

Inspection Practices for Atmospheric and Low-pressure Storage Tanks

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Inspection Practices for Atmospheric and Low-pressure Storage Tanks

1 Scope

This document provides useful information and recommended practices for the maintenance and inspection of atmospheric and low-pressure storage tanks. While these maintenance and inspection guidelines may apply to other types of tanks, these practices are intended primarily for existing tanks that were constructed to one of the following four standards: API Std 12A, API Spec 12C, API Std 620, or API Std 650. This document addresses the following:

- a) descriptions and illustrations of the various types of storage tanks;
- b) new tank construction standards;
- c) maintenance practices;
- d) reasons for inspection;
- e) causes of deterioration;
- f) frequency of inspection;
- g) methods of inspection;
- h) inspection of repairs;
- i) preparation of records and reports;
- j) safe and efficient operation;
- k) leak prevention methods.

This recommended practice is intended to supplement API Std 653, which provides minimum requirements for maintaining the integrity of storage tanks after they have been placed in service.

2 Normative References

2.1 Codes, Standards, and Related Publications

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*

2.2 Other References

The following codes and standards are cited in the text of this recommended practice or included in the knowledge base to develop this document. Familiarity with these documents is suggested as they provide additional information pertaining to the inspection and repair of aboveground storage tanks.

API Standard 12A, *Specification for Oil Storage Tanks with Riveted Shells* (withdrawn)

API Specification 12B, *Specification for Bolted Tanks for Storage of Production Liquids*

API Standard 12C, *Specification for Welded Oil Storage Tanks* (withdrawn)

API Specification 12D, *Specification for Field-welded Tanks for Storage of Production Liquids*

API Standard 12E, *Specification for Wooden Production Tanks* (withdrawn)

API Specification 12F, *Specification for Shop-welded Tanks for Storage of Production Liquids*

API Specification 12P, *Specification for Fiberglass Reinforced Plastic Tanks*

API Standard 12R1, *Installation, Operation, Maintenance, Inspection, and Repair of Tanks in Production Service*

API Publication 306, *An Engineering Assessment of Volumetric Methods of Leak Detection in Aboveground Storage Tanks*

API Publication 307, *An Engineering Assessment of Acoustic Methods of Leak Detection in Aboveground Storage Tanks*

API Publication 315, *Assessment of Tankfield Dike Lining Materials and Methods*

API Publication 322, *An Engineering Evaluation of Acoustic Methods of Leak Detection in Aboveground Storage Tanks*

API Publication 323, *An Engineering Evaluation of Volumetric Methods of Leak Detection in Aboveground Storage Tanks*

API Publication 325, *An Evaluation of a Methodology for the Detection of Leaks in Aboveground Storage Tanks*

API Publication 334, *A Guide to Leak Detection for Aboveground Storage Tanks*

API Publication 340, *Liquid Release Prevention and Detection Measures for Aboveground Storage Facilities*

API Publication 341, *A Survey of Diked-area Liner Use at Aboveground Storage Tank Facilities*

API 510, *Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration*

API 570, *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems*

API Recommended Practice 571, *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry*

API Recommended Practice 572, *Inspection Practices for Pressure Vessels*

API Recommended Practice 576, *Inspection of Pressure-relieving Devices*

API Recommended Practice 579-1/ASME FFS-1, *Fitness-For-Service*

API Recommended Practice 580, *Risk-Based Inspection*

API Recommended Practice 581, *Risk-Based Inspection Methodology*

API Recommended Practice 583, *Corrosion Under Insulation and Fireproofing*

API Standard 598, *Valve Inspection and Testing*

API Standard 620, *Design and Construction of Large, Welded, Low-pressure Storage Tanks*

API Standard 625, *Tank Systems for Refrigerated Liquefied Gas Storage*

API Standard 650, *Welded Tanks for Oil Storage*

API Recommended Practice 651, *Cathodic Protection of Aboveground Petroleum Storage Tanks*

API Recommended Practice 652, *Linings of Aboveground Petroleum Storage Tank Bottoms*

API Bulletin 939-E, *Identification, Repair, and Mitigation of Cracking of Steel Equipment in Fuel Ethanol Service*

API Standard 2000, *Venting Atmospheric and Low-pressure Storage Tanks*

API Recommended Practice 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*

API Standard 2015, *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*

API Standard 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities*

ACI 376 ¹, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases and Commentary*

AISC ², *Steel Construction Manual*

ASME Boiler and Pressure Vessel Code (BPVC) ³, *Section V: Nondestructive Examination*

ASME Boiler and Pressure Vessel Code (BPVC), *Section VIII: Rules for the Construction of Pressure Vessels*

ASME Boiler and Pressure Vessel Code (BPVC), *Section IX: Welding, Brazing, and Fusing Qualifications*

ASNT CP-189 ⁴, *Standard for Qualification and Certification of Nondestructive Testing Personnel*

ASNT SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*

ASTM D3359 ⁵, *Standard Test Methods for Rating Adhesion by Tape Test*

EEMUA 159 ⁶, *Users' Guide to the Inspection, Maintenance and Repair of Aboveground Vertical Cylindrical Steel Storage Tanks—Volume 1*

NFPA 30 ⁷, *Flammable and Combustible Liquids Code*

OSHA ⁸, 29 CFR Part 1910.23, *Ladders*

OSHA, 29 CFR Part 1910.106, *Flammable Liquids*

¹ American Concrete Institute, 38800 Country Club Dr., Farmington Hills, MI 48331, www.aci-int.org.

² American Institute of Steel Construction, 130 East Randolph, Suite 2000, Chicago, IL 60601, www.aisc.org.

³ ASME International, 2 Park Avenue, New York, NY 10016-5990, www.asme.org.

⁴ American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228, www.asnt.org.

⁵ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428, www.astm.org.

⁶ Engineering Equipment and Materials Users Association, 16 Black Friars Lane, Second Floor, London EC4V 6EB, UK, www.eemua.org.

⁷ National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471, www.nfpa.org.

⁸ U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue NW, Washington, DC 20210, www.osha.gov.

OSHA, 29 CFR Part 1910.146, *Permit-required Confined Spaces*

STI SP001⁹, *Standard for Inspection of Aboveground Storage Tanks*

UL 142¹⁰, *Standard for Safety Steel Aboveground Tanks for Flammable and Combustible Liquids Steel*

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1

alteration

Any work on a tank that changes the physical dimensions or configuration, in accordance with API Std 653 guidelines.

