



# Engineering Encyclopedia

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## Saudi Aramco DeskTop Standards

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### STORAGE TANK TYPES AND FEATURES

**Note:** The source of the technical material in this volume is the Professional Engineering Development Program (PEDP) of Engineering Services.

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## INTRODUCTION

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This module provides an overview of the types of storage tanks that are used in Saudi Aramco facilities and builds upon information that was previously discussed in CSE 110.01. CSE 110.01 and this module serve as a foundation for the more detailed modules that will follow.

This module identifies the various types of storage tanks, their functions in Saudi Aramco operations, their primary components, typical storage tank operations, and storage tank design specifications. It also identifies the functions of the primary appurtenances and the operation of safety systems of storage tanks.

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## **TYPES, FUNCTIONS, COMPONENTS, OPERATIONS, AND DESIGN SPECIFICATIONS OF SAUDI ARAMCO STORAGE TANKS**

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This section discusses the standard types of storage tanks that are used in Saudi Aramco operations and their functions. It also discusses the functions of the principle storage tank operations. This section concludes with discussions of the function and components of a storage tank design specification, and the contents of a typical storage tank Contractor Design Package.

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### **Types and Functions of Storage Tanks**

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Storage tanks are used in refinery, chemical, and petrochemical, and operations to store crude oil, intermediate and refined products, gas, chemicals, and water. Such characteristics of the stored fluid as quantity, volatility, chemical characteristics, and corrosiveness combine with such considerations as the required storage pressure to determine the type, size, and construction material of a storage tank. When corrosion is expected on the inside of a tank, a corrosion allowance is typically added to the tank component thickness as part of the original design. In extreme cases, internal lining or coating systems (such as epoxy- or fiberglass-reinforced plastic) may be considered in place of a very large corrosion allowance or the use of alloy materials.

Saudi Aramco uses the following standard types of storage tanks:

- Atmospheric
- Low-pressure
- Low-temperature

These storage tank types were discussed in CSE 110.01.

Saudi Aramco currently does not have a large number of either low-pressure or low-temperature storage tanks. This module identifies the primary design considerations for low-pressure and low-temperature tanks, along with the primary areas where Saudi Aramco requirements differ from the requirements of the relevant industry standard. The course will not discuss these two tank types after this module, and will concentrate only on atmospheric storage tanks.

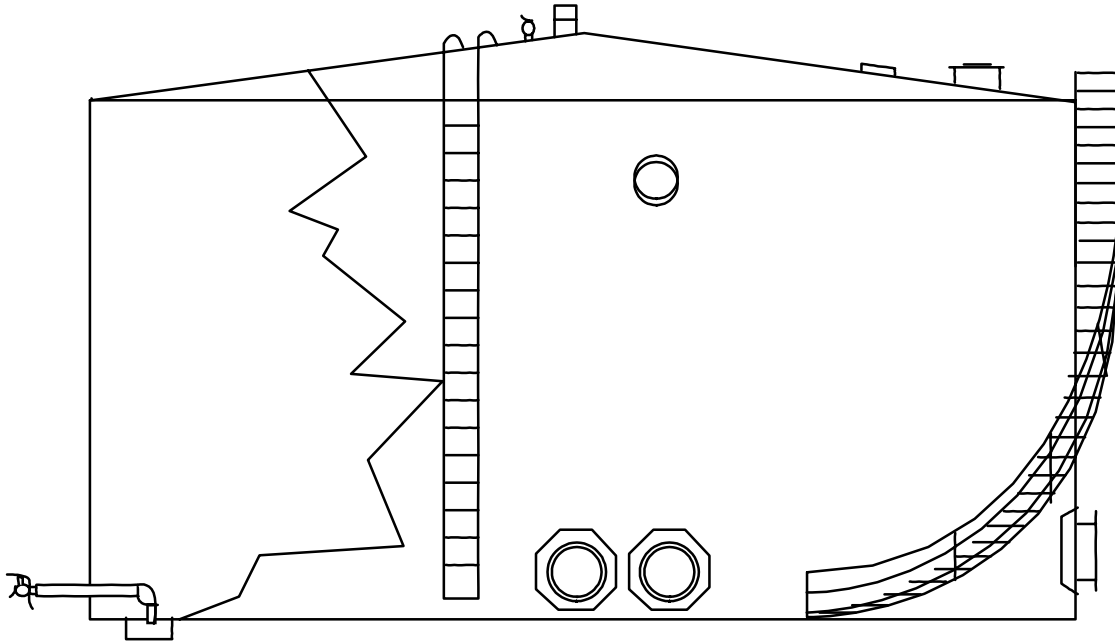
## Atmospheric Storage Tanks

Atmospheric storage tanks are designed to store liquids such as crude oil, gasoline, and other products, and water. Atmospheric storage tanks operate with the internal pressure of their vapor space at approximately atmospheric pressure (an internal pressure that is less than the weight of the roof). These tanks are typically of all-welded carbon steel construction; however, tanks that constructed before reliable welding equipment and practices were available used bolted or riveted construction. This course discusses only welded steel storage tanks, although most of the topics apply to any type of construction.

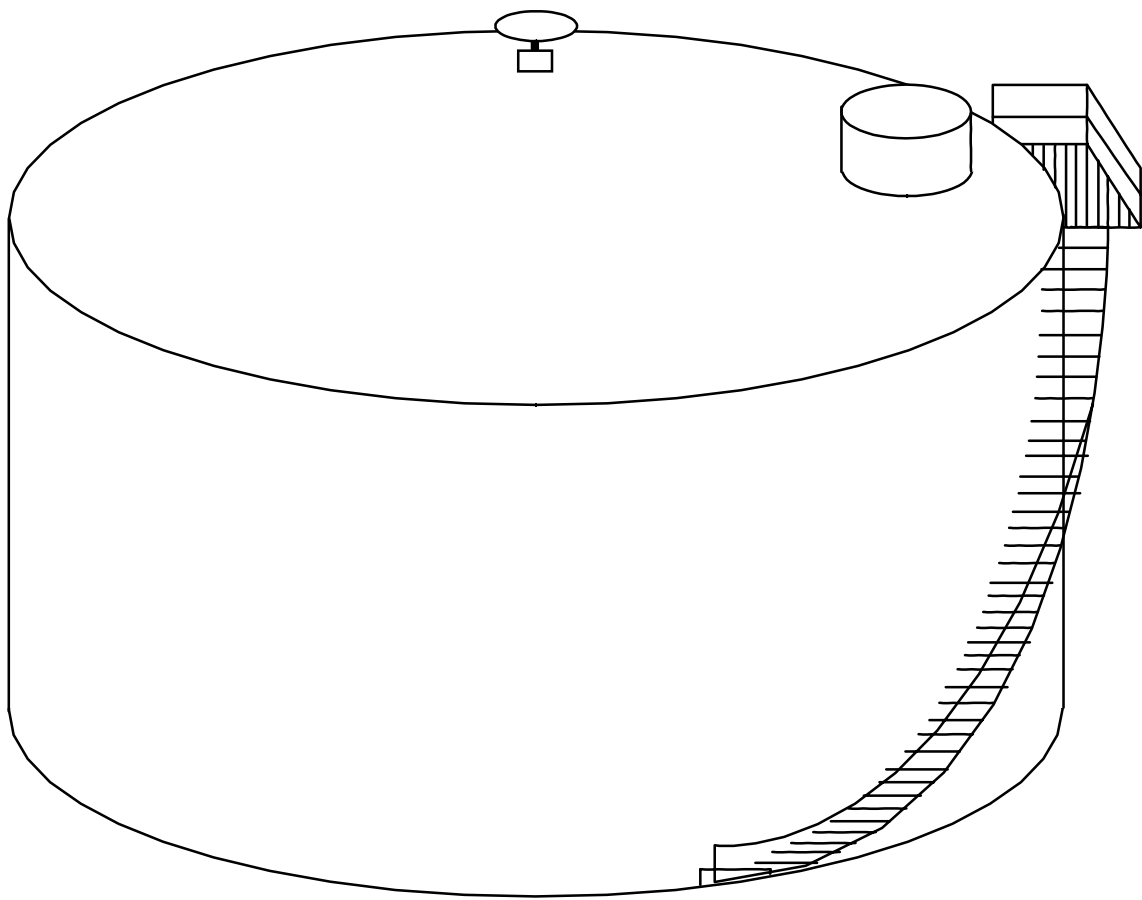
Atmospheric storage tanks are usually classified by the type of roof that is installed. The major types of atmospheric storage tanks are as follows:

- Fixed roof
- Floating roof
- Fixed roof with internal floating roof

**Fixed Roof Tanks** are the simplest type of atmospheric storage tank. The roof is usually in the form of a cone or dome. Figures 1 and 2 provide examples of cone roof and dome roof tanks. Cone roof tanks can be up to 90 m (300 ft.) in diameter and 20 m (64 ft.) in height. In larger diameter tanks, internal structural members that consist of girders, rafters, and columns must be used to support the roof. The fixed roofs of smaller diameter tanks may be designed to be self-supporting.

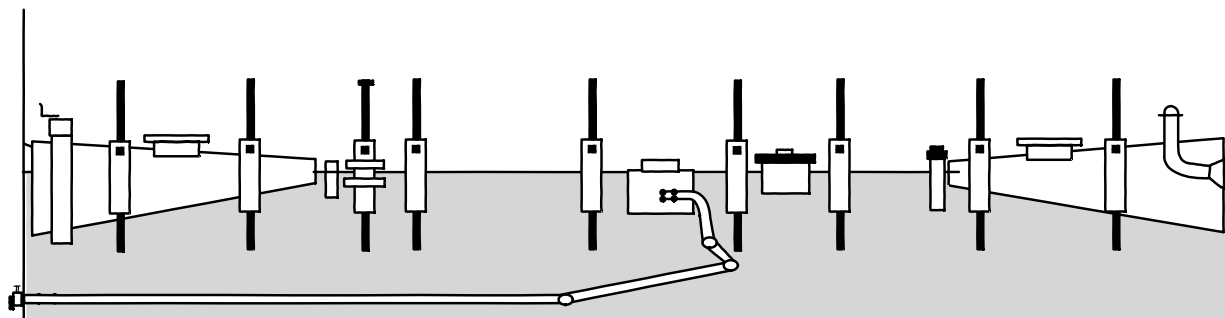


**Figure 1. Cone Roof Tank**

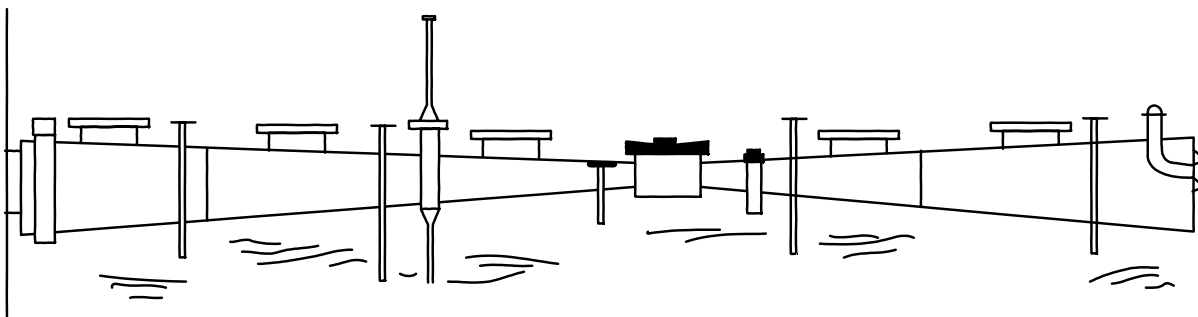


**Figure 2. Dome Roof Tank**

**Floating Roof Tanks** are another common type of atmospheric storage tank. The design of floating roof storage tanks minimizes breathing losses of hydrocarbon vapor when the tank is filled and emptied. The floating roof eliminates a vapor space above the stored liquid or maintains a small and constant vapor space. The shell and bottom of floating roof tanks are similar to cone roof storage tanks, but the roof is designed to float on the stored liquid. The most common type of floating roof is the annular-pontoon-type. The double-deck-type floating roof is used for very large diameter tanks in order to increase roof stability. Figures 3 and 4 provide cross-sectional illustrations of floating roof storage tanks.



