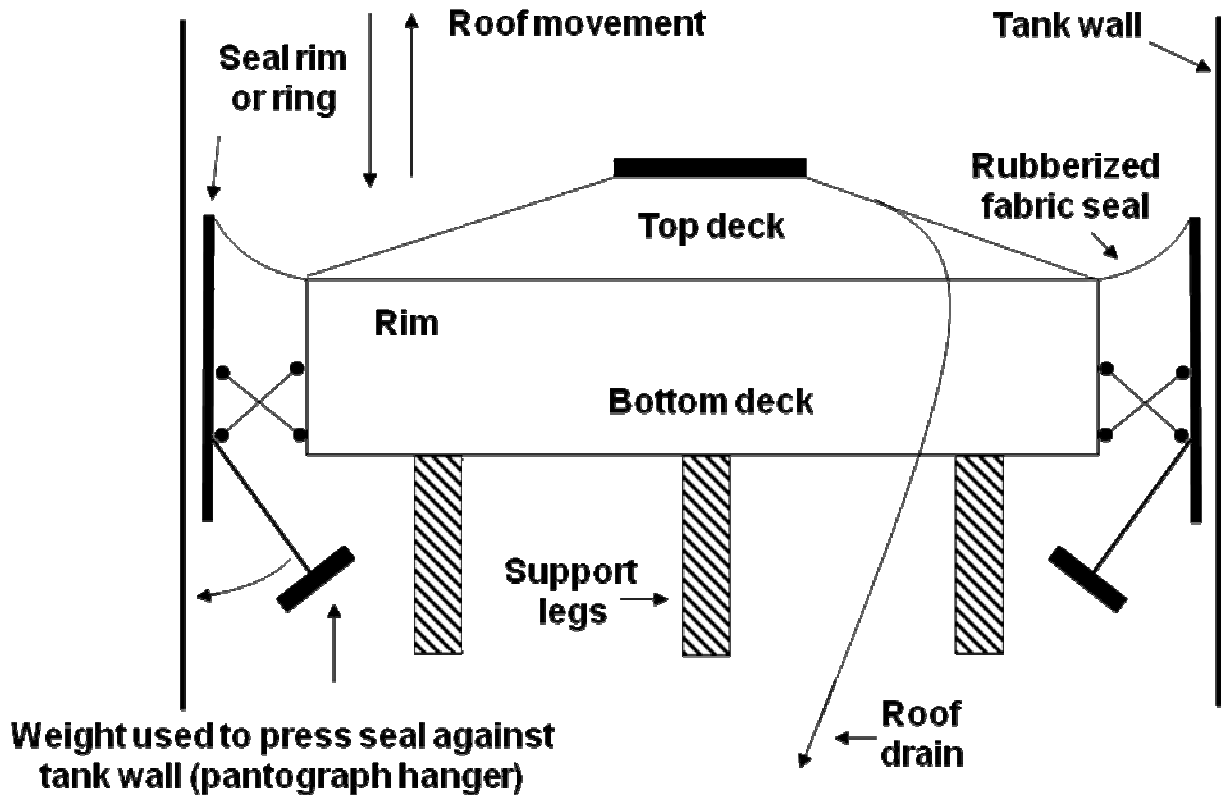


Figure 4: External Floating Roof Tanks 2

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		Rev: 02
		JUNE 2012

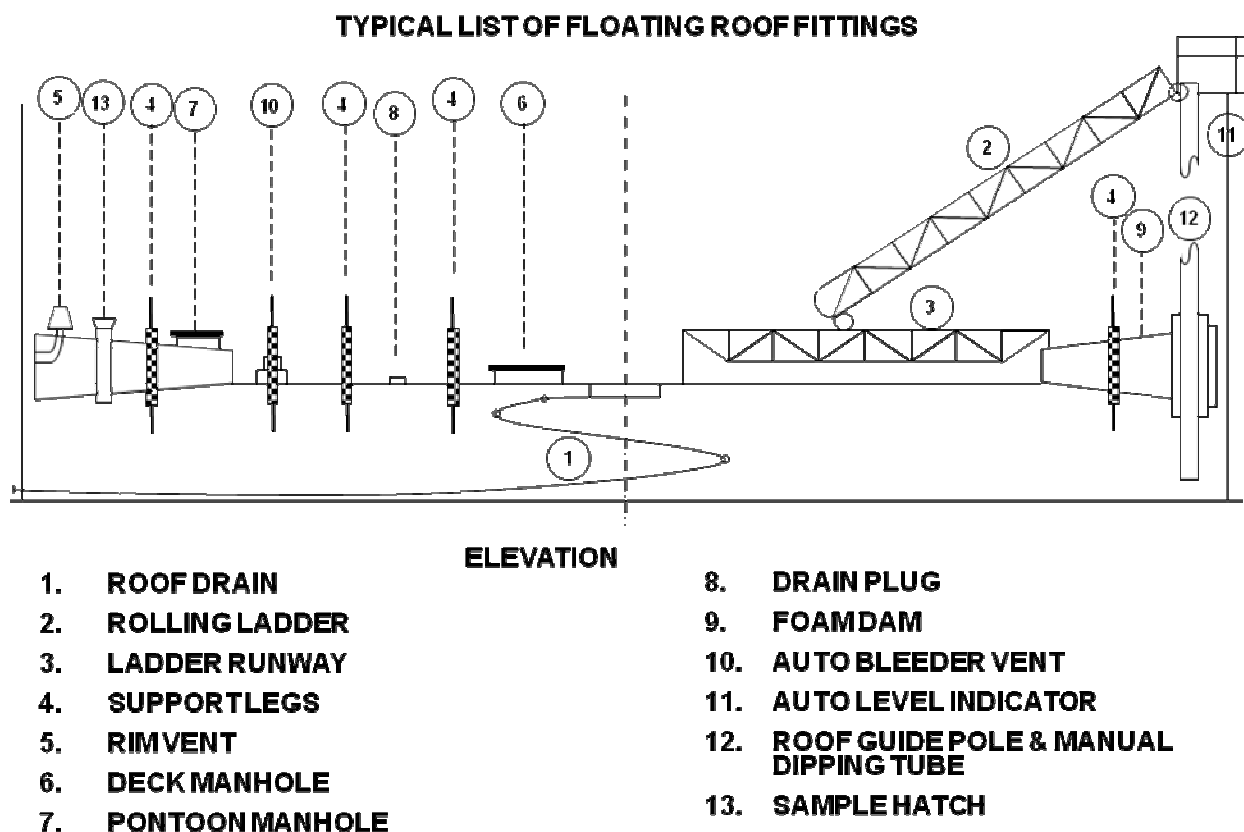


Figure 5: Typical List of Floating Roof Fittings

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmttechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 16 of 92
		Rev: 02
		JUNE 2012