3.2

applicable standard

The original standard of construction, such as API standards or specifications or Underwriter Laboratories (UL) standards, unless the original standard of construction has been superseded or withdrawn from publication; in this event, applicable standard means the current edition of the appropriate standard. See API Std 653, Annex A for background on editions of API welded storage tank standards.

3.3

atmospheric pressure

When referring to vertical tanks, the term “atmospheric pressure” usually means tanks designed to API Std 650, although API Std 620 uses the term atmospheric pressure to describe tanks designed to withstand an internal pressure not exceeding the weight of the roof plates. API Std 650 also provides for rules to design tanks for “higher internal pressure” up to 2.5 psi (18 kPa). API Std 653 uses the generic meaning for atmospheric pressure to describe tanks designed to withstand an internal pressure up to, but not exceeding, 2.5 psi (18 kPa) gauge.

3.4

authorized inspection agency

Any one of the following that can provide inspection services of authorized tank inspectors:

- a) the inspection organization of the jurisdiction in which the aboveground storage tank is located;
- b) the inspection organization of an insurance company that is licensed or registered to write and does write aboveground storage tank insurance;
- c) the inspection organization of an owner or operator of one or more aboveground storage tank(s) who maintains an inspection organization for activities relating only to their equipment and not for aboveground storage tanks intended for sale or resale; or
- d) an independent organization or individual that is under contract to and under the direction of an owner or operator and that is recognized by the jurisdiction in which the aboveground storage tank is operated. The owner or operator’s inspection program should provide the controls necessary when contract inspectors are used.

⁹ Steel Tank Institute/Steel Plate Fabricators Association (STI/SPFA), 944 Donata Court, Lake Zurich, IL 60047, www.steeltank.com

¹⁰ Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062, www.ul.com.

3.5**authorized inspector**

An employee of an authorized inspection agency, who is qualified and certified to perform inspections under API Std 653, Annex D. Whenever the term “inspector” is used in API RP 575, it refers to an authorized aboveground storage tank inspector.

3.6**bottom sediment and water****BS&W**

Bottom sediment and water (BS&W) that may settle out or exist in the non-agitated portion of the tank.

3.7**change in service**

A change from previous operating conditions involving different properties of the stored product such as specific gravity, corrosivity, or different service conditions of temperature or pressure.

3.8**condition monitoring location****CML**

Designated areas on tanks where periodic examinations are conducted in order to directly assess the condition of the tank. Condition monitoring locations (CMLs) may contain one or more examination points and utilize multiple inspection techniques that are based on the predicted damage mechanism to give the highest probability of detection. CMLs can be a single small area on a tank (e.g. a 2-in. diameter spot or a plane through a section of a nozzle) where recording points exist in all four quadrants of the plane.

NOTE CMLs include, but are not limited to, thickness measurement locations (TMLs).

3.9**corrosion allowance**

Additional material thickness available to allow for metal loss during the service life of the tank component.

3.10**corrosion rate**

The rate of metal loss due to erosion, corrosion, a chemical reaction(s) with the environment, either internal or external. Corrosion rates depend on how and where the measurements are taken. Guidance on determining corrosion rates in tanks is provided in API Std 653.

3.11**corrosion specialist**

A person, acceptable to the owner/operator, who has knowledge and experience in corrosion damage mechanisms, metallurgy, materials selection, and corrosion monitoring techniques.

3.12**corrosion under insulation****CUI**

Refers to all forms of corrosion under the insulation (CUI) including stress corrosion cracking (SCC).

3.13**damage mechanism**

Any type of deterioration encountered in the refining and chemical process industry that can result in flaws or defects that can affect the integrity of tanks (e.g. corrosion, cracking, erosion, dents, and other mechanical, physical, or chemical impacts). See API RP 571 for a comprehensive list and description of damage mechanisms.

3.14**defect**

An imperfection whose type or size exceeds the applicable acceptance criteria and is therefore rejectable.

3.15**documentation**

Records containing descriptions of specific tank design, personnel training, inspection plans, inspection results, nondestructive examination (NDE), repair, alteration, operating heights or capacities, Fitness-For-Service (FFS) assessments, procedures for undertaking these activities, or any other information pertinent to maintaining the integrity and reliability of the tank.

3.16**examinations**

Quality control (QC) functions performed by examiners in accordance with approved NDE procedures.

3.17**examiner**

A person who assists the API authorized tank inspector by performing specific NDE on the tank and interprets the results for compliance with the applicable acceptance criteria, whereas the authorized inspector evaluates the results of those examinations in accordance with API Std 653 and this recommended practice.

3.18**external inspection**

A visual inspection performed from the outside to find conditions that could impact the tank's ability to maintain integrity or conditions that compromise the integrity of the supporting structures (e.g. ladders, platforms, supports). The external inspection may be done either while the tank is operating or while the tank is out-of-service.

3.19**Fitness-For-Service evaluation****FFS evaluation**

A methodology where flaws and other deterioration or damage or operating conditions contained within a tank are assessed in order to determine the integrity of the tank for continued service.

3.20**general corrosion**

Corrosion that is distributed more or less uniformly over the surface of the metal, as opposed to localized corrosion.

3.21**heat-affected zone**

The portion of the base metal whose mechanical properties or microstructure have been altered by the heat of welding or thermal cutting.

3.22**hydrostatic pressure**

The pressure exerted by a fluid at equilibrium at a given point within the fluid, due to the force of gravity. Hydrostatic pressure increases in proportion to the depth measured from the surface because of the increasing weight of the fluid exerting downward force from above.

3.23**indications**

A response or evidence resulting from the application of NDE that may be nonrelevant or could be flaws or defects upon further analysis.

3.24**in service**

Designates a tank that has been placed in operation and has not been emptied and cleaned.

3.25**in-service inspection**

All inspection activities associated with a tank once it has been placed in service but before it is emptied and cleaned.

3.26**inspection**

The external, internal, or in-service evaluation (or any combination of the three) of the condition of a tank conducted in accordance with API Std 653.

3.27**inspection plan**

A strategy defining how and when a tank or its devices will be inspected, repaired, and/or maintained.

3.28**inspector**

(See definition for **authorized inspector**.)

3.29**internal inspection**

An inspection performed from the inside of a tank using visual and NDE techniques.