**Figure 3. Annular-Pontoon-Type Floating Roof Tank**

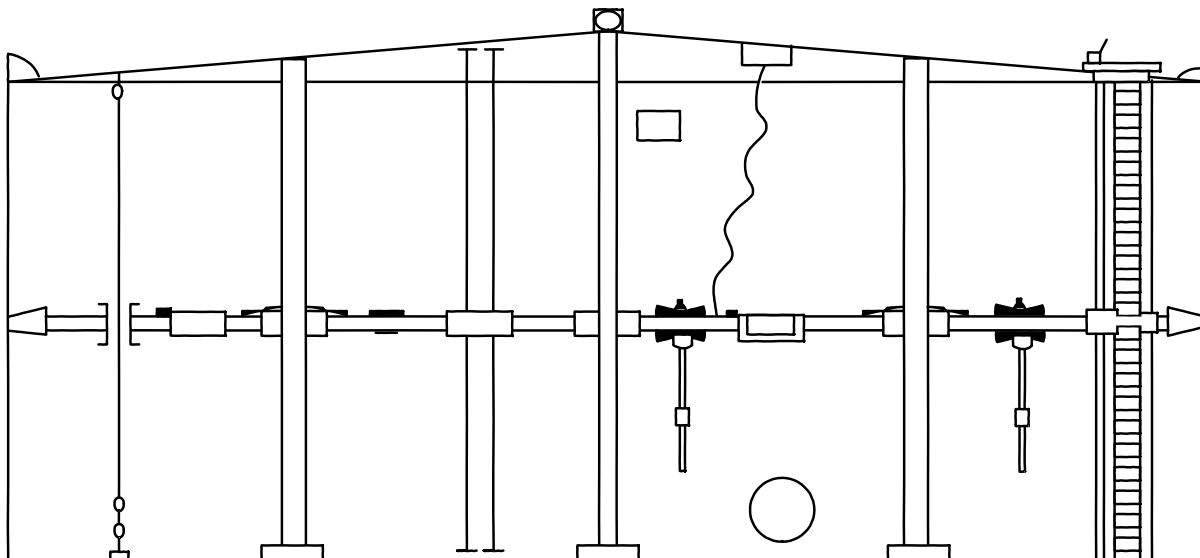


**Figure 4. Double-Deck-Type Floating Roof Tank**

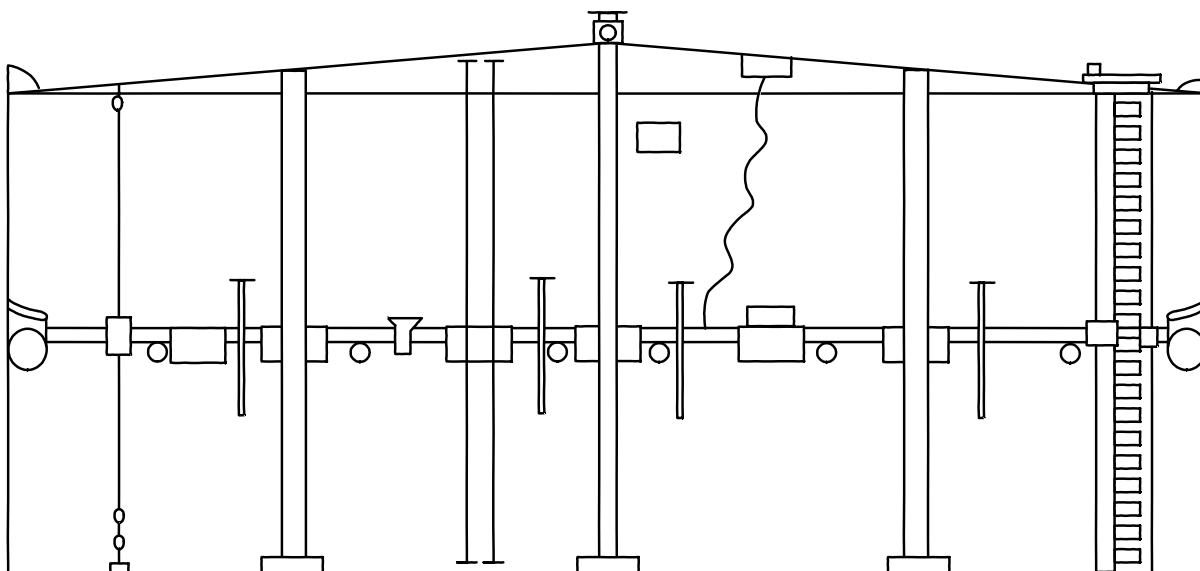
**Fixed Roof with Internal Floating Roof Tanks** usually consist of a cone roof storage tank with a pan-type, panel-type, or pontoon-type floating roof located inside. The floating roof in this case is called an internal floating roof. The internal floating roof may be constructed of materials other than steel, such as aluminum or plastic. Figures 5 and 6 provide cross-sectional illustrations of tanks with internal floating roofs. The primary types of internal floating roofs are as follows:

- Metallic Pan roof (in contact with the liquid and with a peripheral seal).
- Metallic bulkhead roof (in contact with the liquid and with open-top bulkheads).
- Metallic pontoon roof (in contact with the liquid and with closed pontoons).
- Metallic double-deck roof (in contact with the liquid).
- Metallic roof on floats (deck located above the liquid).
- Metallic sandwich panel roof (honeycomb panels with surface coating and in contact with the liquid).
- Plastic sandwich panel roof (rigid panels with surface coating and in contact with the liquid).

The internal floating roof types that are most commonly used in Saudi Aramco facilities are the pan type and the pontoon type.



**Figure 5. Pan-Type Internal Floating Roof Tank**



**Figure 6. Float-Type Internal Floating Roof Tank**

## Low-Pressure Storage Tanks

Low-pressure storage tanks are designed to operate with the internal pressure of their vapor space over the limits of atmospheric tanks but not over 103 kPa (ga; 15 psig). These tanks are of welded steel construction and are normally fabricated from carbon steel; however, stainless steel and nickel alloys may be required for very low temperature applications.

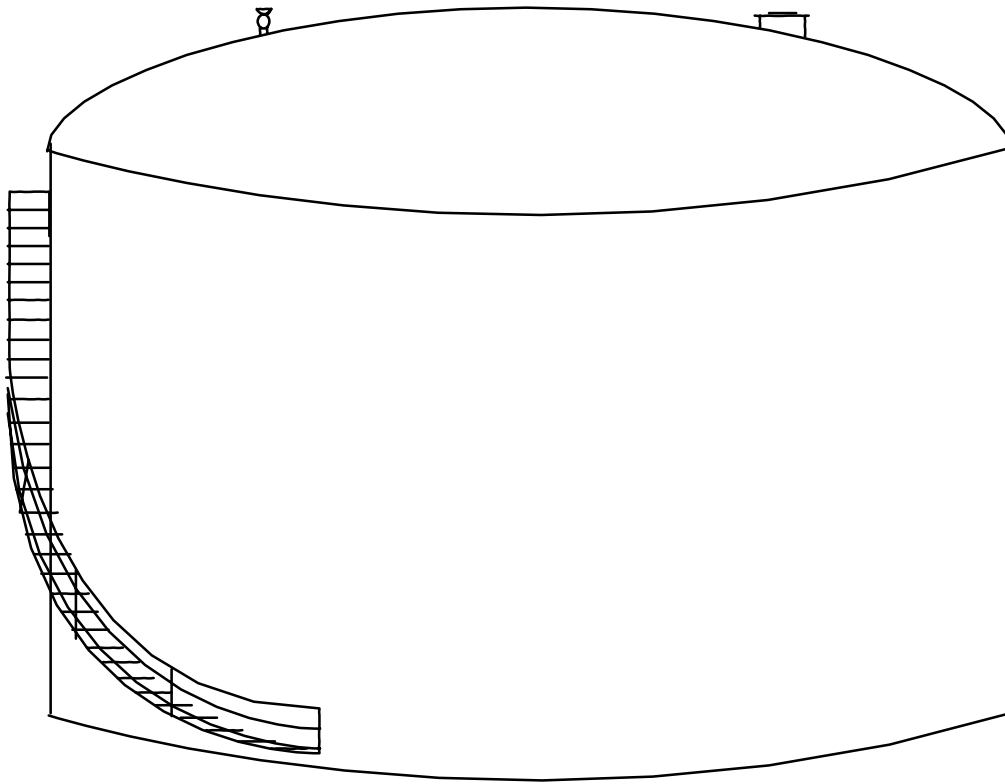
Low-pressure storage tanks are typically used to store substances that have true vapor pressures over 17 kPa (ga; 2.5 psig) but not over 103 kPa (ga; 15 psig). Low-pressure storage tanks store substances such as the following:

- Light crude oils
- Light naphtha's
- Pentane
- Some gasoline blending stocks
- Some volatile chemicals

Low-pressure storage tanks are usually classified by their shape. The major types of low-pressure tanks are as follows:

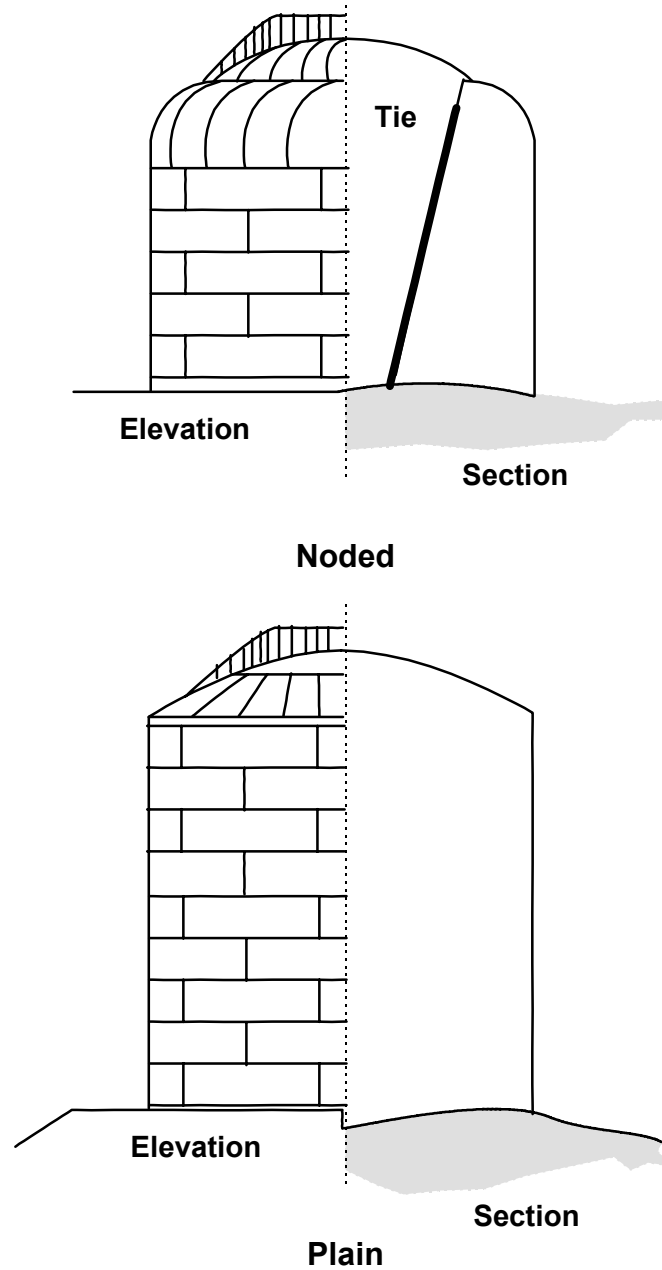
- Cylindrical shell
- Hemispheroidal
- Spheroidal
- Noded spheroidal

Tanks with cylindrical shells and cone roofs or, more commonly, dome roofs are typically used for pressures of 34 kPa (ga; 5 psig) and less. The cylindrical-shell low-pressure storage tank is the most common type of low-pressure tank. The bottoms of the tanks are usually flat but may be shaped like the roofs. Hold-down anchorage is usually required to prevent the internal pressure from lifting the tank off its foundation. Figure 7 illustrates a cylindrical shell low-pressure storage tank.

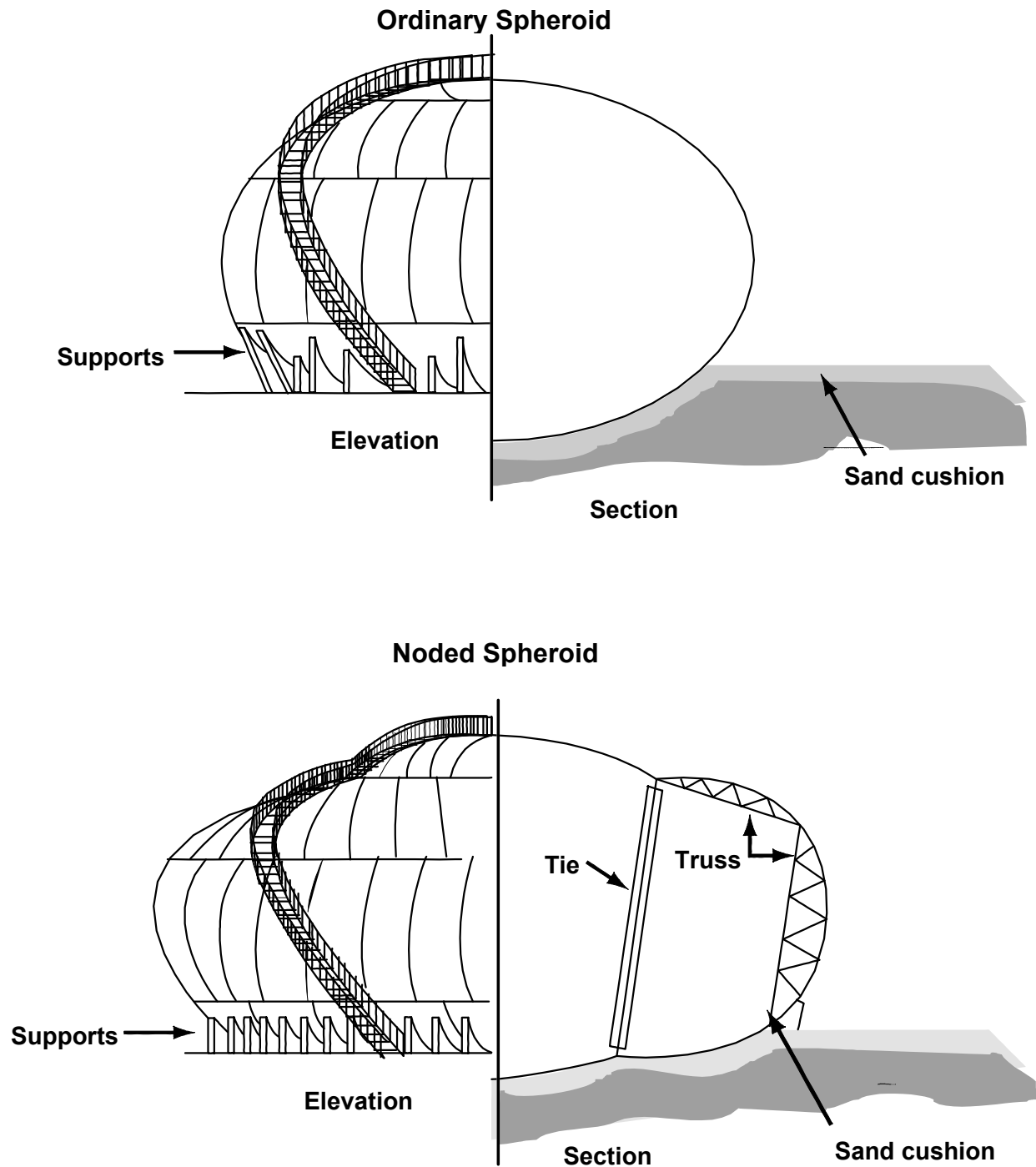


**Figure 7. Cylindrical Shell Low-Pressure Tank**

Hemispheroidal, spheroidal, and noded spheroidal type tanks are typically used for pressures that are greater than 34 kPa (ga; 5 psig). Figure 8 illustrates Hemispheroidal tanks, and Figure 9 illustrates spheroidal tanks. Spheroidal tanks are essentially flattened spheres. Noded spheroidal tanks are designed with internal ties and supports to reduce the stresses in the shell. These noded spheroidal tanks are typically used when larger tank sizes are required.