3. Internal Floating Roof Tanks

An internal floating roof tank has both a permanent fixed roof and a floating roof inside. There are two basic types of internal floating roof tanks: tanks in which the fixed roof is supported by vertical columns within the tank; and tanks with a self-supporting fixed roof and no internal support columns. The fixed roof is not necessarily free of openings but does span the entire open plan area of the vessel. Fixed roof tanks that have been retrofitted to employ an internal floating roof are typically of the first type, while external floating roof tanks that have been converted to an internal floating roof tank typically have a self-supporting roof.

Tanks initially constructed with both a fixed roof and an internal floating roof may be of either type. An internal floating roof tank has both a permanently affixed roof and a roof that floats inside the tank on the liquid surface (contact deck) or is supported on pontoons several inches above the liquid surface (noncontact deck). The internal floating roof rises and falls with the liquid level. A typical internal floating roof tank is shown in figure below

Contact-type decks include (1) aluminum sandwich panels with a honeycombed aluminum core floating in contact with the liquid; (2) resin-coated, fiberglass-reinforced polyester (FRP), buoyant panels floating in contact with the liquid; and (3) pan-type steel roofs, floating in contact with the liquid with or without the aid of pontoons. The majority of contact internal floating decks currently in VOL service are pan-type steel or aluminum sandwich panel type. The FRP decks are less common.

Several variations of the pan-type contact steel roof exist. The design may include bulkheads or open compartments around the perimeter of the deck so that any liquid that may leak or spill onto the deck is contained. Alternatively, the bulkheads may be covered to form sealed compartments (i.e., pontoons), or the entire pan may be covered to form a sealed, double deck, steel floating roof. Generally, construction is of welded steel.

Noncontact-type decks are the most common type of deck currently in use, and typically consist of an aluminum deck laid on an aluminum grid framework supported above the liquid surface by tubular aluminum pontoons. The deck skin for the noncontact-type floating decks is typically constructed of rolled aluminum sheets (about 1.5 meters [m] [4.9 feet (ft)] wide and 0.58 millimeter [mm] [0.023 inches (in)]

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 17 of 92
		Rev: 02
		JUNE 2012

thick). The overlapping aluminum sheets are joined by bolted aluminum clamping bars that run perpendicular to the pontoons to improve the rigidity of the frame.

The deck skin seams can be metal on metal or gasketed with a polymeric material. The pontoons and clamping bars form the structural frame of the floating deck. Deck seams in the noncontact internal floating roof design are a source of emissions. Aluminum sandwich panel contact-type internal floating roofs also share this design feature. The sandwich panels are joined with bolted mechanical fasteners that are similar in concept to the noncontact deck skin clamping bars. Steel pan contact internal floating roofs are constructed of welded steel sheets and therefore have no deck seams. Similarly, the resin-coated, reinforced fiberglass panel decks have no apparent deck seams. The panels are butted and lapped with resin-impregnated fiberglass fabric strips.

The internal floating roof physically occupies a finite volume of space that reduces the maximum liquid storage capacity of the tank. When the tank is completely full, the floating roof touches or nearly touches the fixed roof. Consequently, the effective height of the tank decreases, thus limiting the storage capacity. The reduction in the effective height varies from about 0.15 to 0.6 m (0.5 to 2 ft), depending on the type and design of the floating roof employed.

All types of internal floating roofs, like external floating roofs, commonly incorporate rim seals that slide against the tank wall as the roof moves up and down. Circulation vents and an open vent at the top of the fixed roof are generally provided to minimize the accumulation of hydrocarbon vapors in concentrations approaching the flammable range. Flame arresters are an option that can be used to protect the vessel from fire or explosion. When these are used, circulation vents are not provided. Tank venting occurs through a pressure-vacuum vent and flame arrestor.

The design features of internal floating roof can be summary as follow

1. A truly vapor tight metal to metal clamp beam develops the full strength of the deck skin itself
2. A patented pivot joint eliminates stress at pontoon ends by allowing flexure where it is needed

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 18 of 92
		Rev: 02
		JUNE 2012

3. Pontoon saddles support the clamp beams on the pontoon and distribute the concentrated load to assure against localized buckling
4. Bolted connections are corrosion resistant 300 series stainless steel fixings
5. Reduces emissions from fixed roof tanks by up to 97% & meets VOC control and Environmental Protection Standards

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 19 of 92
		Rev: 02
		JUNE 2012