3.30**jurisdiction**

A legally constituted governmental administration that may adopt rules relating to tanks.

3.31**localized corrosion**

Corrosion that is largely confined to a limited or isolated area of the metal surface of a tank.

3.32**magnetic flux leakage****MFL**

An NDE method utilizing electromagnetic or permanent magnets to detect corrosion and pitting on ferromagnetic steels.

3.33**minimum acceptable thickness**

The lowest thickness at which a tank component should operate, as determined by the parameters in the applicable tank design standard (such as API Std 650, API Std 653, etc.), the FFS principles in API 579-1/ASME FFS-1, or other appropriate engineering analysis.

3.34**out of service**

Designates that a tank is clean and empty of product. A tank during original construction, removed from service and cleaned for repair, or a retired tank.

3.35**out-of-service inspection**

All inspection activities that are conducted after the tank has been cleaned and declared to be vapor free.

3.36**owner/operator**

The legal entity having control of and/or responsibility for the operation and maintenance of an existing storage tank.

3.37**procedures**

A document that specifies or describes how an activity is to be performed. It may include methods to be employed, equipment or materials to be used, qualifications of personnel involved, and sequence of work.

3.38**product-side**

The interior surface of a tank bottom, usually used when describing corrosion. Another term with the same meaning is "top-side."

3.39**reconstruction**

The work necessary to re-assemble a tank that has been dismantled and relocated to a new site.

3.40**reconstruction organization**

The organization having assigned responsibility by the owner/operator to design and/or reconstruct a tank.

3.41**release prevention barrier****RPB**

Steel bottoms, synthetic materials, clay liners, and all other barriers or combination of barriers placed in the bottom of or under an aboveground storage tank, which have the following functions:

- a) preventing the escape of contaminated material, and
- b) containing or channeling released material for leak detection.

3.42**repair**

Any work necessary to maintain or restore a tank to a condition suitable for safe and leak-free operation, in accordance with API Std 653.

3.43**risk-based inspection****RBI**

A risk assessment and management process that considers both the probability of failure and the consequence of failure due to a defined damage mechanism (ref. API RP 571) and that is focused on inspection planning to prevent loss of containment of storage tanks due to material deterioration.

NOTE 1 Refer to API RP 571 and API RP 580 for further details on damage mechanisms and risk-based inspections (RBIs), respectively.

NOTE 2 These risks are managed primarily through inspection in order to influence the probability of failure but can also be managed through various other methods to control the probability and consequence of failure.

3.44**soil-side**

The exterior surface of the tank bottom, usually used when describing corrosion. Other terms with the same meaning are "under-side" or "bottom-side."

3.45**sounding**

An inspection technique that relies on impacting the surface with a tapping rod and listening for hollow sounds that indicate delamination or loss of continuity.

3.46**storage tank engineer**

An engineer acceptable to the owner/operator who is knowledgeable and experienced in the engineering disciplines associated with evaluating mechanical and material characteristics affecting the integrity and reliability of tank components and systems. The tank engineer, by consulting with appropriate specialists, should be regarded as a composite of all entities necessary to properly address technical requirements and engineering evaluations.

3.47**tank**

The term tank refers to aboveground storage tanks, typically either a fixed or floating-roof design, or both.

3.48**temporary repairs**

Repairs made to storage tanks to restore sufficient integrity to continue safe operation until permanent repairs are conducted.

3.49**top-side**

See definition for **product-side**.

3.50**water bottom**

See definition for **BS&W**.

4 Types of Storage Tanks

4.1 General

4.1.1 Tank Design and Materials

Storage tanks are used to store fluids such as crude oil, intermediate and refined products, gas, chemicals, waste products, water, and water/product mixtures. Important factors such as the volatility of the stored fluid and the desired storage pressure and temperature result in tanks being built of various types, sizes, and materials of construction. In this document, only atmospheric and low-pressure storage tanks are considered. Guidelines for inspection of pressure vessels operating at pressures greater than 15 psi (103 kPa) gauge are covered in API RP 572.

There are two types of tanks commonly found in industry: fixed roof and floating roofs. Fixed roof tanks can be constructed out of carbon steel, alloy steel, aluminum, or other metals. In addition to these materials, tanks can be constructed out of nonmetallic materials such as concrete, reinforced thermoset plastics, and wood (API Std 12E). Floating-roof tanks are commonly made out of carbon steel but can also be made of other alloys. Atmospheric tanks are generally welded but can also be riveted (API Std 12A) or bolted (API Spec 12B).

4.1.2 Storage Tanks with Linings and/or Cathodic Protection

Where internal corrosion is experienced or expected, tanks can be lined with a variety of corrosion-resistant materials such as coatings of epoxy or vinyl, fiberglass, poured or sprayed concrete, alloy steel, aluminum, rubber, lead, synthetics such as high-density polyethylene (HDPE) or other synthetic rubber, and glass.

See API RP 652 for provisions for the application of some types of tank bottom linings to both existing and new storage tanks.

Cathodic protection systems are often provided for control of external bottom corrosion and, combined with internal linings, may also be used to protect tank bottoms internally. See API RP 651 for design, maintenance, and monitoring recommendations for such systems.

4.1.3 Storage Tanks with Passive Leak Detection Systems

Leak detection systems are installed for early awareness of a potential leak. API Std 650, Annex I provides design guidelines for leak detection and subgrade protection. Reference also API Publication 306, API Publication 307, API Publication 315, API Publication 322, API Publication 323, API Publication 325, API Publication 334, API Publication 340, and API Publication 341 for additional information on leak detection systems for storage tanks and dike containment areas.

4.1.4 Storage Tanks with Auxiliary Equipment

Most storage tanks are provided with some of the following auxiliary equipment such as liquid-level gauges, high-and low-level alarms and other overfill prevention systems, pressure-relieving devices, vacuum venting devices, emergency vents, gauging hatches, roof drain systems, flame arrestors, fire protection systems, and mixing devices.

Stairways, ladders, platforms, handrails, piping connections and valves, manholes, electric grounding connections (as required), and cathodic protection systems are considered examples of storage tank auxiliary equipment.

Insulation may also be present to maintain product temperature. Insulation can vary from externally jacketed panel systems to sprayed-on foam systems to loose-fill systems in double-wall tank construction.

Inspection and failure of auxiliary equipment are covered in 5.5.