**Figure 8. Hemispheroidal Low-Pressure Tanks**



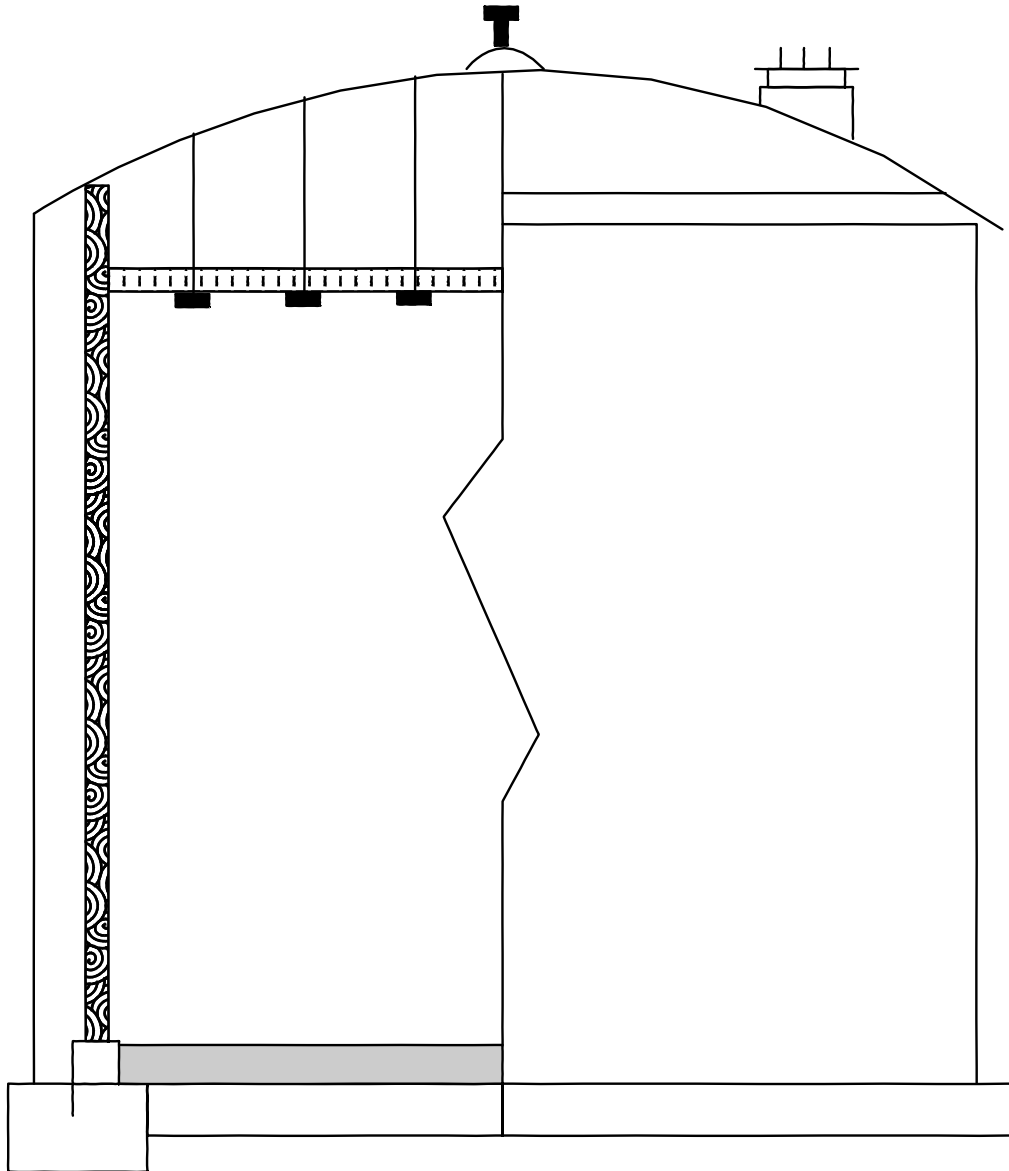
**Figure 9. Spheroidal Low-Pressure Tanks**

## Low-Temperature Storage Tanks

Low-temperature storage tanks are designed to operate at temperatures below the ambient temperature and with the internal pressure of their vapor space not exceeding 103 kPa (ga; 15 psig). These tanks are of welded steel construction.

Low-temperature storage tanks are used when economic studies show that these tanks give a higher economic return than can be obtained with pressurized storage, typically for large-volume applications. Low-temperature storage tanks are used for refrigerated product storage or for liquefied hydrocarbon gases, such as ethane, ethylene, or methane.

Refrigerated tanks are either single-wall insulated tanks or double-wall insulated tanks. A double-wall tank consists of an inner tank that stores the refrigerated liquid and an outer tank that encloses an insulation space around the inner tank. A double-wall tank is a composite tank; the outer tank is not required to contain the product that is enclosed by the inner tank. In a double-wall tank, differences in materials, design, and testing apply to the inner and outer tank because of their different functions. Figure 10 illustrates a cross-section of a typical double-wall tank.



**Figure 10. Double-Wall, Low-Temperature Storage Tank**

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## Components of Storage Tanks

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The primary components of storage tank systems are as follows:

- Foundation
- Shell, Bottom ,and Roof

### Foundation

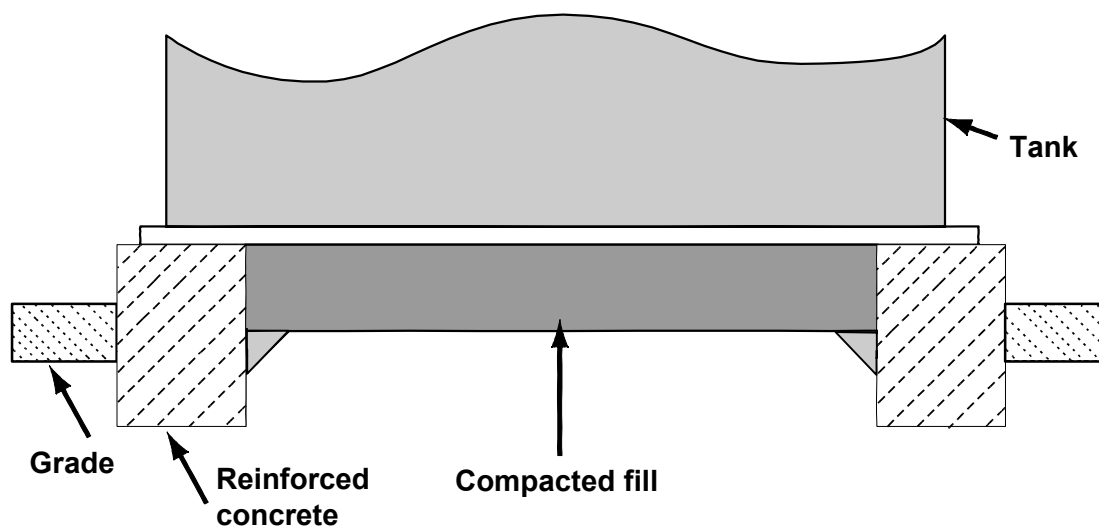
The foundation under the storage tank supports the tank and its contents and elevates the tank structure itself above the surrounding pit grade. The foundation must provide the required support under all design load conditions. Depending on the application, foundations may be composed of compacted earth or sand, crushed stone, concrete, or combinations of these materials. Most Saudi Aramco storage tanks use a concrete ringwall type of construction. Typical Saudi Aramco tank foundation design details are provided on Standard Drawing no. AB - 036050. A copy of this drawing is contained in Course Handout 3. Detailed foundation design is the responsibility of the civil engineers.

A concrete ringwall foundation is used for a large capacity storage tank that imposes large weight loads on the foundation under the shell. A concrete ringwall foundation consists of a ring of concrete that encloses an area of compacted fill material (earth, sand). This foundation is illustrated in Figure 11. The ringwall provides a better distribution of the concentrated load from the shell and produces more uniform soil loading under the tank than does a foundation that does not use a ringwall. A uniform soil loading minimizes local tank settlement and the resulting shell distortions.

Ringwall foundations have the following additional advantages over foundations without ringwalls:

- Ringwall foundations provide a level plane to start shell construction.
- They provide a better means to level the tank grade and preserve its contour during construction.
- They retain the fill under the tank bottom and prevent material loss due to erosion.
- They help minimize moisture under the tank.

Earth foundations without a ringwall would typically only be used for relatively small capacity tanks that are constructed on stable soil sub-surfaces; however, the performance of this foundation type must be the same as for the ringwall type foundation.



**Figure 11. Concrete Ringwall Construction**

### **Shell, Bottom, and Roof**

The shell, bottom, and roof form a closed container that holds the liquid inside the tank and prevents anything from entering the tank from the outside. Types of shell and roofs were previously discussed. The storage tank bottom is continuously supported by the foundation.

## Operations Performed on Storage Tanks

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Storage tanks are periodically filled and emptied. The actual liquid level that is maintained in a storage tank and how frequently the liquid level is changed are functions of the particular storage tank operation. A tank is generally not completely emptied unless it is being taken out of service for inspection or maintenance. Tanks are also often operated at liquid levels that are somewhat less than their maximum limit. The inside of a storage tank must be periodically cleaned to maintain the maximum available storage volume and to reduce the buildup of potentially corrosive deposits on the bottom. Cleaning is also required before internal inspection and repair in order to make all tank surfaces readily visible. Mechanical or chemical methods, or a combination of both, may be used to clean the inside of the tank. Mechanical cleaning methods include all forms of mixing, agitation, and manual processes. Chemical cleaning methods include the use of solvents and chemical dispersants, demulsifiers, and dilutents.

A storage tank must be periodically inspected, and necessary repairs must be made to maintain the tank as a safe and reliable storage device. It may also be necessary to make the modifications to the tank because of changed geometrical requirements. MEX 203.08 discusses storage tank maintenance requirements in detail.

## Storage Tank Design Specifications

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Saudi Aramco employs a prime contractor to provide engineering, procurement, and construction services for major capital projects. In the case of storage tanks, the contractor's responsibilities include specifying the required design basis. The tank design basis includes the tank capacity, service, design code, materials, design conditions, external loads, appurtenances, and connections that are needed for a particular storage tank application. Storage tank design specifications are used to specify these requirements. The specifications consist of engineering standards and a storage tank design specification sheet.

## Standards and Specifications

The prime contractor acts on behalf of Saudi Aramco and purchases storage tanks from a tank manufacturer. The engineering, design and erection details of a storage tank are prepared by the tank manufacturer and are based on the design specification information that was provided.

The term *Contractor Design Package*, as used in this course, refers to all the detailed design information that has been specified for the storage tank by both the tank manufacturer and the prime engineering contractor. The job of a Saudi Aramco engineer will normally be to review the information that is contained in the Contractor Design Package for acceptability based on Saudi Aramco requirements.

The Saudi Aramco Engineering Standards (SAESs) and Saudi Aramco Materials System Specifications (SAMSSs) are the primary documents that define Saudi Aramco's engineering requirements.

The SAESs specify the engineering requirements that apply to a broad equipment category or system, such as storage tanks. The SAESs are used by the prime engineering contractor that is employed by Saudi Aramco for a particular project. The prime engineering contractor extracts the SAES requirements that are relevant for a particular equipment purchase. These relevant SAES requirements are then included in the technical design specification that is sent to the equipment manufacturer or supplier. The prime contractor must ensure that the manufacturer receives all relevant SAES requirements and that the manufacturer does not have to read the entire SAES to find only the items that apply to his scope of supply. An SAES is typically not included in its entirety in a design specification.

The SAMSSs specify detailed engineering requirements that apply to a particular equipment type or component. The relevant SAMSSs are included in their entirety in a technical design specification that is sent to a manufacturer. The manufacturer must ensure that all the requirements that are contained in the included SAMSS are met.

Both the SAESs and SAMSSs supplement applicable industry standards with additional engineering requirements that Saudi Aramco wants to employ. The SAESs and SAMSSs will typically reference relevant industry standards, and thus make them mandatory requirements for Saudi Aramco purposes. Then the SAESs and SAMSSs add additional Saudi Aramco requirements. Use of the SAESs and SAMSSs as described above applies for all Saudi Aramco equipment purchases, not just for storage tanks. The primary industry standards that apply to new storage tanks are API-650, *Welded Steel Tanks for Oil Storage*, and API-620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*.

The following paragraphs briefly summarize the scopes of the primary SAESs and SAMSSs that are related to storage tanks and the areas where these Saudi Aramco documents supplement the API standards. More detailed discussions of specific Saudi Aramco requirements are contained in later modules.

**SAES-D-100** - Saudi Aramco Engineering Standard SAES-D-100, *Atmospheric and Low-Pressure Tanks*, contains requirements for the selection, design, and installation of atmospheric and low-pressure, above ground, welded steel, flat-bottom tanks for the storage of crude oil, petroleum products, water, and other liquids at internal operating pressures not exceeding 103 kPa (ga; 15 psig) and design temperatures between -168°C (-270°F) and 260°C (500°F).