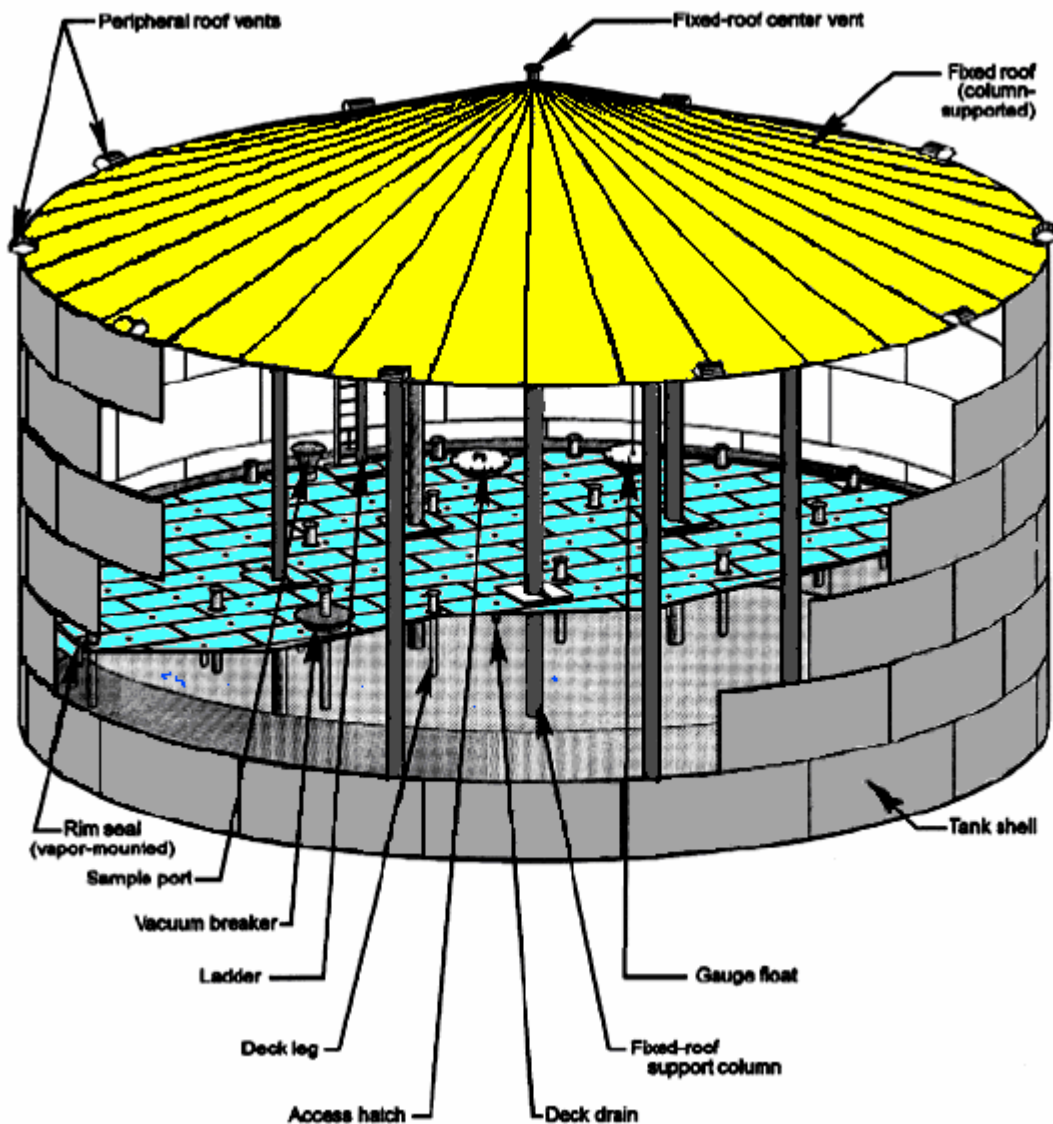


Figure 6: Internal Floating Roof

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 20 of 92
		Rev: 02
		JUNE 2012

4. Domed External Floating Roof Tanks

Domed external floating roof tanks have the heavier type of deck used in external floating roof tanks as well as a fixed roof at the top of the shell like internal floating roof tanks. Domed external floating roof tanks usually result from retrofitting an external floating roof tank with a fixed roof. A typical domed external floating roof tank is shown in Figure 7.

As with the internal floating roof tanks, the function of the fixed roof is not to act as a vapor barrier, but to block the wind. The type of fixed roof most commonly used is a self supporting aluminum dome roof, which is of bolted construction. Like the internal floating roof tanks, these tanks are freely vented by circulation vents at the top of the fixed roof. The deck fittings and rim seals, however, are basically identical to those on external floating roof tanks.

Aluminum dome roof have some advance features :

1. The Clear Span design eliminates the need for interior support structures while high strength aluminum alloys and corrosion resistant materials provide for a long service life.
2. Properly designed tension rings ensure that the lateral force generated by the dome is not translated to the tank shell, eliminating the need for additional tank shell reinforcement or modifications.
3. Beams are designed with an extruded continuous threaded bolting slot. This bolting slot provides more thread engagement area and more pull resistance than in conventional designs.
4. The overlapping panels naturally shed water and are secured in place with a patented Batten Bar and hidden gasket system. This design allows the roof panels to flex while keeping sheets from puckering and bolts from leaking.
5. Aluminum Dome reduces wind induced vapor losses, aids in odor abatement and provides significant emission credits.
6. Floating roof and seal maintenance are drastically reduced due to the lack of rainwater and UV exposure.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 21 of 92
		Rev: 02
		JUNE 2012



Figure 7: Dome External Floating Roof

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 22 of 92
		Rev: 02
		JUNE 2012

5. Horizontal Tanks

Horizontal tanks are constructed for both above-ground and underground service. Figures 8 present schematics of typical underground and above-ground horizontal tanks. Horizontal tanks are usually constructed of steel, steel with a fiberglass overlay, or fiberglass-reinforced polyester. Horizontal tanks are generally small storage tanks with capacities of less than 75,710 L (20,000 gallons).