4.2 Atmospheric Storage Tanks

4.2.1 Construction, Materials, and Design Standards

Atmospheric storage tanks are designed to operate with internal gas and vapor spaces at pressures close to atmospheric pressure. Such tanks are usually constructed of carbon steel, alloy steel, aluminum, or other metals, depending on service. Additionally, some tanks are constructed of nonmetallic materials such as reinforced concrete, reinforced thermoset plastics, and wood. Some wooden tanks constructed to API Std 12E are still in service. Atmospheric storage tanks are generally welded. Some riveted tanks constructed to API Std 12A and some bolted tanks constructed to API Spec 12B can also be found still in service. Information for the construction of atmospheric storage tanks is given in API Std 12A (withdrawn), API Spec 12B, API Spec 12C (the predecessor to API Std 650 and now withdrawn), API Spec 12D, API Std 12E (withdrawn), API Spec 12F, API Std 650, API Std 620, and API Std 2000. API Std 625 covers the selection, design and construction of tank systems for refrigerated liquefied gas storage on land. API Std 653 provides information pertaining to requirements for inspection, repair, and reconstruction of aboveground storage tanks.

4.2.2 Use of Atmospheric Storage Tanks

Atmospheric storage tanks in the petroleum industry are normally used for fluids having a true vapor pressure that is less than atmospheric pressure. Vapor pressure is the pressure on the surface of a confined liquid caused by the vapors of that liquid. Vapor pressure increases with increasing temperature. Crude oil, heavy oils, gas oils, furnace oils, naphtha, gasoline, and nonvolatile chemicals are usually stored in atmospheric storage tanks. Many of these tanks are protected by pressure/vacuum vents that limit the pressure difference between the tank vapor space and the outside atmosphere to a few ounces per square inch.

Non-petroleum industry uses of atmospheric tanks include storage of a variety of chemicals and other substances operated in closed-loop systems not vented to atmosphere and with pressure control and relief devices as required. These tanks may be designed and operated as low-pressure storage tanks per API Std 620. See 4.3 for additional information on tanks operated at low pressure.

Additional uses for atmospheric storage tanks can include the storage of liquid (both hydrocarbon and non-hydrocarbon), storage in horizontal vessels, and the storage of process liquids or granular solids in skirt-supported or column-supported tanks with elevated cone bottoms (non-flat bottom), and the storage of process water/liquids in open-top tanks.

4.2.3 Types of Atmospheric Storage Tank Roofs

4.2.3.1 Cone Roof Tanks

The most common type of atmospheric storage tank is the fixed cone roof tank (see Figure 1). Fixed cone roof tanks may typically be up to 300 ft (91.5 m) in diameter and 64 ft (19.5 m) in height, although larger-diameter tanks have been built. These roofs are normally supported by internal structural rafters, girders, and columns but can be fully self-supporting in smaller diameters [typically 60 ft (18.3 m) diameter or less]. Self-supporting aluminum dome roofs (e.g. geodesic dome roofs) may be applied to most diameter tanks without the need for internal supporting columns.

4.2.3.2 Umbrella Roof Tanks

The umbrella roof tank (shown in Figure 2) and the self-supporting aluminum dome roof tank (shown in Figure 3) are variations of the fixed roof tank. The umbrella roof has radially arched segmental plates with integral framing support members (usually without internal support columns). The aluminum dome utilizes the geometric properties of the geodesic design and tubing members covered by aluminum sheeting for strength. In the steel dome roof tank shown in Figure 4, the roof plates are usually formed with curved segments joined to be self-supporting.



Figure 1—Cone Roof Tank



Figure 2—Umbrella Roof Tank

4.2.3.3 External Floating-roof Tanks

4.2.3.3.1 General

The floating-roof tank is another common type of atmospheric storage tank. The floating-roof tank is designed to minimize filling and breathing losses by eliminating or minimizing the vapor space above the stored liquid. The shell and bottom of this type of tank are similar to those of the fixed roof tanks, but in this case, the roof is designed to float on the surface of the stored liquid. Older styles of external floating roofs include single steel deck designs without annular pontoons as shown in Figure 5. This external floating roof type is no longer permitted under API Std 650, Annex C. Such roofs have no reserve buoyancy and are susceptible to sinking in service.



Figure 3—Self-supporting Aluminum (Geodesic) Dome Roof Tank



Figure 4—Self-supporting Dome Roof Tank



Figure 5—Externally Stiffened Pan-type Floating-roof Tank

4.2.3.3.2 Variations

Annular-pontoon and double-deck roofs are shown in Figure 6 and Figure 7, respectively. Some floating-roof tanks have fixed aluminum geodesic dome roofs installed on top of the tank shell to reduce product vapor loss or to eliminate the need to drain rainwater from the roof. These are considered internal floating roofs for purposes of emissions control, confined space entry, etc.