A copy of SAES-D-100 is in Course Handout 2. Based on the scope described above, SAES-D-100 contains engineering requirements that are applicable to both API-650 and API-620 storage tanks. Thus, for example, if an API-650 tank is being purchased, the prime contractor must extract the API-650 related items from SAES-D-100 and include these requirements in the tank design specification. SAES-D-100 contains supplementary requirements in the following primary areas:

- Materials
- Design
- Tank Connections and Appurtenances
- Fabrication
- Installation
- Testing and Inspection

**32-SAMSS-005 and API-650** - Saudi Aramco Materials System Specification 32-SAMSS-005, *Atmospheric Steel Tanks*, covers the design, fabrication, and erection of welded atmospheric steel tanks. A copy of 32-SAMSS-005 is included in Course Handout 2. API-650 is the applicable industry standard that is used for the purchase of atmospheric storage tanks. A copy of API-650 is included in Course Handout 1.

32-SAMSS-005 will be included in the design specification of all atmospheric storage tanks, and it supplements API-650 requirements in the following primary areas:

- Materials
- Design
- Fabrication
- Erection
- External floating roofs
- Seismic design

API-650 covers the material selection, design, fabrication, erection, and testing requirements for vertical, cylindrical, above ground, closed- and open-top, welded steel storage tanks for internal pressures that are approximately equal to atmospheric pressure. If the supplemental requirements that are contained in Appendix F of API-650 are applied, storage tanks may be designed for internal pressures up to 17 kPa (ga; 2.5 psig). The entire tank bottom must be uniformly supported. API-650 tanks must be in nonrefrigerated service and they will typically have a maximum operating temperature of 93°C (200°F). A maximum operating temperature of 260°C (500°F) is permitted when the additional requirements contained in Appendix M of API-650 are followed.

**32-SAMSS-006 and API-620** - Saudi Aramco Materials System Specification 32-SAMSS-006, *Large, Welded Low-Pressure Tanks*, covers the design, fabrication and erection of large, welded steel, low-pressure tanks. A copy of 32-SAMSS-006 is included in Course Handout 2. API-620 is the applicable industry standard that is used for the purchase of all low-pressure storage tanks over 17 kPa (ga; 2.5 psig). API-620 is also used for the purchase of all low-temperature storage tanks.

32-SAMSS-006 will be included in the design specification of all low-pressure storage tanks. 32-SAMSS-006 supplements API-620 requirements in the following primary areas:

- Materials
- Design
- Fabrication
- Inspection and Testing

API-620 covers the design and construction of large, welded, low-pressure carbon steel above ground storage tanks that have a single vertical axis of revolution. The maximum permitted internal pressure in the vapor space is 103 kPa (ga; 15 psig), and the maximum permitted temperature is 120°C (250°F). The basic API-620 rules permit design to a lowest one-day mean atmospheric temperature of -46°C (-50°F). This temperature corresponds to a minimum acceptable design metal temperature of -37°C (-35°F); however, Appendix R covers tanks that are used for refrigerated product services with a minimum design metal temperature between +4°C to -50°C (+40°F to -60°F). API-620, Appendix Q, covers tanks that are used to store liquefied hydrocarbon gases that have a design metal temperature as low as -168°C (270°F).

The primary additional design considerations for API-620 tanks, when compared to API-650 tanks, relate to the specified design pressure and minimum design temperature. CSE 110.01 pointed out that the minimum required shell thickness of an API-650 tank does not consider internal pressure. An API-620 tank may be used at a higher internal pressure than an API-650 tank. Therefore, the minimum used at a higher internal pressure than an API-650 tank. Therefore, the minimum required thickness of the shell and roof of an API-620 tank must account for the higher specified design pressure. The shell and roof for an API-620 tank will typically be thicker than for an API-650 tank if all other design parameters are identical. An API-620 tank may be used at a much lower temperature than an API-650 tank. COE 105 explained that material selection is low-temperature services must consider the potential for brittle fracture. Therefore, the material selection for API-620 tanks that are in low-temperature applications must consider brittle fracture.

32-SAMSS-006 supplements API-620 requirements in the primary areas previously listed. Several of these additional requirements are as follows:

- The portion of the tank bottom that is located directly under the shell is specified to be of the same material as the lower shell course. This requirement reduces the likelihood that a brittle fracture will occur at this critical location.
- Minimum corrosion allowances are specified on the basis of tank material. The corrosion allowance accounts for shell thinning and permits a longer operating life for the tank.
- More stringent fabrication tolerances and inspection details are specified in order to improve the overall quality of the tank.

Participants are referred to the copy of 32-SAMSS-006 in Course Handout 2 for additional information.

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## Storage Tank Design Specification Sheet

This section describes the various subjects that comprises the API Standard Form 650 Storage Tank Design-Data Sheet.

### Uses

Specific design requirements for each storage tank that is to be constructed for Saudi Aramco are defined by a tank design specification sheet, Standard Drawing No. 2696, Layout of Appurtenances. A copy of the current version of this sheet is contained in Course Handout 3. This sheet specifies the design details that are needed to completely define the tank that will be constructed.

## Information Categories

The general categories of information that are contained on Drawing No. 2696 are as follows:

- The title block includes the tank diameter, height, and type of roof. The title block also contains the tank identification number and service.
- The “Design and Construction Notes” contain tank capacity information and maximum filling and emptying rates.
- Other reference drawings that apply to a particular tank are referenced. These reference drawings must be given to the tank supplier to ensure that they are considered in his design.
- Additional descriptive information for the bottom, shell, and roof plates may be provided; however, this additional descriptive information is generally defined by the tank manufacturer as part of his responsibility.
- Appurtenances and accessories for the shell must be defined and located on the layout drawings as applicable. These appurtenances and accessories include items such as nozzles, manholes, cleanout doors, ladders and stairs, and wind girders. Many of these items will be identified later in this module and will be discussed more fully in later modules. Standard Saudi Aramco design drawings are referenced for several of these items.
- Appurtenances and accessories for the roof must be defined, and they must be located on the layout drawings as applicable. These appurtenances and accessories include items such as nozzles, manholes, gauge hatch and well, liquid level indicator, and vents. Standard Saudi Aramco design drawings are referenced for several of these items.

Drawing 2696 may be used to completely specify the design requirements for a new storage tank; however, Drawing 2696 does not explicitly contain several categories of information that the tank manufacturer needs to completely define the tank requirements. Additional design requirements such as corrosion allowance, roof design loads, wind or earthquake requirements, or foundation type must be added as supplementary notes.

The use of an additional tank data sheet may be considered as an alternative to the addition of supplementary notes to Drawing 2696. An example of such a tank data sheet is contained in Appendix L of API-650. Figure 12 contains an excerpt from this API-650 data sheet. Refer to the copy of API-650 that is in Course Handout 1 to review the complete contents of this data sheet.

A completed Drawing No. 2696, a supplementary tank data sheet (if needed), the applicable SAMSS (32-SAMSS-005) or 32-SAMSS-006), and applicable requirements from SAES-D-100 form the core technical documents of a storage tank design specification. These core technical documents reference other Saudi Aramco and industry technical standards that are also included, as applicable, for particular applications.

|                                                                |                                                                                                    |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| <p><b>API STANDARD 650<br/>STORAGE TANK<br/>DATA SHEET</b></p> | <p>DATE _____</p> <p>BY _____</p> <p>FILE NO. _____</p> <p>PAGE _____ 1 _____ OF _____ 3 _____</p> |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------|

| GENERAL INFORMATION (TO BE COMPLETED BY PURCHASER)                                                                                   |                                                                       |
|--------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| 1. PURCHASER/AGENT _____                                                                                                             |                                                                       |
| ADDRESS _____                                                                                                                        |                                                                       |
| CITY _____                                                                                                                           | STATE _____ ZIP CODE _____ PHONE _____                                |
| 2. USER _____                                                                                                                        |                                                                       |
| 3. ERECTION SITE                                                                                                                     | NAME OF PLANT _____                                                   |
|                                                                                                                                      | LOCATION _____                                                        |
| 4. TANK NO.                                                                                                                          | NORMAL CAPACITY _____ BARRELS      NET WORKING CAPACITY _____ BARRELS |
| 5. PUMPING RATES:                                                                                                                    | IN _____ BARRELS/HOUR      OUT _____ BARRELS/HOUR                     |
| 6. MAXIMUM OPERATING TEMPERATURE _____ °F                                                                                            |                                                                       |
| 7. PRODUCT STORED _____                                                                                                              | DESIGN SPECIFIC GRAVITY ____ AT _____ °F                              |
| DESIGN METAL TEMPERATURE _____ °F                                                                                                    | VAPOR PRESSURE _____ INCHES WATER                                     |
| 8. CORROSION ALLOWANCE:                                                                                                              | SHELL _____ INCHES      ROOF _____ INCHES                             |
|                                                                                                                                      | BOTTOM _____ INCHES      STRUCTURALS _____ INCHES                     |
| 9. SHELL DESIGN: <input type="checkbox"/> BASIC STANDARD 650 <input type="checkbox"/> APPENDIX A <input type="checkbox"/> APPENDIX F |                                                                       |
|                                                                                                                                      | DESIGN PRESSURE _____ POUNDS/SQUARE INCH                              |

**Figure 12. API Standard 650 Storage Tank Data Sheet (Excerpt)**

## Contractor Design Package

In most situations, the Saudi Aramco engineer will not take the lead role in the initial specification and mechanical design of a new storage tank. These lead roles are taken by the prime contractor that Saudi Aramco has employed for the particular project and by the specific tank contractor who will supply the tank. A Saudi Aramco engineer typically will not do this specification and design work himself. Instead, he normally reviews the work that is done by the prime contractor and tank contractor and determines the acceptability of this work with respect to Saudi Aramco and industry requirements. The term *Contractor Design Package*, as used in this course, describes the total of *all* the detailed design information for the tank that is prepared by *both* the prime contractor and the tank contractor. The Saudi Aramco engineer uses the information that is contained in a Contractor Design Package to review the contractors' work.

A complete Contractor Design Package will contain the following items:

- A completed Drawing 2696. Drawing 2696 would be supplied by Saudi Aramco or a Saudi Aramco prime contractor. The contents of this form were previously discussed. Refer to the copy of this form that is contained in Course Handout 3.
- A completed storage tank data sheet. This data sheet also would be supplied by Saudi Aramco or a Saudi Aramco prime contractor, unless all the needed tank design information has been included on Drawing 2696. The typical contents of a tank data sheet were previously discussed. Refer to a typical tank data sheet in Appendix L of API-650 that is contained in Course Handout 1.
- Tank design calculations. The tank design calculations will be prepared by the tank contractor and will be discussed in MEX 203.03.

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Storage Tank Types and Features

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- Detailed fabrication drawings and welding requirements for all the tank components, such as the shell, roof, bottom, nozzles, wind girder, or frangible joint. These fabrication drawings and welding requirements will be prepared by the tank contractor. Fabrication requirements will be discussed in MEX 203.04.
- Tank inspection plan. The tank inspection plan will be prepared by the tank contractor. Inspection requirements will be discussed in MEX 203.05.
- Tank hydrotest procedure, in the form of a drawing or a written stepwise procedure. The tank hydrotest procedure will be prepared by the tank contractor. Hydrotest requirements will be discussed in MEX 203.05.
- Vent and fire-protection system requirements. These requirements are typically specified by the prime contractor, and the tank contractor will provide the final details. Vent and fire-protection system requirements will be highlighted later in this module and will be discussed further in MEX 203.06.
- Safety Instruction Sheet Form 2693. Note that this form may actually be completed by either a Saudi Aramco engineer or the prime contractor, depending on the particular situation. Completion of the Safety Instruction Sheet will be discussed in MEX 203.07.

The information that Participants will use to solve Exercises and Evaluations that are contained in MEX 203.02 through MEX 203.07 is contained in Contractor Design Packages that are located in Course Handout 4.

## FUNCTIONS OF APPURTENANCES AND THE OPERATION OF SAFETY SYSTEMS OF SAUDI ARAMCO STORAGE TANKS

This section discusses the functions of storage tank appurtenances and the operation of safety systems.

### Functions of Appurtenances

Figures 13 through 16 use illustrations of the various types of storage tanks to identify appurtenances. The appurtenances that are shown and other appurtenances are discussed in the paragraphs that follow. The figures also highlight several other tank construction details in order to aid clarity.