Horizontal tanks are constructed such that the length of the tank is not greater than six times the diameter to ensure structural integrity. Horizontal tanks are usually equipped with pressure-vacuum vents, gauge hatches and sample wells, and manholes

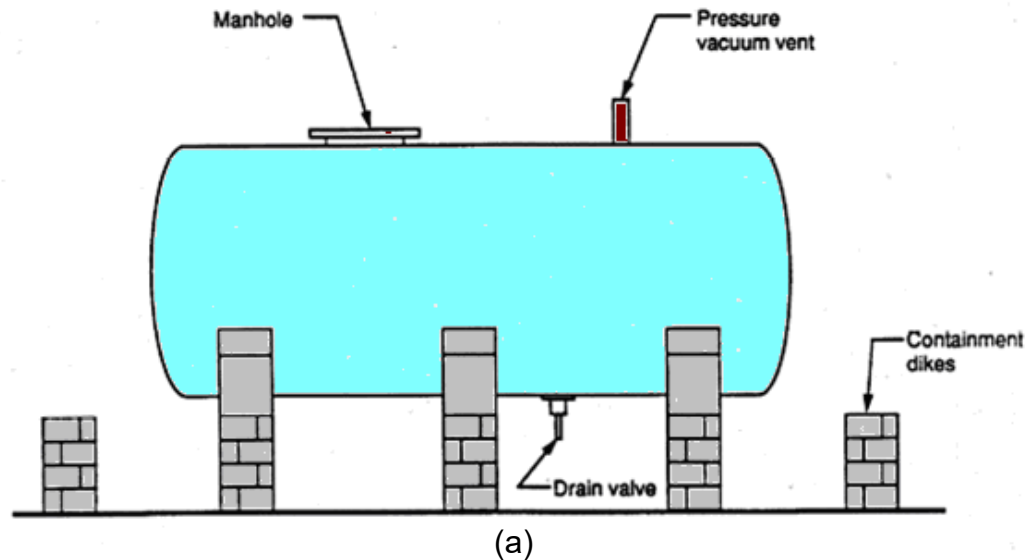
to provide accessibility to these tanks. In addition, underground tanks may be cathodically protected to prevent corrosion of the tank shell. Cathodic protection is accomplished by placing sacrificial anodes in the tank that are connected to an impressed current system or by using galvanic anodes in the tank. However, internal cathodic protection is no longer widely used in the petroleum industry, due to corrosion inhibitors that are now found in most refined petroleum products.

The potential emission sources for above-ground horizontal tanks are the same as those for fixed-roof tanks. Emissions from underground storage tanks are mainly associated with changes in the liquid level in the tank. Losses due to changes in temperature or barometric pressure are minimal for underground tanks because the surrounding earth limits the diurnal temperature change and changes in the barometric pressure would result in only small losses.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 23 of 92
		Rev: 02
		JUNE 2012



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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 24 of 92
		Rev: 02
		JUNE 2012

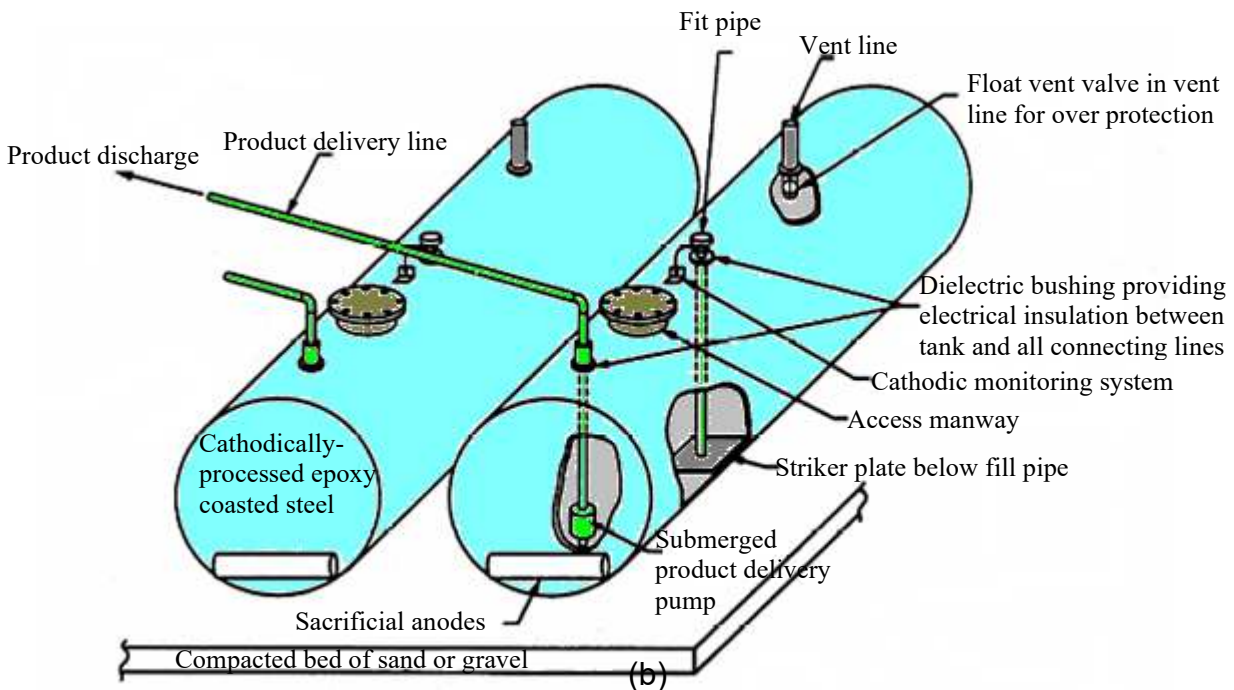


Figure 8: schematics of typical above-ground horizontal (a) and underground tanks (b)

6. Pressure Tanks

Two classes of pressure tanks are in general use: low pressure (2.5 to 15 psig) and high pressure (higher than 15 psig). Pressure tanks generally are used for storing organic liquids and gases with high vapor pressures and are found in many sizes and shapes, depending on the operating pressure of the tank. Pressure tanks are equipped with a pressure/vacuum vent that is set to prevent venting loss from boiling and breathing loss from daily temperature or barometric pressure changes.