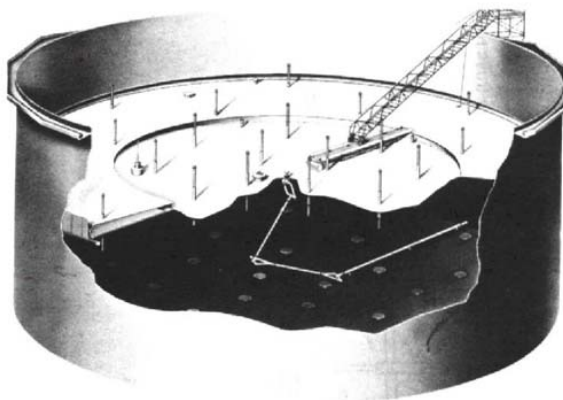


Figure 6—Annular-pontoon Floating-roof Tank

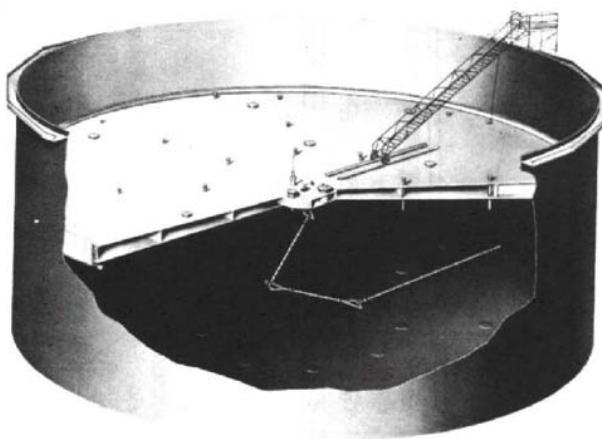
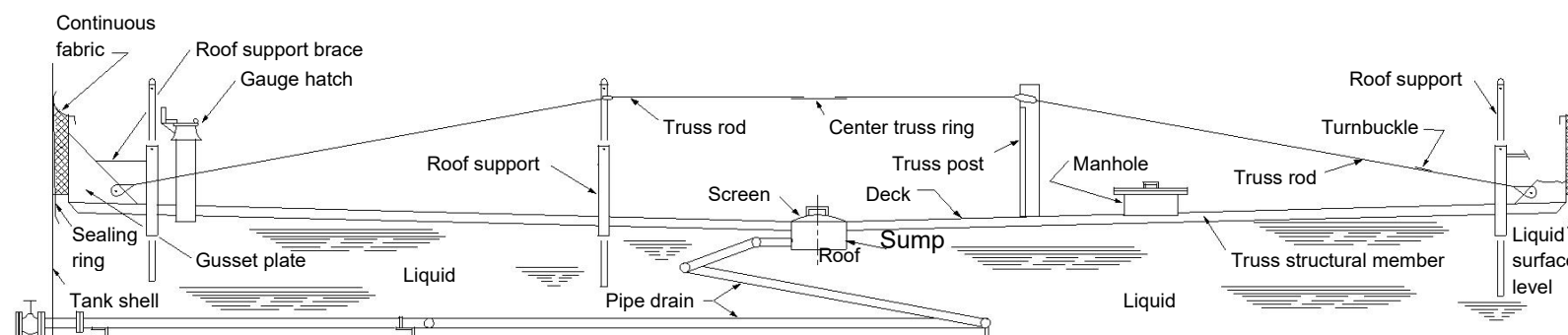


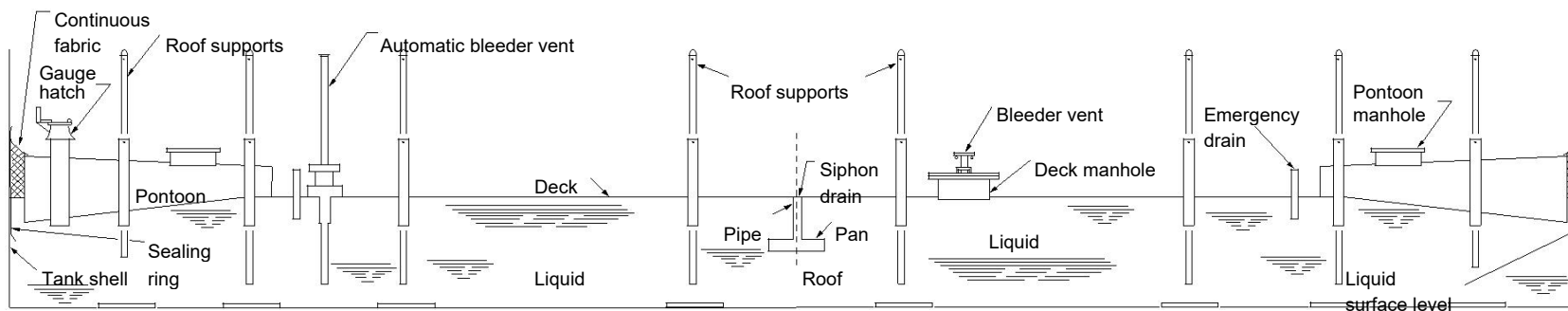
Figure 7—Double-deck Floating-roof Tank

4.2.3.3.3 Features

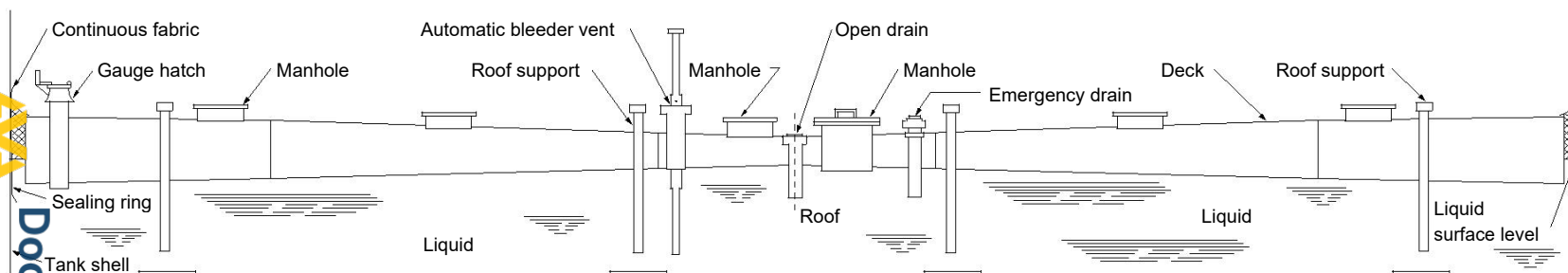
Cross-sectional sketches showing important features of floating roofs are shown in Figure 8. Floating-roof sealing systems are used to seal the space between the tank wall and the floating roof, typically with a mechanical seal. This type of seal consists of a shoe that is a plate pressed against the tank wall by springs (or by counterweights in older designs) or other tensioning system, with a flexible vapor membrane attached between the shoe and the floating-roof outer rim. Typical examples of this type of floating-roof seal are shown in Figure 9, Figure 10, and Figure 11. One alternative seal detail occasionally still found in existing tanks is the tube seal shown in Figure 12. These tubes are filled with solid foam, liquid, or air. Figure 13 illustrates various pontoon roofs and seal details.