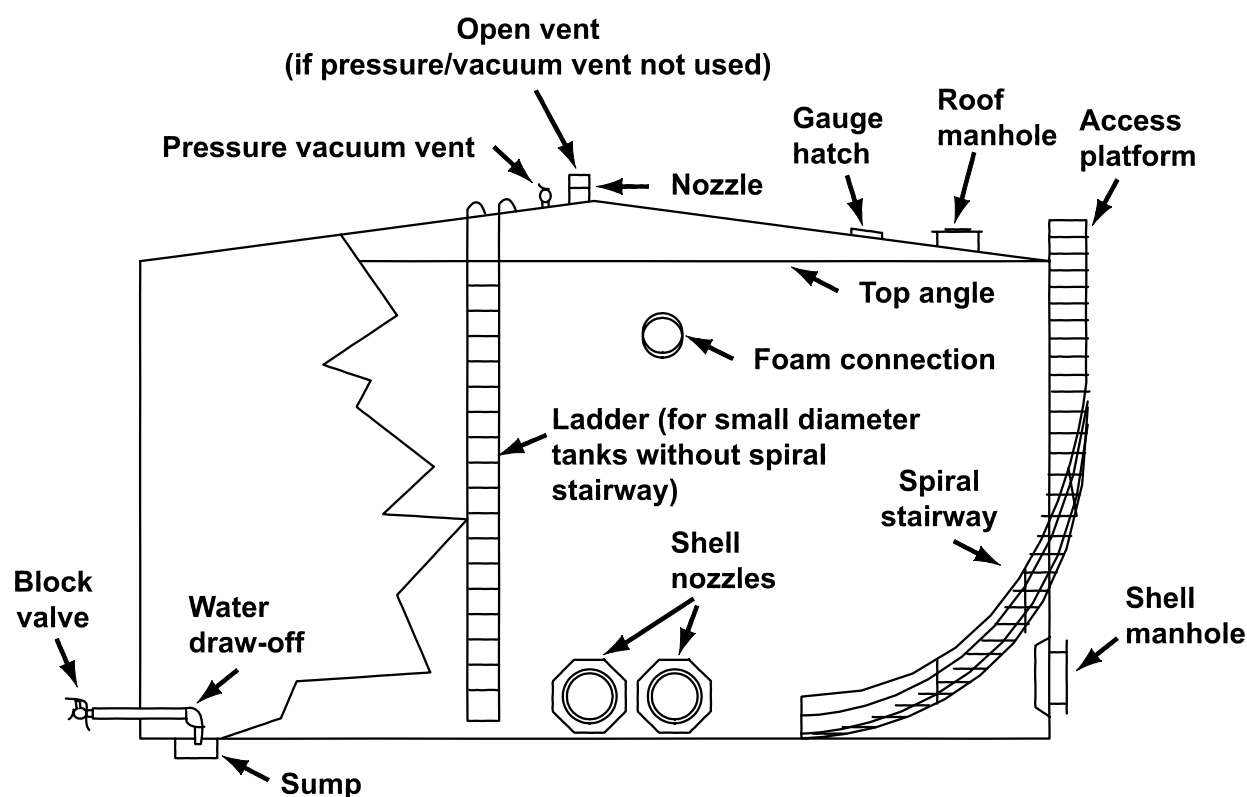


Figure 13. Appurtenances on Cone Roof Tank

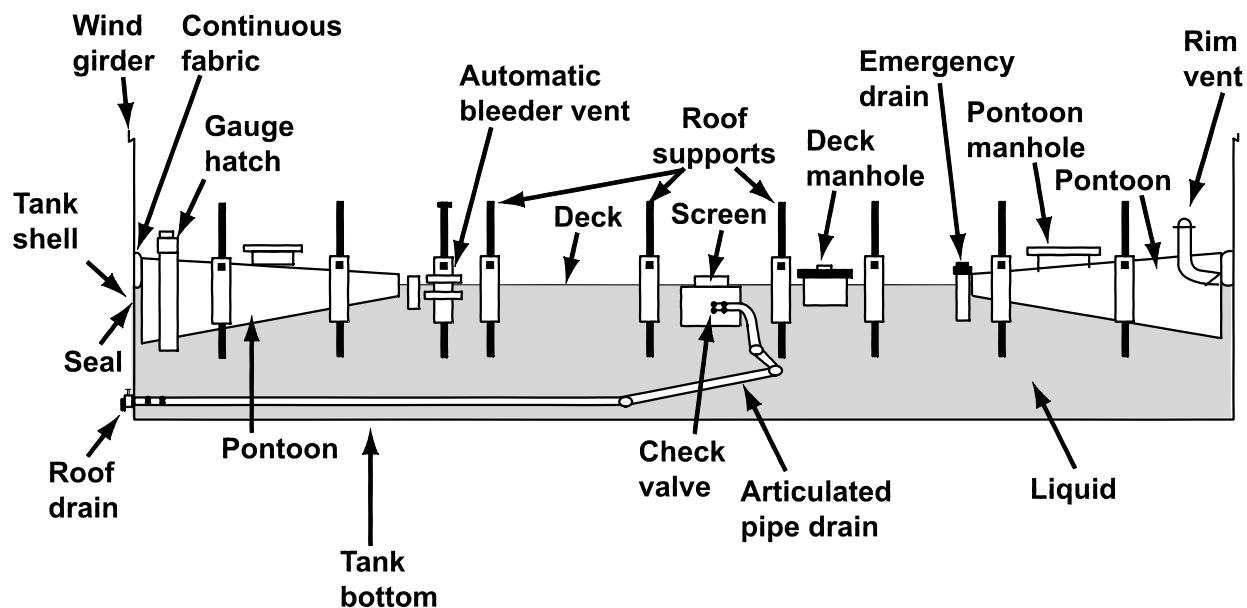


Figure 14. Appurtenances on Annular-Pontoon-Type Floating Roof Tank

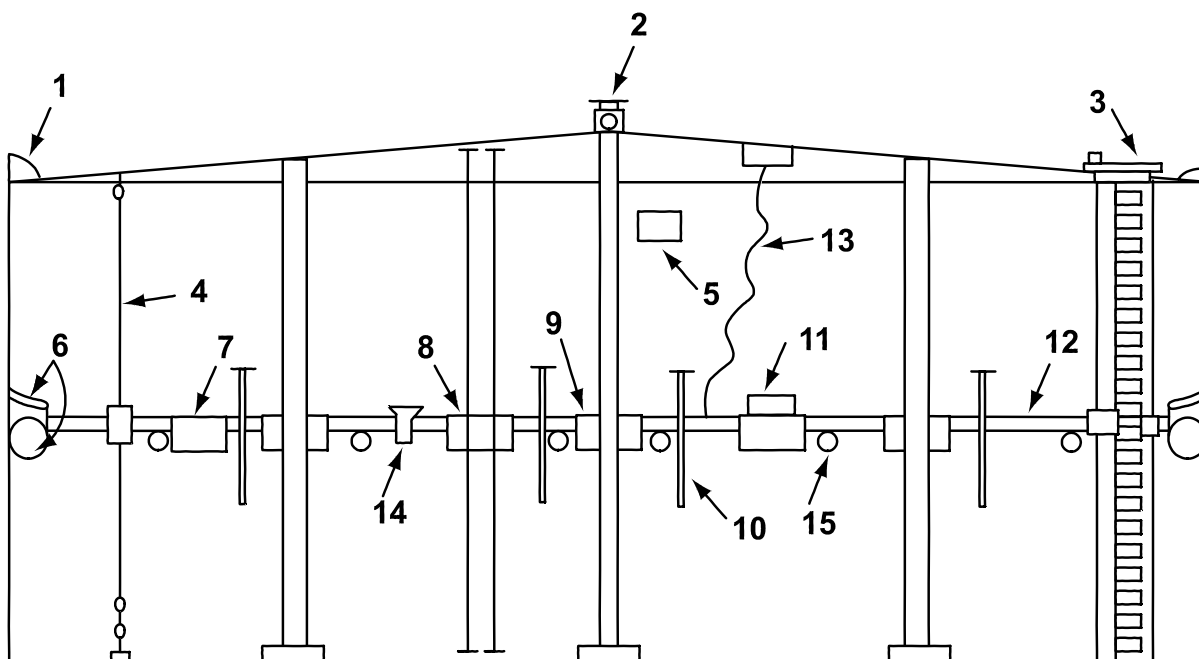
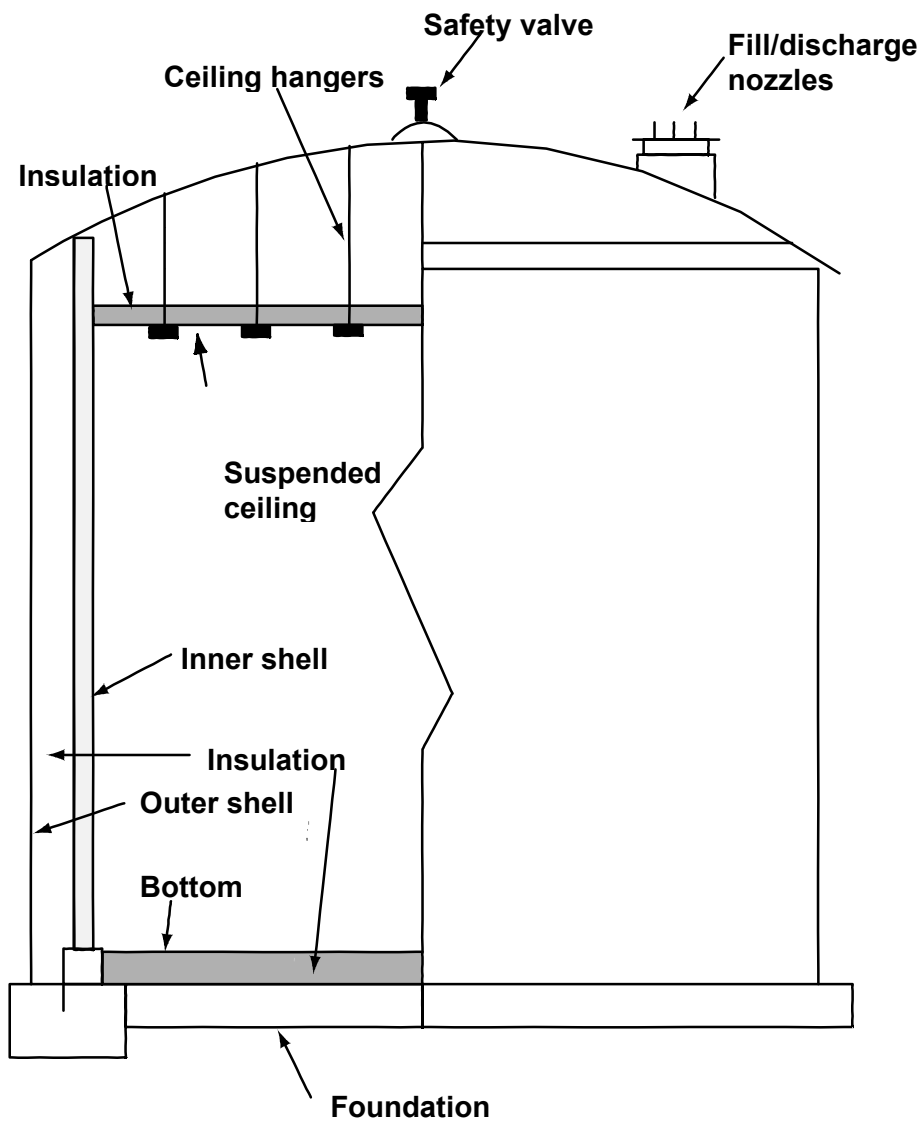


Figure 15. Appurtenances on Float-Type Internal Floating Roof Tank



**Figure 16. Appurtenances and Detail of Double-Wall, Low-Temperature Tank**

Appurtenances are auxiliary equipment items that are added to storage tanks to perform specific functions. The types and number of appurtenances that are installed on a specific tank depend on the storage tank type, size, and service. The paragraphs that follow highlight the function of the following appurtenances:

- Vents
- Drains
- Seals
- Heaters
- Mixers
- Access Hatches
- Platforms, Ladders, and Stairways
- Gauging devices

Later modules discuss some of these appurtenances in more detail.

## Vents

Vent connections on fixed roof atmospheric storage tanks prevent both an excessive positive pressure and a vacuum condition within the tank when it is filled and emptied or during fire emergency conditions. Safety valves on pressurized storage tanks ensure that the tank's internal pressure does not exceed its design capabilities. Vents on a fixed cone roof tank are shown in Figure 13. Detailed information on safety and relief valves is contained in AGE-110, *Safety, Relief and Flare Systems*.

Rim vents on floating roofs relieve excessive vapor pressure that can build up under the floating roof seal. Automatic bleeder vents on floating roofs open automatically when the roof approaches its lowest level of operation and close automatically when the roof rises above this level. These bleeder vents allow ventilation of the vapor space that is created between the liquid level and the roof when the roof is at its lowest position and rests on its support legs. Figures 14 and 15 locate the vents for external and internal floating roof tanks.

Typical vent location requirements for fixed and external floating roof tanks are contained in standard drawing AB-036003 (See Course Handout 3).

## Drains

Drains in the roof of external floating roof tanks remove accumulated rainfall and thus prevent accumulation of excessive rainwater which could overload a floating roof and damage it or cause it to sink.

Figure 17 illustrates a typical floating roof drain system. A sump is located in the center of the roof. The sump has a pipe connection and check valve installed in it. Either articulated pipe with swivel joints (as shown in Figure 17) or flexible hose connects the pipe to an outlet nozzle that is located in the bottom shell course. When the tank is filled and emptied, the flexibility of the pipe or hose permits the needed free vertical roof movement. The check valve is oriented to permit rainwater to flow off the roof but to prevent any stored liquid from getting on the roof. Stored liquid could get on the roof if the pipe or hose failed. The block valve at the shell outlet nozzle is opened as needed to drain any accumulated rainwater.