The pressure tank allows the pump to run occasionally instead of every time a faucet is opened. The basic system is often enhanced, either by necessity or for improved performance, with a constant pressure delivery system.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 25 of 92
		Rev: 02
		JUNE 2012

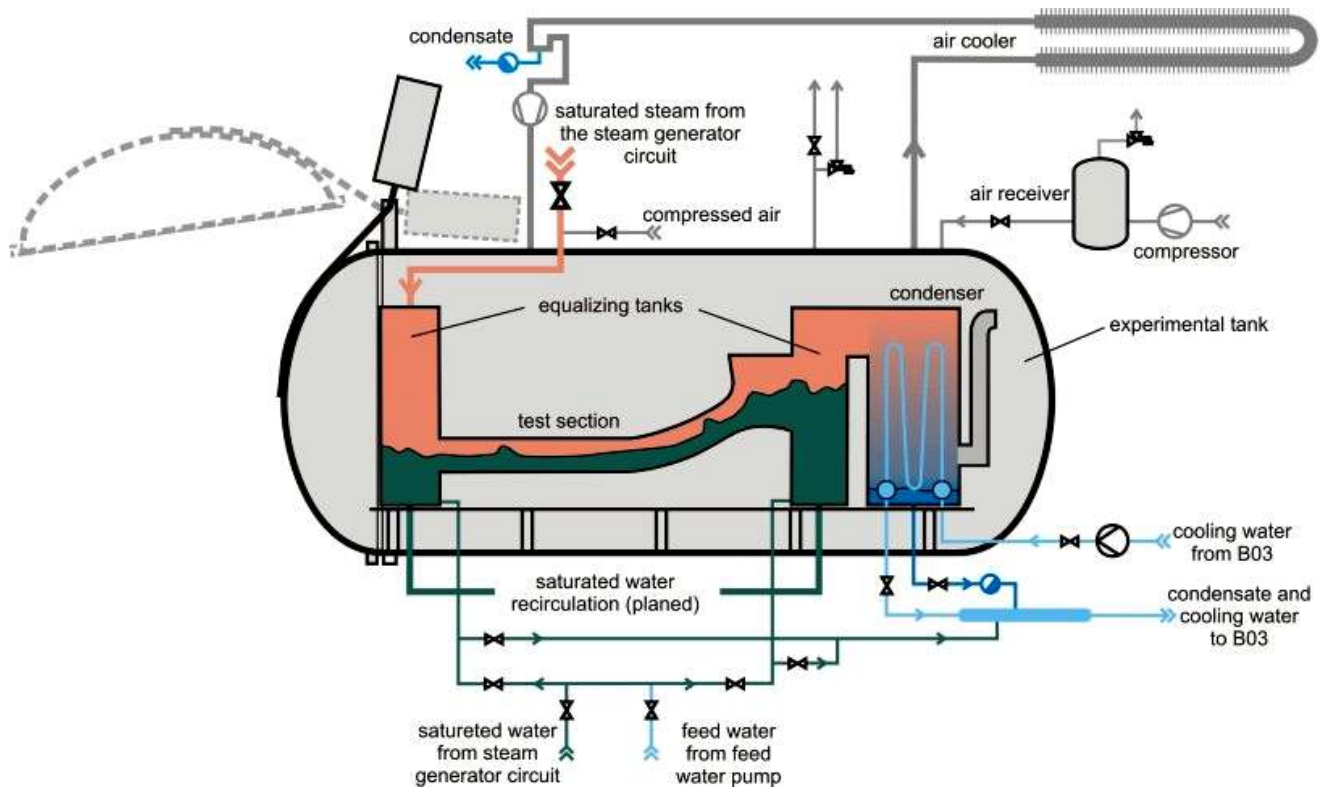


Figure 9: Scheme of Pressure Tank

7. Variable Vapor Space Tanks

Variable vapor space tanks are equipped with expandable vapor reservoirs to accommodate vapor volume fluctuations attributable to temperature and barometric pressure changes. Although variable vapor space tanks are sometimes used independently, they are normally connected to the vapor spaces of one or more fixed roof tanks. The two most common types of variable vapor space tanks are lifter roof tanks and flexible diaphragm tanks. Lifter roof tanks have a telescoping roof that fits loosely around the outside of the main tank wall. The space between the roof and the wall is closed by either a wet seal, which is a trough filled with liquid, or a dry seal, which uses a flexible coated fabric.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 26 of 92
		Rev: 02
		JUNE 2012

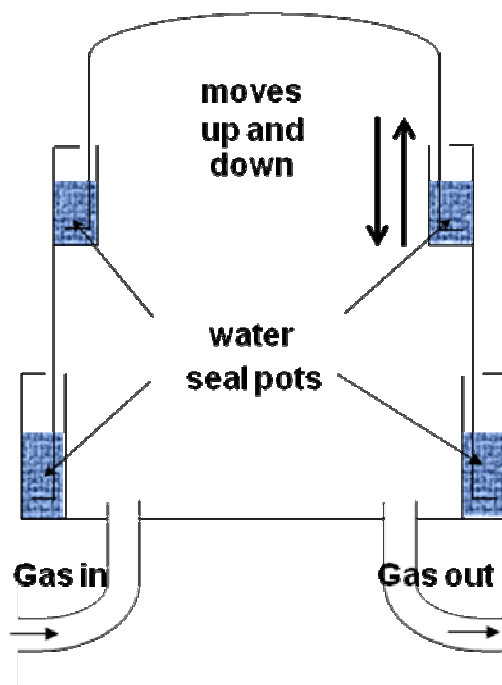
Flexible diaphragm tanks use flexible membranes to provide expandable volume. They may be either separate gasholder units or integral units mounted atop fixed roof tanks. Variable vapor space tank losses occur during tank filling when vapor is displaced by liquid. Loss of vapor occurs only when the tank's vapor storage capacity is exceeded.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 27 of 92
		Rev: 02
		JUNE 2012