PAN FLOATING ROOF



PONTON FLOATING ROOF



DOUBLE DECK FLOATING ROOF

Figure 8—Cross-section Sketches of Floating-roof Tanks Showing the Most Important Features

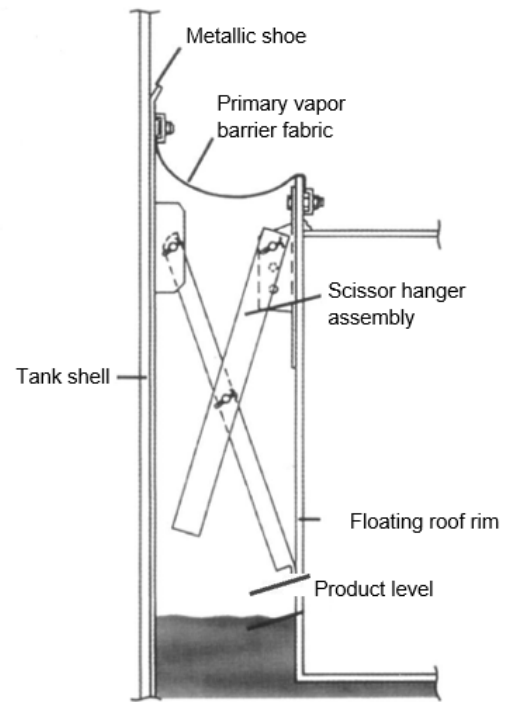
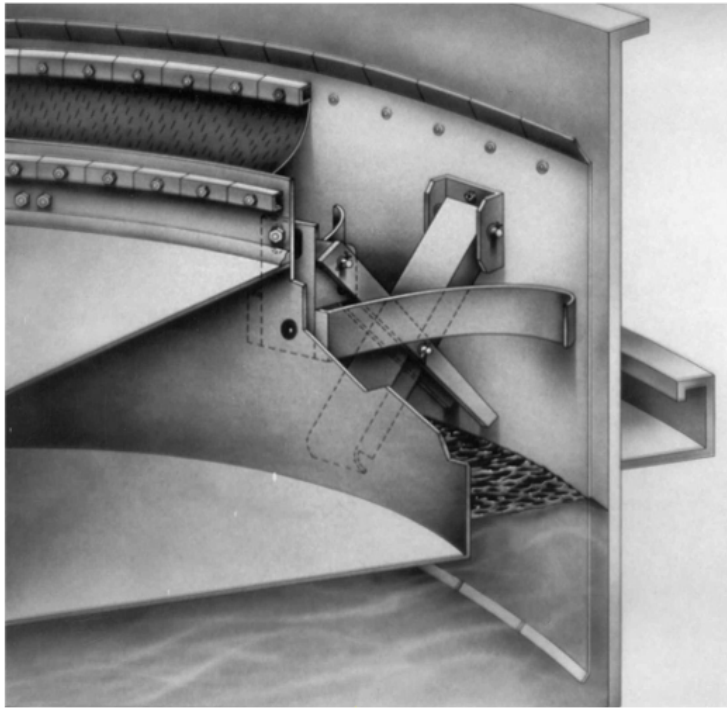
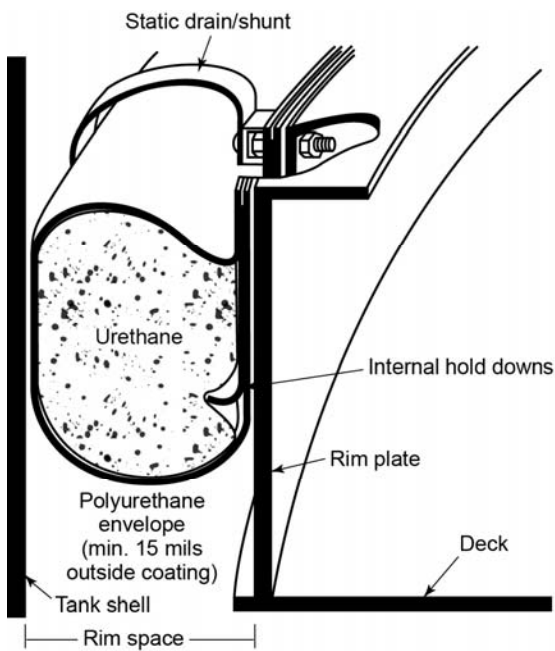
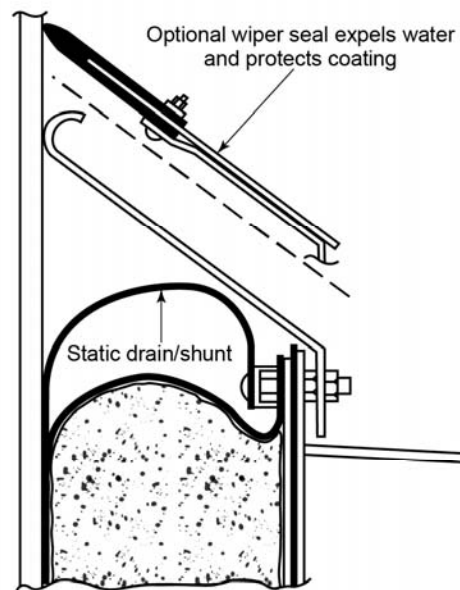


Figure 9—Floating-roof Shoe Seal



Cross-Section Foam Seal for Steel Floating Roof



Cross-Section Foam Seal in Hand Floating Roof with Standard Weather Shield for Longer Seal Life