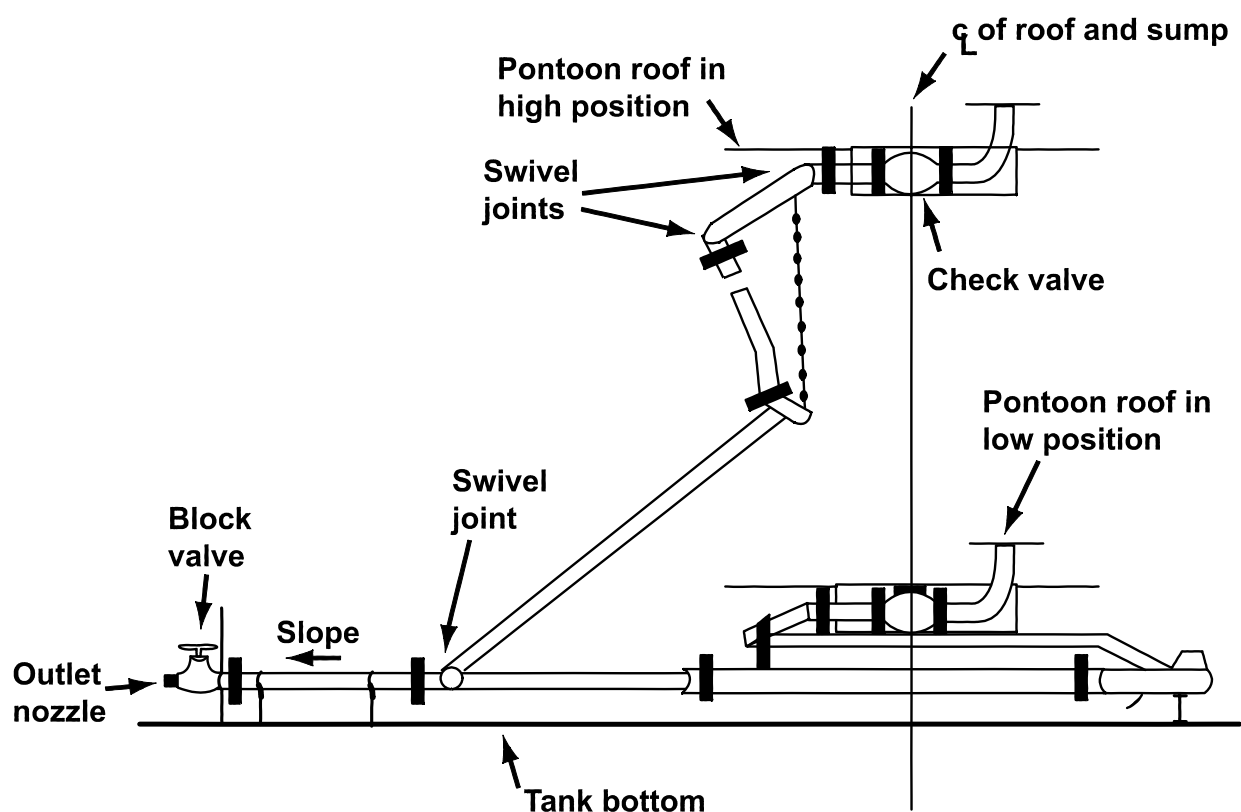
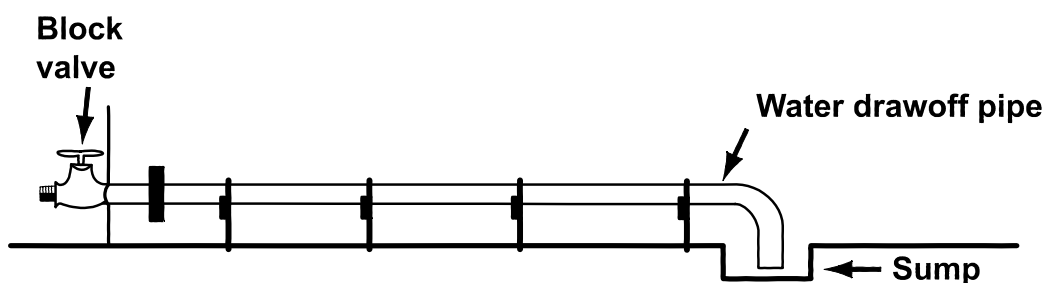


Figure 17. Typical Floating Roof Drain System

Atmospheric storage tanks are frequently equipped with an internal water drawoff sump and drain. Water can enter a tank from atmospheric breathing, with the stored hydrocarbon as either free or dissolved water. Water can also enter a tank when water that has accumulated on top of an external floating roof leaks into the tank. The sump and drain are used to remove the water that collects at the bottom of the tank under the hydrocarbon that is being stored. A water drawoff valve located at the tank shell is opened periodically to drain accumulated water. Figure 18 illustrates the water drawoff sump and valve. Standard Saudi Aramco design details for water drawoff sumps are contained in standard drawing AB-0364500 (See Course Handout 3).

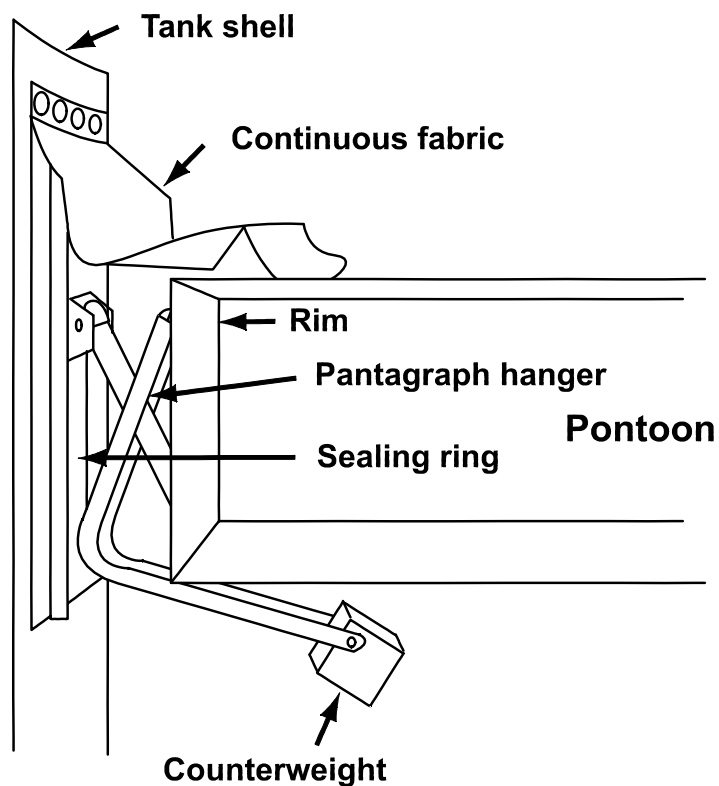
If water that has entered the tank is not periodically removed, it accumulates until it is drawn out with the hydrocarbon. This accumulated water can result in a product being out of specification, or it can disrupt the operation of downstream process units. In addition, the presence of water in the bottom of a tank increases bottom corrosion, promotes biological growth, and can significantly increase the number of sulfate-reducing bacteria, which can cause severe tank bottom pitting.



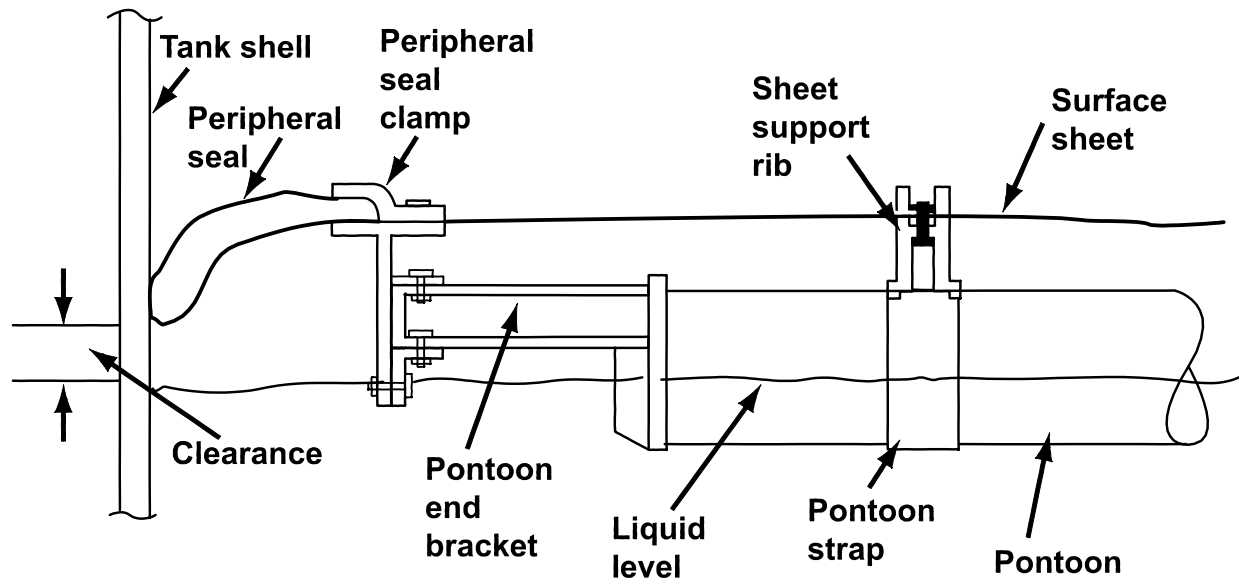
**Figure 18. Internal Water Drawoff System**

## Seals

Seals are located between the roof outside diameter and the tank inside diameter on external and internal floating roof tanks. These seals close the gap between the roof and shell. Closing the gap in this manner minimizes hydrocarbon emissions and permits free vertical motion of the roof as the stored liquid level changes. Seals typically have either a metal plate or a flexible membrane between the roof pontoon and the tank shell. When a metal-plate-type of seal is used, a counterweight system is used to press the metal plate against the tank wall. Figure 19 illustrates this type of seal. Other seals consist of tubes that are filled with solid foam, liquid, or air. Figure 20 illustrates a typical seal for an internal floating roof.



**Figure 19. Metal-Plate-Type Floating Roof Seal**



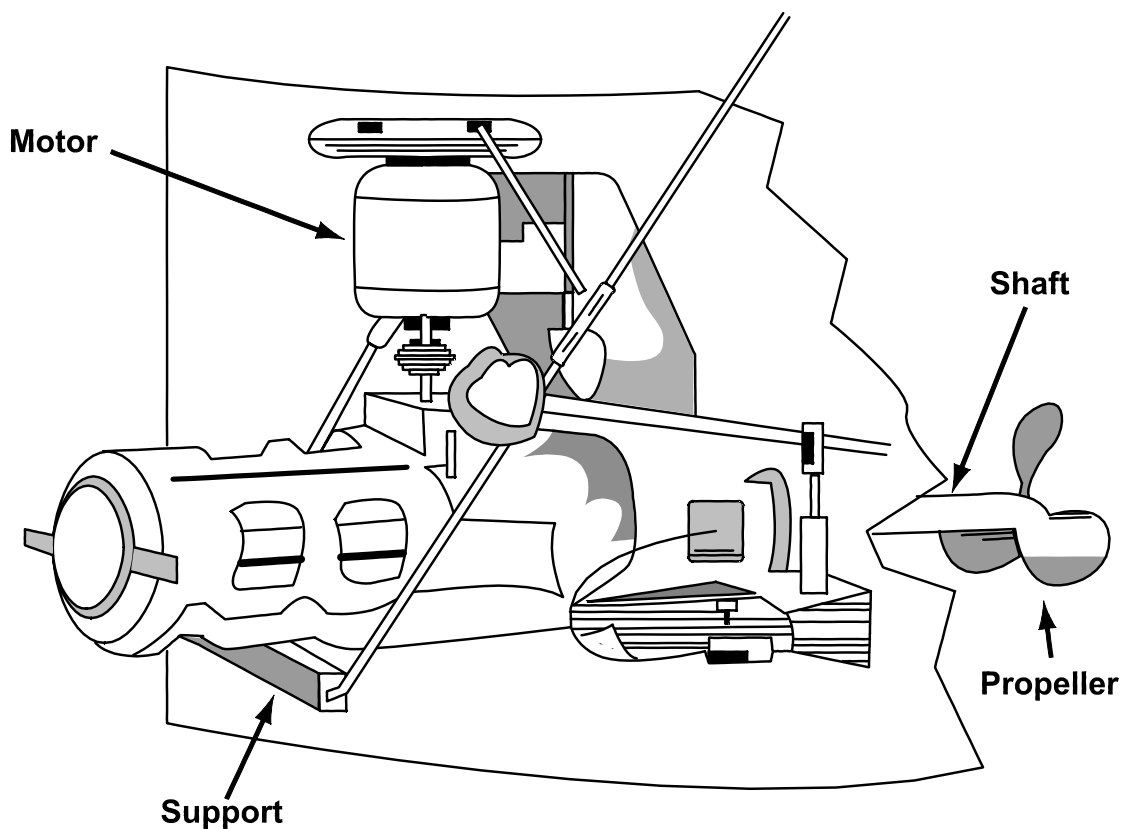
**Figure 20. Typical Seal For Internal Floating Roof**

## Heaters

Heating coils or heaters are installed in tanks that store products that have a high pour point (products that are very viscous at ambient temperature). These heaters warm the product and make it easier for the product to flow and empty out. Occasionally, other tanks have heating coils or heaters to prevent solidification of accumulated sludge.

## Mixers

Mixers are installed in storage tanks to blend products, to prevent sludge deposition, and to maintain bottom sediment and water in suspension, thus preventing bottom sediment and water from accumulating at the bottom. The most common type of mixer uses propeller-type mechanical agitators. Figure 21 illustrates a propeller-type mixer.