(a) water sealed gasholders



(a) piston type

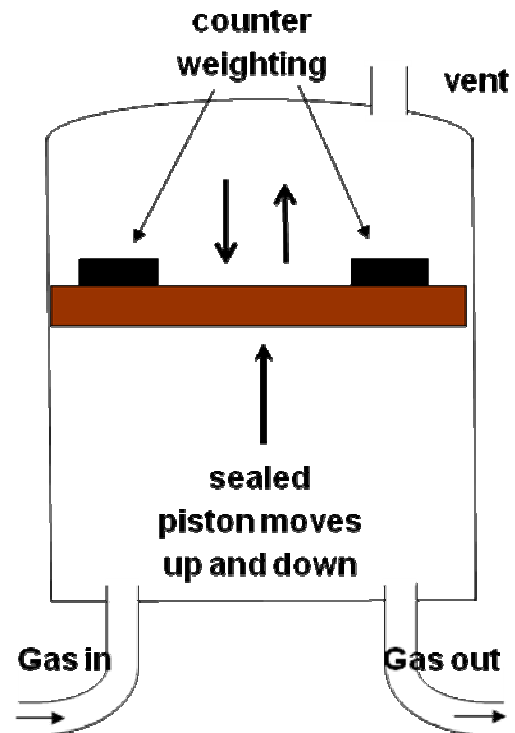


Figure 10: Variable Vapor Space Tanks

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 28 of 92
		Rev: 02
		JUNE 2012

DEFINITIONS

Above Ground Storage Tank (AST) - any one or combination of tanks, including pipes connected thereto and any ancillary equipment and containment system, that is used to contain an accumulation of liquids or gases, and the volume of which, including the volume of connected piping.

Accuracy - The ability of a measuring instrument to indicate values closely approximating the true value of the quantity measured.

Atmospheric Storage Tank – a storage tank which has been designed to operate at pressures from atmospheric through 0.5 psig

Autoignition Temperature - The temperature to which a flammable mixture of vapor and air in the explosive range must be heated for ignition to occur spontaneously without external source of ignition.

API Gravity (Relative Density) - A means used by the petroleum industry to express the density of petroleum liquids. API gravity is measured by a hydrometer instrument having a scale graduated in degrees API. The relation between API gravity and relative density (formerly called specific gravity) is:

$$\text{API Gravity at 60 Deg. F.} = \frac{141.5}{\text{Relative Density 60F/60F}} - 131.5$$

Ballast Water - Oil contaminated water contained in the cargo compartments of marine vessels. Ballast water is taken aboard empty or near empty vessels to provide a safe level of stability for the vessel. Tankers arriving at a shipping dock to take on product, discharge ballast water into a shore side storage tanks for subsequent wastewater treatment. This operation is known as de-ballasting.

Barrel (BBL) - A unit of volume equal to 42 U.S. gallons or 9702.0 cubic inches.

Blocked Operation - The use of a single process unit alternately in more than one operation to manufacture various grades of product. Lube oils and certain chemicals such as linear paraffins are often made in blocked operation.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 29 of 92
		Rev: 02
		JUNE 2012

Breathing Loss - Loss associated with thermal expansion and contraction of the vapor space, resulting from the daily temperature cycle or any such temperature cycle that can be induced by weather conditions such as rainstorms.

BS&W (Bottom sediment and water) - The sludge and water which settles to the bottom of storage tanks, as measured by standard test method and expressed in volume percent.

Calibration Tables (Gauge Or Tank Tables, Innage/ Ullage Tables) - Tables developed by recognized industry methods that represent volumes in each tank according to the liquid (innage) or empty space (ullage) measured in the tank. The tables are entered with linear measurements (for example, feet, inches, meters, centimeters) to obtain calibrated volumes (for example, barrels, cubic meters or cubic feet).

Closed Gauging System - A method of obtaining measurements of the tank contents without opening the tank. This may be accomplished by using automatic tank gauges or by taking measurements through a pressure/vapor lock standpipe. This type of gauging is done extensively on vessels with inert gas systems.

Closed System Gauging Unit - Closed gauging system measurement equipment specially designed to be used with a specific type of standpipe/vapor lock. The unit may have a single purpose such as taking temperature, ullages, watercuts or samples, or may be a combined unit capable of performing all necessary measurement functions.

Coalescer - A device used to cause the separation and removal of one liquid from another such as water from a petroleum liquid.

Cone Bottom Up - A tank bottom configuration that slopes up from the side to the center. This configuration is usually limited to locations with poor soil conditions, small diameter tanks such as in marketing terminals, and molten sulfur tanks.

Cone Bottom Down - A tank bottom configuration that slopes down from the side to the center. The apex for either cone bottom up or down is generally but not necessarily located at the center of the tank.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 30 of 92
		Rev: 02
		JUNE 2012

Critical Zone - A term used to define the liquid level in a floating roof type storage tank from the point where floating of the roof begins to the point where the roof is fully floating. Sometimes known as the “inaccurate zone” or “partially floating region.” The critical zone is identified on tank calibration tables where appropriate.

Density - The density of a homogeneous substance is the ratio of its mass to its volume. The density varies as the temperature changes and it is usually expressed as the mass per unit volume at a specified temperature.

Absolute Density – The mass of a substance per unit volume at a specified temperature.

Relative Density - The ratio of the mass of a given volume of fluid to the mass of an equal volume of pure water at the same temperature and pressure. Relative density replaces the term “specific gravity”.

Relative Density At 60° - Fluid relative density measured against water with both materials at 60 degrees F and reference pressure of 14.696 psia (or equilibrium pressure). Equivalent to “RD 60/60”.

Dike - A dike is an earthen or concrete wall providing a specified liquid retention for the enclosed vessel(s).

Dome Roof - A fixed truss roof design that is in the shape of a dome. The dome roof can be designed to carry small internal pressures of 1 to 1.5 psig (7 to 10 kPa gage). In special cases, roofs can be designed for higher pressure, but such designs are usually not economical.

Explosive Limits - These are the limits of the explosive (flammable) range, i.e., the range between the minimum and maximum concentrations of a flammable vapor in air, which form explosive mixtures. These conditions may exist in the vapor space of ordinary fixed roof tanks.

Flash Point - The lowest temperature of a petroleum liquid at which sufficient vapors are produced to form a mixture with air that will ignite in the presence of an ignition source, as measured under specified conditions in standardized test apparatus.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 31 of 92
		Rev: 02
		JUNE 2012

Floating Roof - A roof which floats on the surface of the liquid in a tank. The floating roof is used to eliminate a vapor space in atmospheric storage tanks, thereby reducing evaporation losses and providing increased safety. A floating roof may be installed in either an open roof (external floater) or a cone roof tank (internal floater).