Figure 10—Floating-roof Log Seal

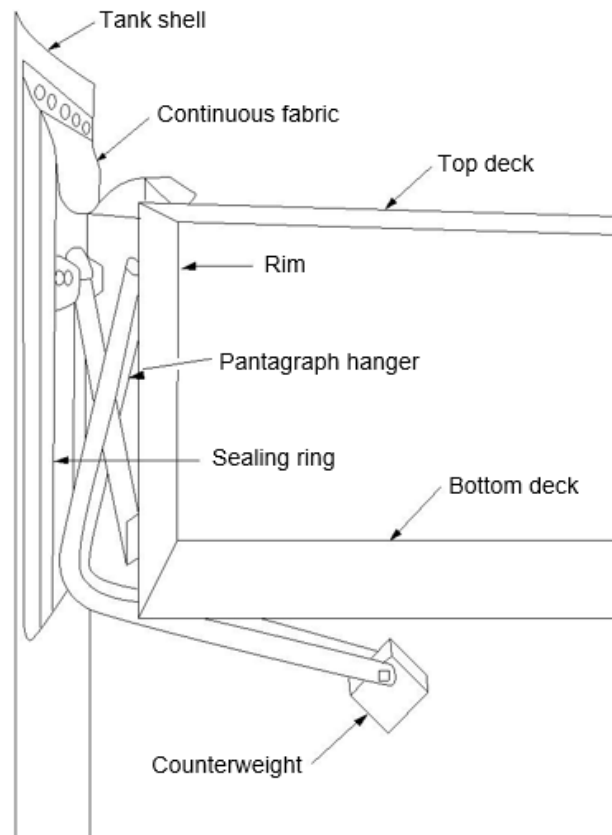


Figure 11—Floating Roof Using Counterweights to Maintain Seal

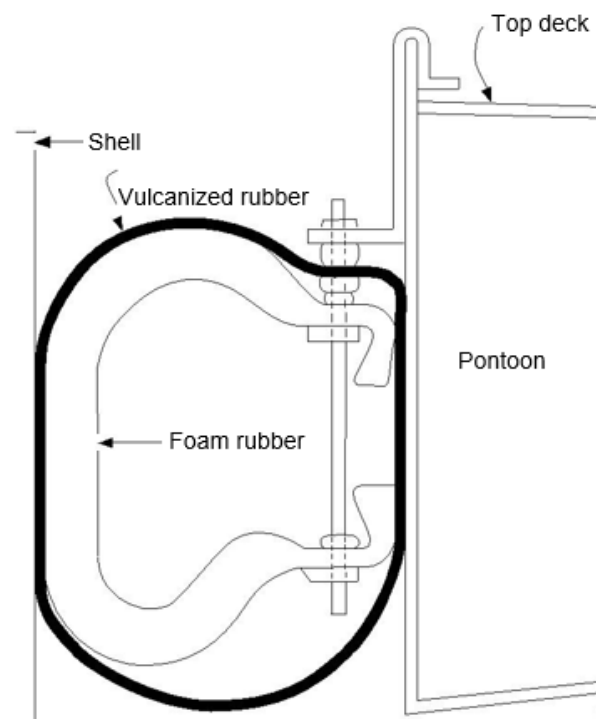


Figure 12—Floating Roof Using Resilient Tube-type Seal

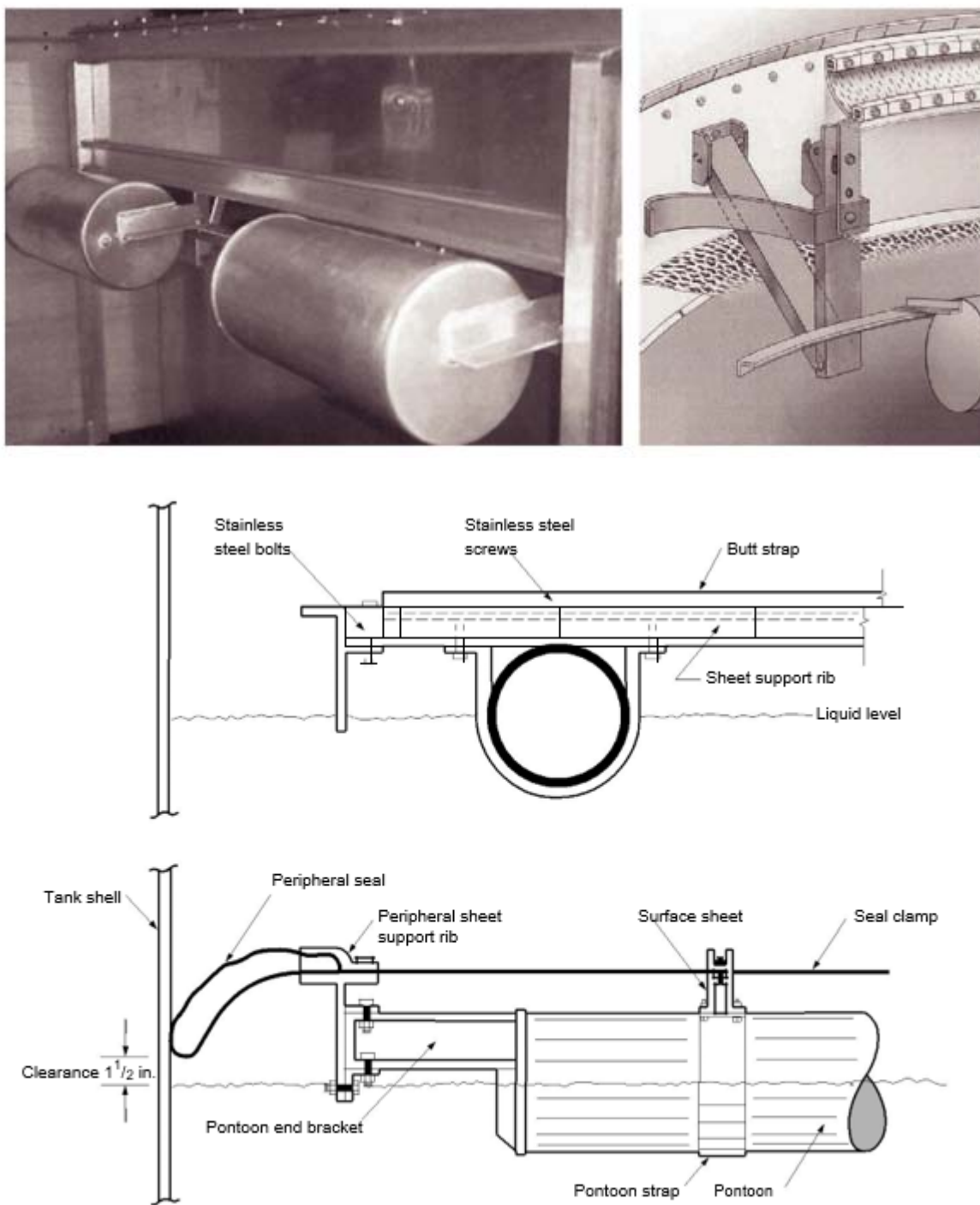
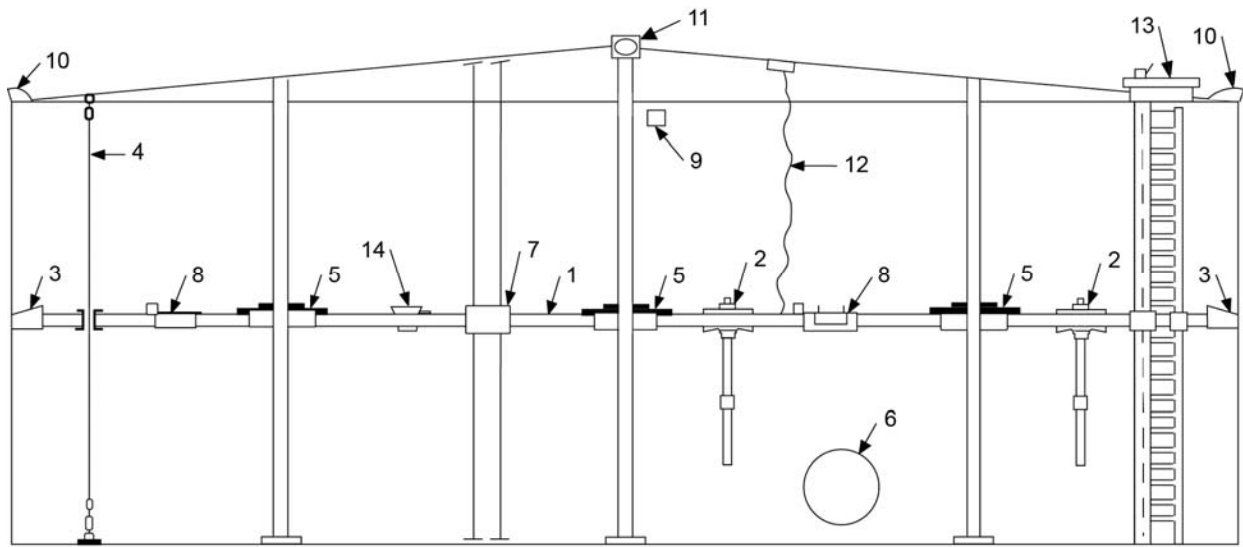