**Figure 21. Propeller-Type Mixer**

## Access Hatches

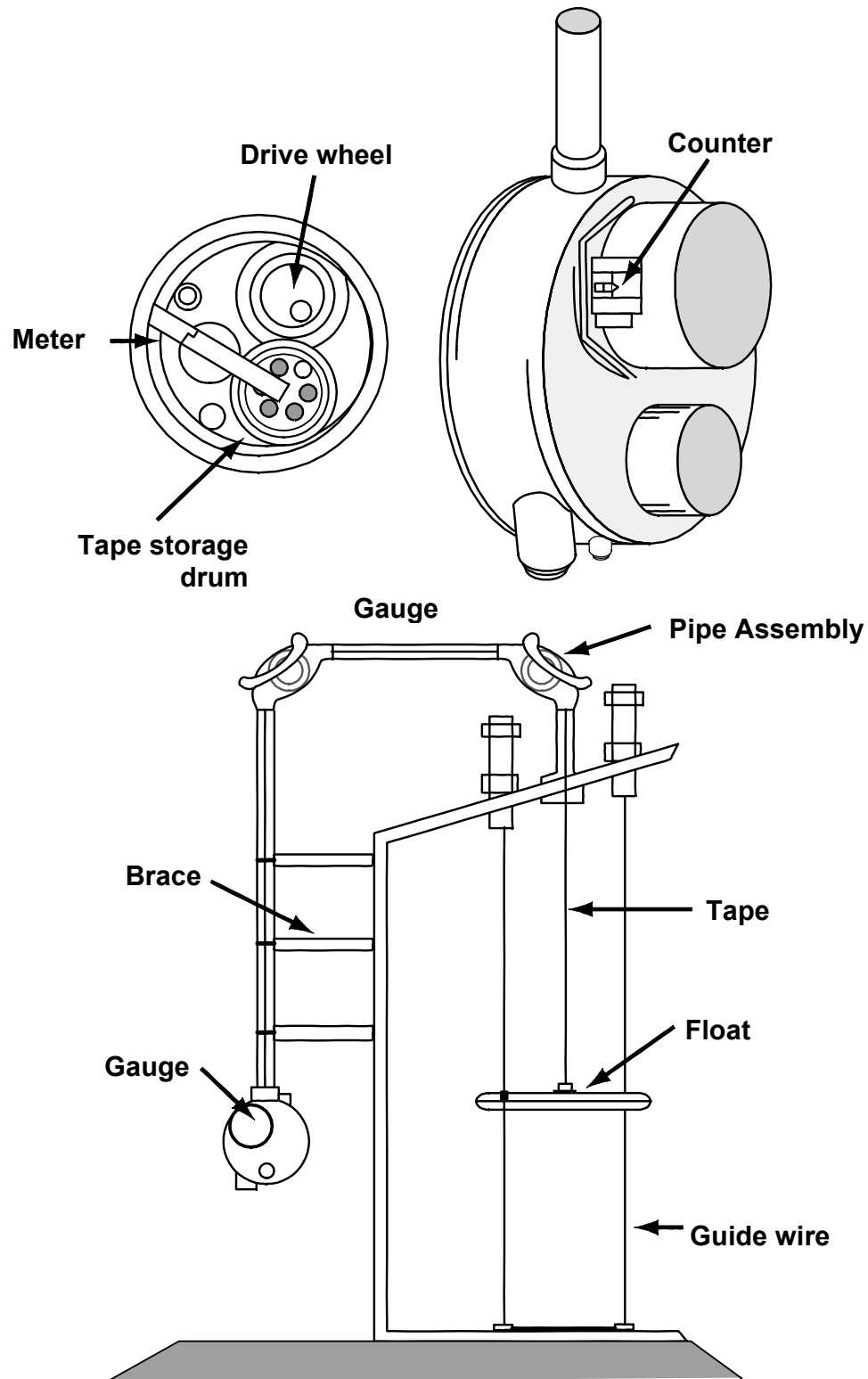
Access to the interior of a tank is required to permit inspection and maintenance activities and liquid level gauging. Access to the tank interior is provided by multiple manways in the tank shell and by at least one large cleanout fitting that is installed flush with the tank floor. Fixed and floating roofs are equipped with access manways and tank-level gauging hatches for either manual or automatic gauging. These features are illustrated in Figures 13 through 15. Typical manhole requirements are contained in standard drawing AB-036003 (See Course Handout 3).

## Platforms, Ladders, and Stairways

All tanks have a platform at the top of the shell with a means to access the platform. The platform is needed to reach the roof and gauge well. Typically, large-diameter tanks use spiral stairways and small-diameter tanks use standard vertical ladders. Platforms, ladders, and stairways are illustrated in Figure 13. Floating roof tanks also have a rolling ladder that extends from the platform down to the roof. The end of the ladder nearest the shell can pivot, and the end on top of the roof has wheels that are mounted within rails. This “rolling ladder” arrangement permits the ladder to move freely without binding or damaging the roof as the level of the stored liquid changes.

## Gauging Devices

Every tank must have at least one level-gauging device that is readable from grade. The float-type automatic tank level gauge is the most common type and is illustrated in Figure 22. One end of a perforated tape is connected to a float in the tank, and the float acts to sense the liquid level for the gauge. The other end of the tape runs over alignment wheels that are positioned inside pipe and down the side of the tank to a storage drum in the gauge head. As the float moves vertically in the tank, the tape winds and unwinds on the drum and registers the liquid level on a counter mechanism. A motor that is located in the gauge head is typically used to maintain a constant tension on the tape regardless of float position.



**Figure 22. Float-Type Level-Gauging Device**

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## Safety Systems

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All tanks are equipped with safety systems. The following paragraphs briefly explain the operation of fire-fighting systems, the use of grounding systems, and the function of an alarm system. All safety systems must be maintained in operable condition and emergency procedures must be prepared so that operating personnel have the capabilities to respond in the case of fire or other emergency.

### Fire-Fighting Systems

The fire-fighting system that is used for a particular storage tank depends primarily on the type of tank and the liquid that is being stored. This section discusses the operation of the following fire-fighting systems:

- Air foam fire protection systems
- Water fire-fighting systems

**Air Foam Fire Protection Systems** - Open-top floating roof storage tanks typically have an air foam fire protection system that is installed to fight a fire that could occur in the rim space between the roof and tank shell. A typical floating roof tank foam distribution system is illustrated in Figure 23. Piping brings foam to the top of the tank (Figure 23B). The pipe outlet is pointed at a deflector which directs the foam against a backboard that distributes the foam circumferentially around the tank (Figure 23A and Figure 23C). The number of foam outlets and backboards that is required increases as the tank diameter increases. A vertical plate called a “foam dam” is welded to the top pontoon plate a relatively short distance from the tank shell (Figure 23A and Figure 23C). The foam dam extends around the entire circumference of the roof and keeps the foam from spreading away from the rim space.

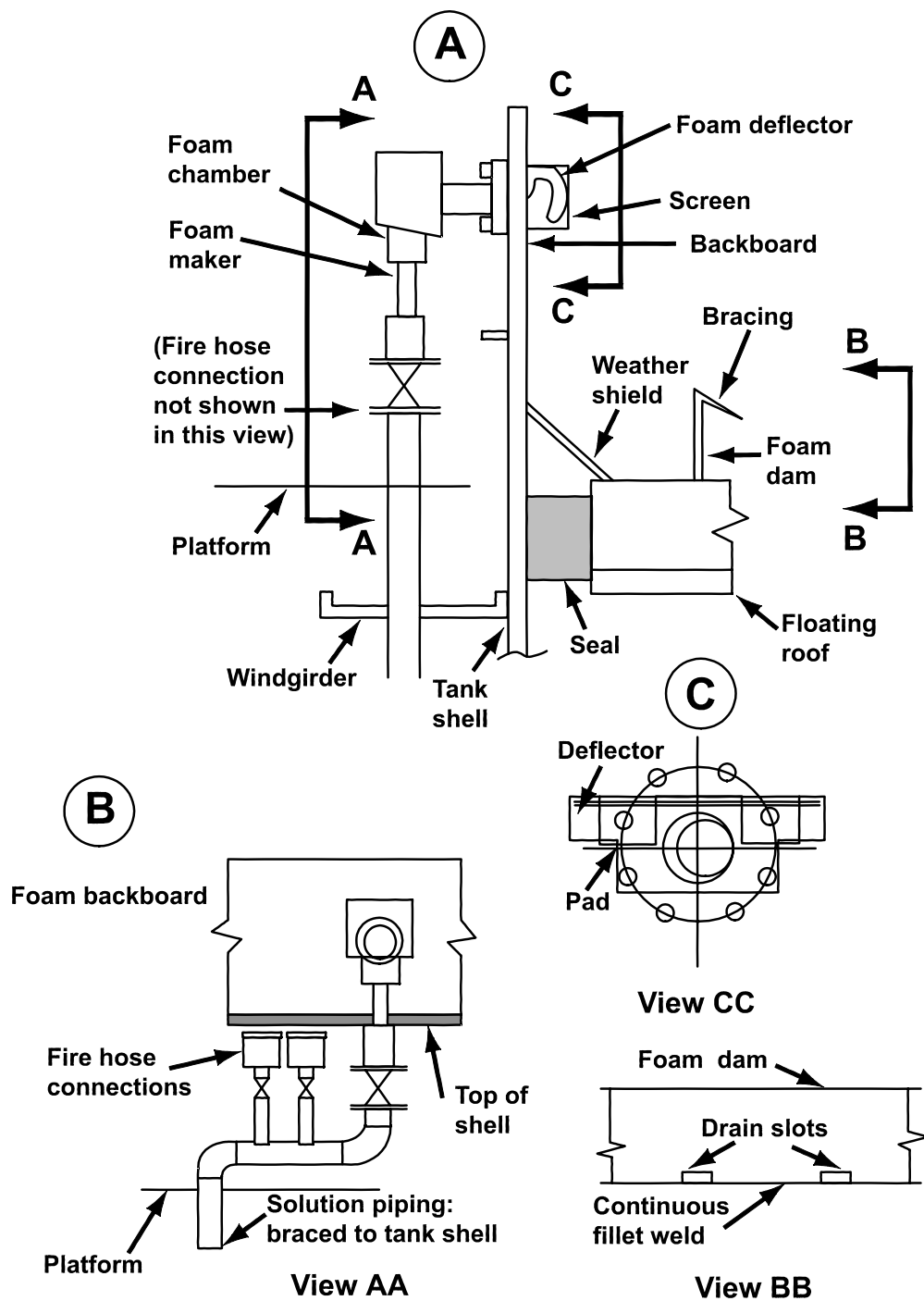
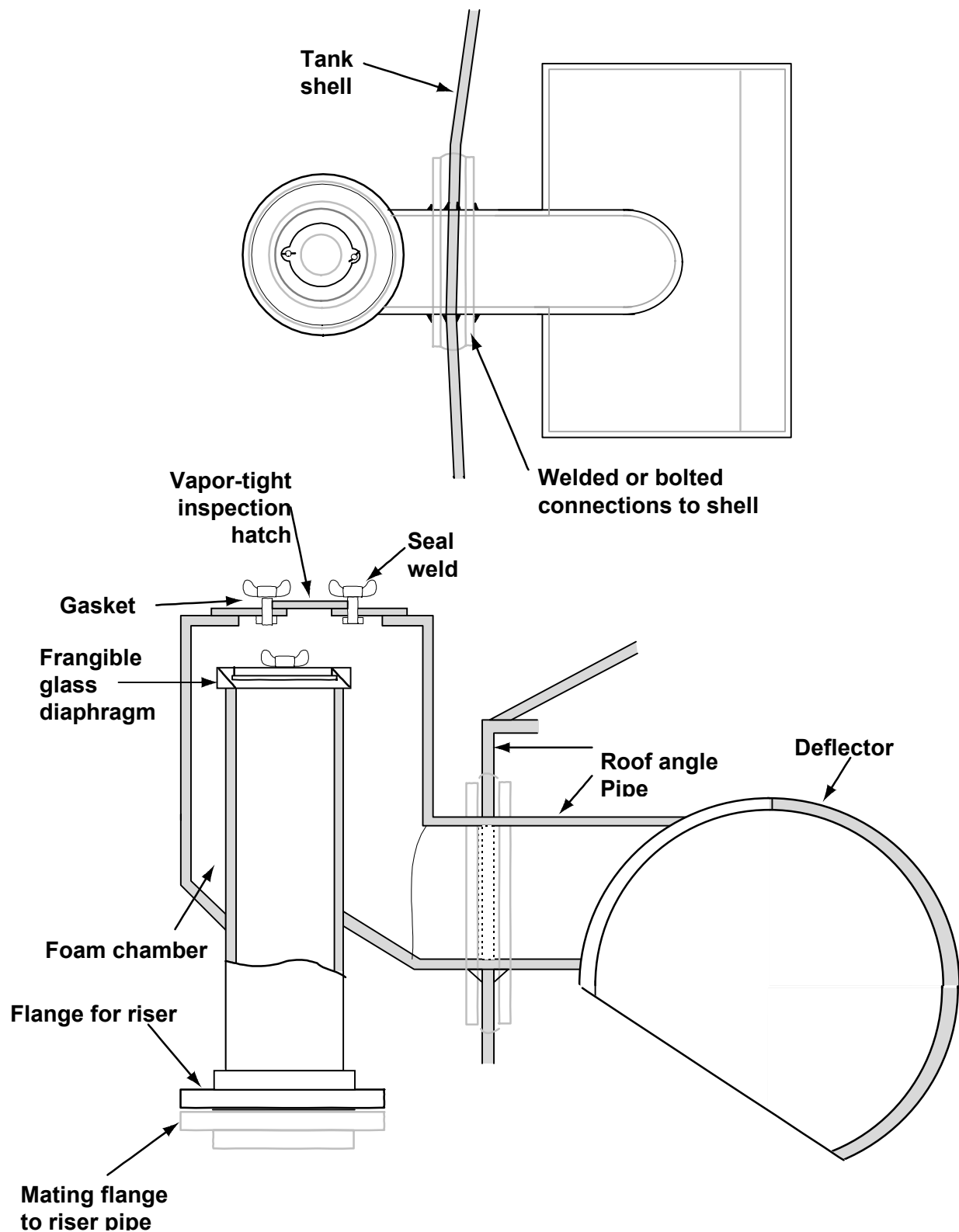