Flush Nozzle - A rectangular tank nozzle which enters the side of the tank and has the underside flush with the tank bottom.

Frangible Roof - A frangible roof is basically a weak roof-to-shell seam which will rupture before any other part of the tank fails if over pressurized.

Gauging Equipment - Equipment that indicates the level of a liquid inside the tank relative to the tank base line.

Gauging - A process of measuring height of a liquid in a storage tank usually using a weighted graduated steel tape and bob.

Alternate Innage Gauge - The innage obtained by subtracting the measured distance between the surface of the liquid in the tank and the reference point from the official reference height of the tank.

Alternate Ullage Gauge - The ullage obtained by subtracting the measured height of the liquid in the tank from the official reference height of the tank.

Innage Gauge (Dip, Sounding) - The height of the liquid surface from the bottom of the tank (or datum plate).

Ullage (Outage) Gauge - The distance from the liquid surface to the top of the tank (or reference point).

Gross Tankage Volume - The total geometric tank volume below the shell height.

High Temperature Tanks - Tanks which are operated at temperatures above 265°F (130°C).

Low Pressure Storage Tank - a storage tank which has been designed to operate at pressures above 0.5 psig but not more than 15 psig.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 32 of 92
		Rev: 02
		JUNE 2012

Net Tank Volume - The total usable volume inside a tank. Net volume equals gross volume less the volume equivalent attributable to tank heel.

Pour Point - The lowest temperature at which oil will pour or flow when it is chilled under prescribed ASTM test conditions.

Pressure - The amount of force exerted on a unit of area by a fluid.

Absolute Pressure - The pressure referenced to a perfect vacuum as zero pounds per square inch absolute.

Atmospheric Pressure - The pressure exerted by the atmosphere. Although this pressure varies with altitude, barometric pressure and humidity, the atmospheric pressure can be defined in custody transfer contracts, or by state and federal authorities. Atmospheric pressure is most often stated as 14.696 pounds per square inch absolute.

Back Pressure - The operating pressure level measured upstream from a control valve.

Gauge Pressure - That pressure measured relative to atmospheric pressure as zero, usually designated psig.

High Vapor Pressure - A fluid which, at the measurement or proving temperature, has a vapor pressure that is equal to or higher than atmospheric pressure.

Low Vapor Pressure - A fluid which, at the measurement or proving temperature, has a vapor pressure that is less than atmospheric pressure.

Reid Vapor Pressure (RVP) - The vapor pressure of a fluid at 100 degrees Fahrenheit as determined by test method ASTM D 323-58. RVP is one of the important specifications for gasoline and solvents. It is a measure of the vapor pressure of a sample at 100°F (38°C), in the presence of air. A test is made in a bomb, and the results are reported in pounds per square inch absolute.

Static Pressure - The pressure in a fluid that is exerted normal to the surface. In a moving fluid, the static pressure is measured at right angles to the direction of flow.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 33 of 92
		Rev: 02
		JUNE 2012

Pressure Storage - A storage vessel whose design pressure is greater than 2.5 psig (17 kPa).

Pressure Vacuum Vent (P-V Vent) - A particular type of vent used on tank roofs which reduces normal breathing losses and protects the tank from external ignition sources. Unlike the open type of vent, the P-V vent is normally closed, but opens under the action of slight internal pressure or vacuum.

Pyrophoric Material - A material which forms under oxygen deficient conditions, which when exposed to air, will oxidize and slowly build up in temperature until glowing red particles can ignite flammable mixtures.

Refrigerated Storage - Any conventional storage vessel in which the contents are stored below ambient temperature.

Rundown Line - The pipeline from a process unit to a tank, through which the unit's production flows.

Sampling - The process of obtaining a sample of the material in the tank, container or pipeline to use for testing or other purposes. This can be achieved by automatic or manual means. The following are the most common types of samples taken:

All-Levels Sample - A sample obtained by lowering a weighted, stoppered bottle or beaker or bottle to a point 1 foot (0.3 meter) above the free water level and then, with a sharp jerk of the line opening the sampler and raising it at a rate that it is about 75% full (a maximum of 85% full) as it emerges from the liquid.

Automatic Sample - A sample taken by automatic means. The two basic types of automatic samples are:

Flow-Proportional Sample - A sample taken by an automatic sampler from a pipeline at a rate that is proportional to the liquid flow rate.

Time-Proportional Sample - A sample taken from a pipeline at regular intervals during a batch transfer period.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 34 of 92
		Rev: 02
		JUNE 2012

Bottom Sample - A spot sample taken from the material at the bottom of the tank.

Lower Sample - A spot sample obtained at the midpoint of the lower third of the tank contents.

Middle Sample - A spot sample obtained at the midpoint of the middle of the tank contents.

Running Sample - A sample obtained by submerging an unstoppered beaker or bottle from the surface of the liquid to a point as near as possible to the shore tank draw off point or about one foot above the level of the free water in a ship tank, and then raising it without letting it rest, at a rate so that it will be about 75% full as it emerges from the liquid.

Spot Sample - A sample taken at a specific "spot" within a tank using a stoppered bottle or beaker and lowering it to the level of desired sample then opening it and allowing it to remain at that level until full. A thief or a zone sampler may also be used to obtain spot samples.

Tap Sample - A sample taken from a valve or connection on a tank or pipeline.

Upper Sample - A spot sample obtained at the midpoint of the upper of the tank contents.

Upper, Middle, Lower Samples - Spot samples taken from the upper third, the middle and lower thirds of the liquid in the tank. The samples so taken may then be composited or analyzed separately.

Seals for Floating Roof - The mechanism that seals the space between the periphery of the floating roof and the tank shell. The primary seal separates the stored liquid from the atmosphere by sealing the gap between the floating roof and the tank shell. Secondary seals are flexible metal or rubber seals that span the gap between the tank wall and the floating roof, above the primary seal.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 35 of 92
		Rev: 02
		JUNE 2012

Sludge - The material that settles to the bottom of crude tanks and which cannot be removed by normal pumping means.