Figure 23. Typical Floating Roof Tank Foam Distribution System



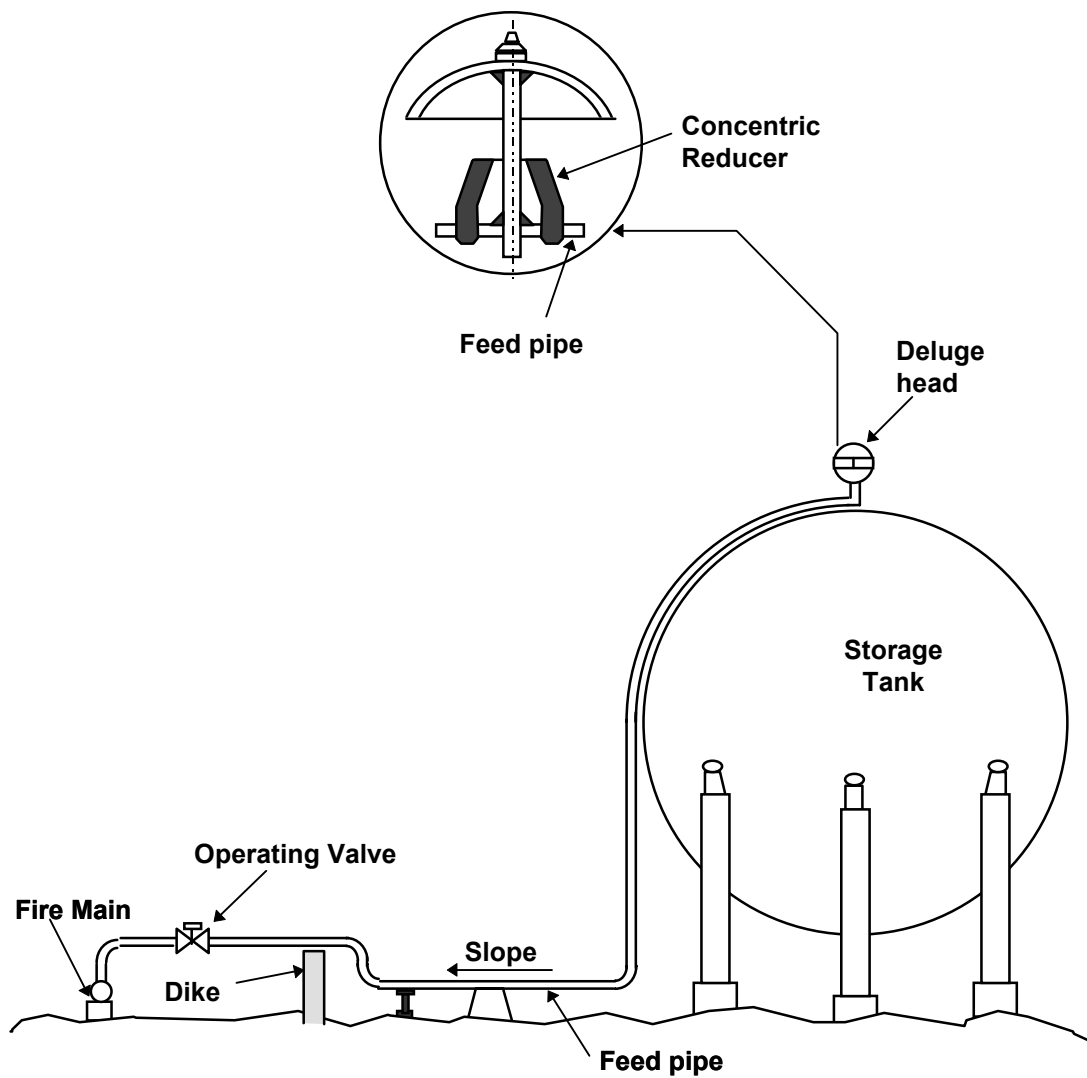
**Figure 24. Typical Fixed Roof Tank Foam Distribution System**

**Fixed roof storage tanks** that are designed to store low flash-point liquids typically have an air foam system that is designed to blanket the liquid surface. A typical fixed roof tank foam distribution system is illustrated in Figure 24.

Foam is piped up the side of the tank, breaks a glass diaphragm, and enters a foam chamber. A pipe is connected to the foam chamber and passes through the tank shell near the top of the tank. A deflector that is attached to the end of the nozzle distributes the foam circumferentially and directs it down on the liquid surface. The foam chamber and deflector are welded to the tank shell or are bolted with vapor-tight connections to injection nozzles that are located near the top of the tank shell. The number of foam chambers that are used increases as the tank diameter increases.

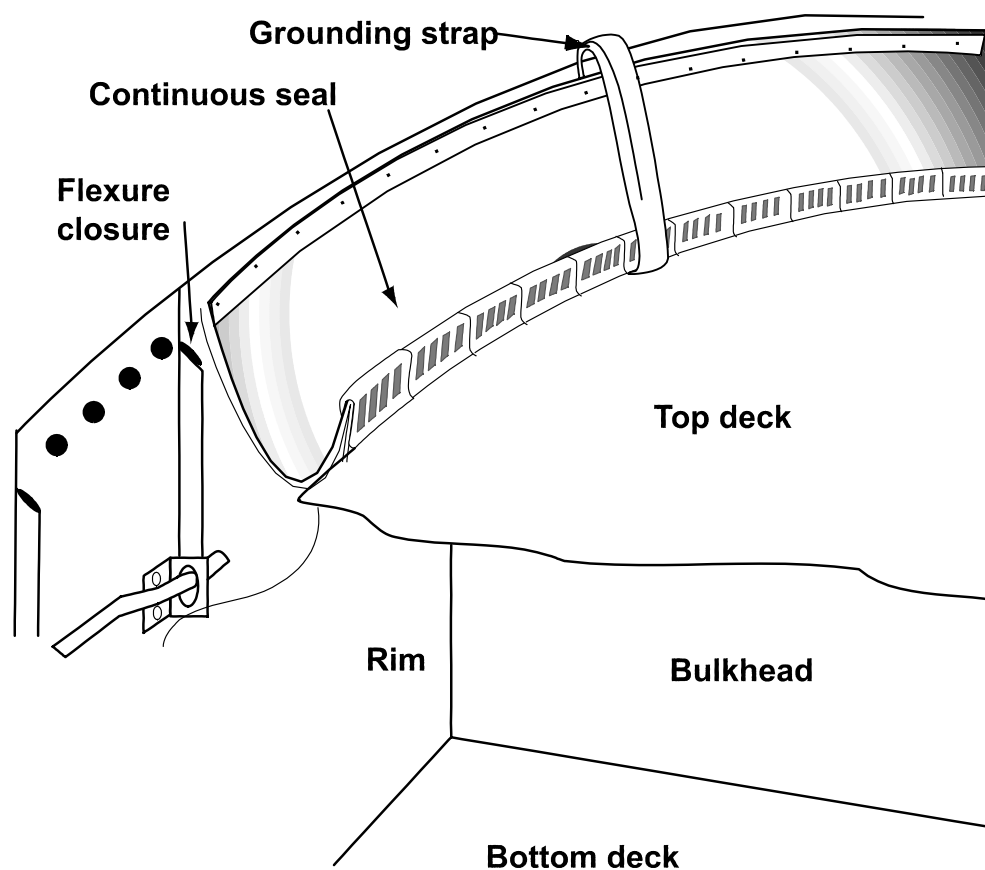
**Water fire-fighting systems** are installed either near to or directly on storage tanks. The specific system and design requirements depend on the type of tank, the stored fluid, and nearby tanks or other equipment. Also note that firewater is also required to generate the foam from foam concentrate when air foam fire protection systems are used. Fire-fighting systems may consist only of strategically located firewater monitors; however, some low-pressure storage tank applications may require fixed water deluge systems that are mounted on top of the tank to provide more direct and high-capacity water flow to cool the tank.

Figure 25 shows a typical water deluge system. Water is taken from the fire main when the operating valve is opened. The water proceeds through the feed pipe to the deluge head that is located on top of the storage tank. The shape of the deluge head directs the water down over the top of the tank. SAES-B-007A, Firewater System Design, specifies design requirements for water deluge systems. These design requirements include the size of the feed pipe and deluge head as a function of tank size. Course Handout 2 contains a copy of SAES-B-007A.

**Figure 25. Water Deluge System**

## Grounding Systems

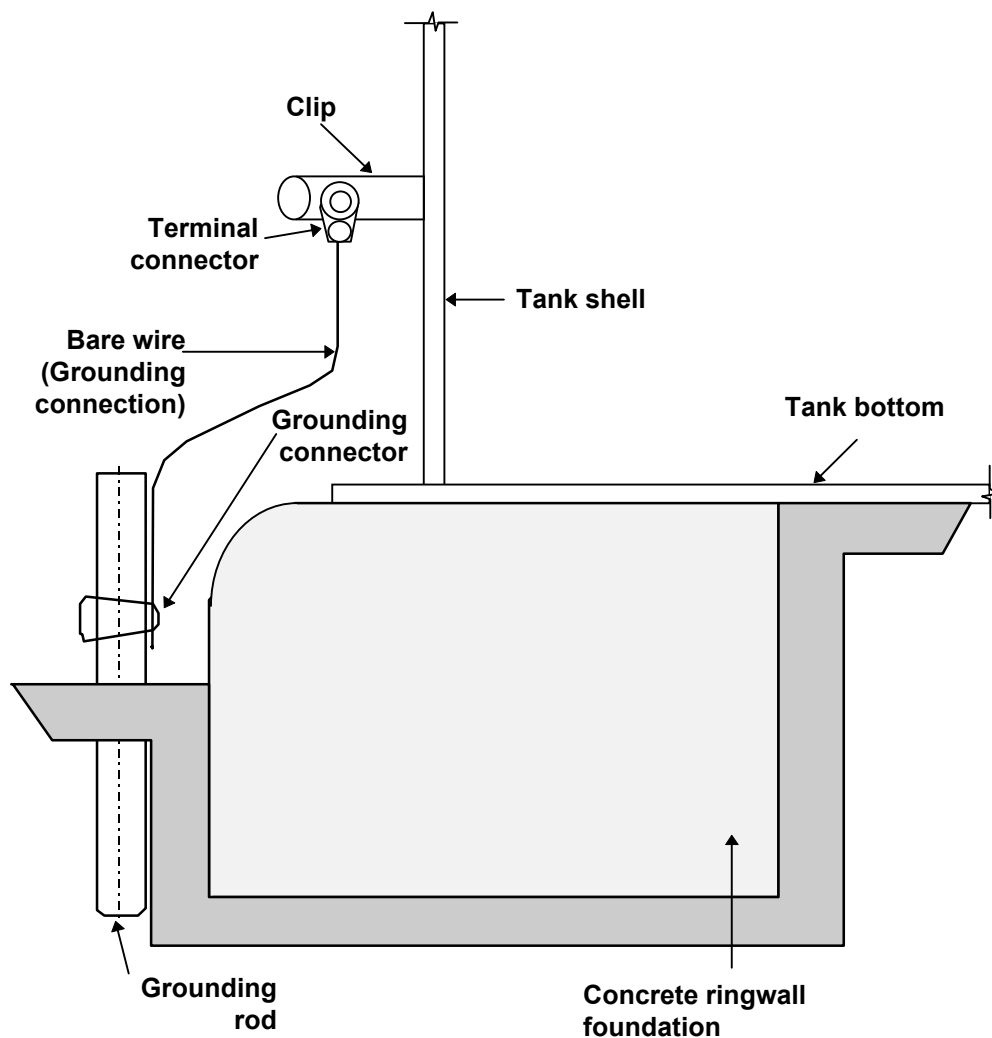
External and internal floating roofs have a grounding strap installed across the seal between the steel roof and the shell. This grounding strap provides electrical continuity between the roof and shell. A typical grounding strap on an external floating roof is illustrated in Figure 26.



**Figure 26. Grounding Strap with External Floating Roof**

All tanks have grounding connections between the shell and a grounding rod that is located in the soil next to the tank. Figure 27 illustrates a typical tank grounding connection. A steel clip is welded to the tank shell. The grounding connection consists of bare wire that is connected between the clip and the grounding rod.

Drawing No. AB-036387 specifies Saudi Aramco grounding connection design details. A copy of this drawing is in Course Handout 3.



**Figure 27. Tank Grounding Connection**

## Alarm Systems

A tank may be equipped with a high-level alarm to warn against overfilling. Whether a high-level alarm is required, and whether this alarm is “local” (annunciates at the tank) or “central” (annunciates in a control room) depends on the operational procedures and requirements at a particular location. One method by which a high-level alarm operates makes use of limit switches that are associated with a fluid level gauging device such as illustrated in Figure 22. The limit switches are calibrated to respond to specific values that represent overly high fluid levels. The switches activate the high-level alarm.

## SUMMARY

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This module has provided an overview of the storage tanks that are used in Saudi Aramco and of the key features of these tanks. The Participant should be able to identify the various types of storage tanks, their primary components, and their functions in Saudi Aramco operations. Definition of storage tank design requirements through the use of a storage tank design specification and the content of a Contractor Design Package were also discussed. The Participant should also be able to identify the functions of typical appurtenances and the operation of safety systems.

MEX 203.02 begins a more detailed treatment of storage tanks by discussing material selection requirements.

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## GLOSSARY

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|                                     |                                                                                                                                                                                                                                                         |
|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>atmospheric storage tank</b>     | <b>A storage tank that is designed to operate with an internal pressure in its vapor space at approximately atmospheric pressure.</b>                                                                                                                   |
| <b>contractor</b>                   | <b>A company that provides engineering, procurement, and construction services to an end-user such as Saudi Aramco for major capital projects. The contractor specifies the design basis for a particular storage tank application.</b>                 |
| <b>fixed roof tank</b>              | <b>An atmospheric storage tank that has a fixed roof, usually in the form of a cone or a dome.</b>                                                                                                                                                      |
| <b>floating roof seal</b>           | <b>Flexible material that closes the gap between a floating roof and the tank shell to minimize hydrocarbon vapor emissions while still permitting free vertical roof travel.</b>                                                                       |
| <b>floating roof tank</b>           | <b>An atmospheric, open-top storage tank with a roof that floats on the liquid surface.</b>                                                                                                                                                             |
| <b>internal floating roof tank</b>  | <b>An atmospheric storage tank that has a fixed roof and an internal floating roof.</b>                                                                                                                                                                 |
| <b>low-pressure storage tank</b>    | <b>A storage tank that is designed to operate with an internal pressure its vapor space greater than atmospheric pressure but not greater than 103 kPa (ga; 15 psig).</b>                                                                               |
| <b>low-temperature storage tank</b> | <b>A storage tank that is designed to operate at tank temperatures below the ambient temperature and with an internal pressure in its vapor space not greater than 103 kPa (ga; 15 psig).</b>                                                           |
| <b>tank manufacturer</b>            | <b>A company that provides the engineering design and erection details of a storage tank based on design basis information that has been provided by a contractor. The words vendor or supplier may also be used interchangeably with manufacturer.</b> |