Tank Stripping Operation - The complete pumping out of a storage tank until it is empty. Temporary pumps are usually used for this operation.

Underground Storage Tank (UST) - means any one or combination of tanks, including underground pipes connected thereto and any underground ancillary equipment and containment system, that is used to contain an accumulation of regulated substances, and the volume of which, including the volume of underground pipes connected thereto, is ten percent or more beneath the surface of the ground.

Volume - The amount of space occupied by a fluid at certain conditions of temperature and pressure. Various types of VOLUMES used in marine custody transfer are defined as follows:

Gross Observed Volume (GOV) - The total volume of all petroleum liquids and sediment and water, excluding free water, at observed temperature and pressure.

Gross Standard Volume (GSV) - The total volume of all petroleum liquids and sediment and water, excluding free water, corrected by the appropriate volume correction factor (Ctl) for the observed temperature and API gravity, relative density, or density to a standard temperature such as 60°F or 15°C and also corrected by the applicable pressure correction factor (Cpl) and meter factor.

Indicated Volume - The change in meter reading that occurs during a receipt or delivery.

Net Standard Volume (NSV) - The total volume of all petroleum liquids, excluding sediment and water and free water, corrected by the appropriate volume correction factor (Ctl) for the observed temperature and API Gravity, relative density, or density to a standard temperature such as 60°F or 15°C and also corrected by the applicable pressure correction factor (Cpl) and meter factor.

On Board Quantity (OBQ) - The material remaining in vessel tanks, void spaces, and/or pipelines prior to loading. On-board quantity includes water, oil, slops, oil residue, oil/water emulsions, sludge, and sediment.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 36 of 92
		Rev: 02
		JUNE 2012

Remaining On Board (ROB) - The material remaining in vessel tanks, void spaces, and/or pipelines after discharge. Remaining on board quantity includes water, oil, slops, oil residue, oil/water emulsions, sludge, and sediment.

Total Calculated Volume (TCV) - The total volume of all petroleum liquids and sediment and water, corrected by the appropriate volume correction factor (Ctl) for the observed temperature and API gravity, relative density, or density to a standard temperature such as 60°F or 15°C and also corrected by the applicable pressure factor (Cpl) and meter factor, and all free water measured at observed temperature and pressure (gross standard volume plus free water).

Total Observed Volume (TOV) - The total measured volume of all petroleum liquids, sediment and water, and free water at observed temperature and pressure.

NOMENCLATURE

c	Corrosion factor
C _s	Shell clingage factor, bbl/1,000 ft ²
D	Tank diameter, ft
D _i	Tank inlet diameter, ft
D _o	Outlet diameter tank, ft
E	Welded joint efficiencies
f	Allowable stress, psi
g	Gravity acceleration, m/s ²
h _h	Head height, in
h _l	Liquid level in tank, ft
H _s	Tank shell height, ft
H _{vo}	Vapor space outage, ft
H _{ro}	Roof outage, ft
I	Daily total solar insolation on a horizontal surface, Btu/ft ² day
ic _r	Inside corner radius, in
K _C	Product factor
K _D	Deck seam loss per unit seam length factor, lb-mole/ft-yr
K _E	Vapor space expansion factor
K _{Fi}	Loss factor for a particular type of deck fitting, lb-mole/yr ⁱ
K _{Fai}	Zero wind speed loss factor for a particular type of fitting, lb-mole/yr
K _{Fbi}	Wind speed loss factor a particular type of fitting, lb-mole/(mph) ^m yr

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 37 of 92
		Rev: 02
		JUNE 2012

K_N	Working loss turnover factor
K_P	Working loss product factor
K_{Ra}	Zero wind speed rim seal loss factor, lb-mole/ft-yr
K_{Rb}	Wind speed, lb-mole/(mph) ⁿ ft-yr
K_S	Vented vapor saturation factor
K_v	Fitting wind speed correction factor.
L_F	Deck fitting loss, lb/yr
L_R	Rim seal loss, lb/yr
L_S	Standing storage losses, lb/yr
L_T	Total losses, lb/yr
L_W	Working losses, lb/yr
L_{WD}	Withdrawal loss, lb/yr
m	Loss factor for a particular type of deck fitting.
m_L	Liquid mass, lb
M_v	Vapor molecular weight, lb/lb-mole
N	Number of turnovers per year
n	Seal-related wind speed exponent
N_C	Number of fixed roof support columns
N_f	Typical number of fitting
ρ_L	Liquid density, lb/ft ³
P	Vapor pressure function
P_A	Atmospheric pressure, psia
P_{design}	Design pressure, psi
$P_{operasi}$	Operation tank pressure, atm
$P_{hidrostatik}$	Hidrostatik pressure, atm
P_{VA}	Vapor pressure liquid surface temperature, psia
Q	Annual net throughput, bbl/yr
R	Ideal gas constant , psia ft ³ /lb-mole °R
r	inlet spherical, in
r_c	Radius of crown, in
R_S	Tank shell radius, ft
S_D	Deck seam length factor, ft/ft ²
sf	Straight flange, in
S_R	Tank cone roof slope, ft/ft
T_{Amax}	Daily maximum ambient temperature, °R
T_{Amin}	Daily minimum ambient temperature, °R
th	Head thickness, in

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions www.klmtechgroup.com	Kolmetz Handbook Of Process Equipment Design STORAGE TANK SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Page 38 of 92
		Rev: 02
		JUNE 2012

T_L	Daily average liquid surface temperature, °R
t_t	Tank thickness, in
v	Average ambient wind speed at tank site, mph
V_L	Volume liquid, ft ³
V_T	Tank volume, ft ³
V_V	Vapor space volume, ft ³
W	Stress intensification factor for torispherical head

Greek Letters

α	Tank paint solar absorptance.
ρ	Density, lb/ft ³

Superscript

L	liquid phase
V	vapor phase

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