Figure 13—Typical Arrangement for Metallic Float Internal Floating-roof Seals

4.2.3.4 Internal Floating Roof Tanks

Another type of tank has both a fixed roof and an internal floating roof. The fixed roof is usually a supported cone or dome (of steel or aluminum). The internal floating roof can be constructed of steel, aluminum, or other material, as shown in Figure 14. Such tanks are usually built to alleviate weather-related concerns about the flotation of an external floating roof, to reduce vapor emissions, or to prevent product contamination. An existing fixed roof tank often can be modified by the installation of an internal floating roof. Cone roofs with an internal floating roof supported by cables suspended from the fixed cone roof are another design that is being used (see Figure 15).



Notes:

- | | |
|------------------------------|---------------------------|
| 1. deck | 8. vacuum relief device |
| 2. support legs | 9. overflow vent |
| 3. seal | 10. peripheral roof vent |
| 4. anti-rotation device | 11. center roof vent |
| 5. column negotiating device | 12. anti-static grounding |
| 6. manway | 13. roof hatch |
| 7. gauge floatwell | 14. gauge funnel |

Figure 14—Typical Internal Floating-roof Components

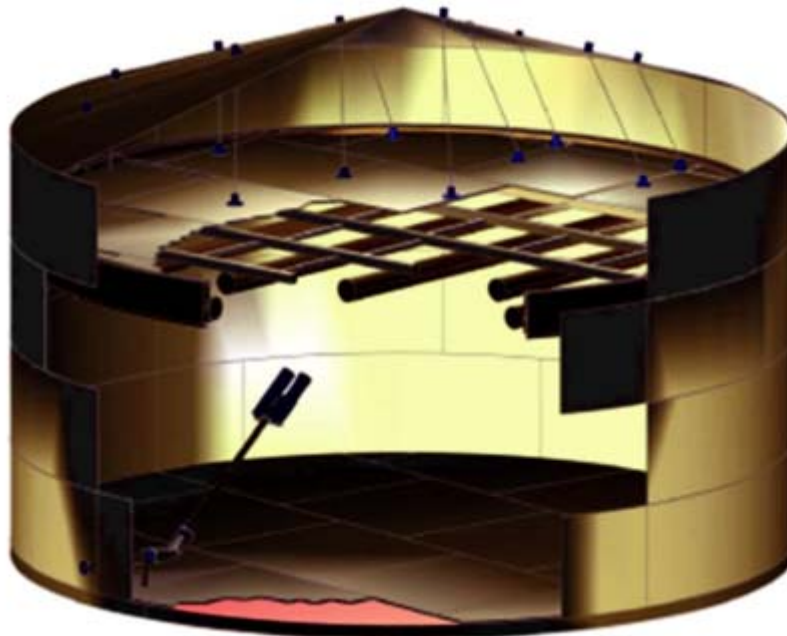


Figure 15—Cable-supported Internal Floating-roof Tank

API Std 650, Annex H classifies internal floating roofs into the following types.

- a) Metallic pan internal floating roofs have a peripheral rim above the liquid for buoyancy. These roofs are in full contact with the liquid surface and are typically constructed of steel. See Figure 5.
- b) Metallic open-top bulk-headed internal floating roofs have peripheral open-top bulk-headed compartments for buoyancy. These roofs are in full contact with the liquid surface and are typically constructed of steel.
- c) Metallic pontoon internal floating roofs have peripheral closed-top bulk-headed compartments for buoyancy. These roofs are in full contact with the liquid surface and are typically constructed of steel.
- d) Metallic double-deck internal floating roofs have continuous closed top and bottom decks that contain bulk-headed compartments for buoyancy. These roofs are in full contact with the liquid surface and are typically constructed of steel.
- e) Metallic internal floating roofs on floats have their deck above the liquid, supported by closed pontoon compartments for buoyancy. These roof decks are not in full contact with the liquid surface and are typically constructed of aluminum alloys or stainless steel.
- f) Metallic sandwich-panel/composite internal floating roofs have metallic composite material panel modules for buoyancy compartments. Panel modules may include a honeycomb or closed cell foam core; however, cell walls within the panel module are not considered “compartments” for purposes of inspection and design buoyancy requirements. These roofs are in full contact with the liquid surface and are typically constructed of aluminum alloys or purchaser-approved composite materials.
- g) Hybrid internal floating roofs shall, upon agreement between the purchaser and the manufacturer, be a design combination of roof types having bulk-headed compartments with closed-top perimeter pontoon and open-top center compartments for buoyancy. These roofs are in full contact with the liquid surface and are typically constructed of steel.
- h) Other roof materials or designs if specified and described in detail by the purchaser.

4.2.3.5 Other Roof Designs

4.2.3.5.1 General

Other less commonly used atmospheric storage tank roof details include the lifter-type roof and the breather-type roof.

4.2.3.5.2 Lifter-type Roof Tanks

Lifter-type roofs prevent vapor losses from the tank by means of liquid or dry seals. Liquid-seal lifter roofs have a skirt on the roof edge that fits into a trough filled with liquid. Dry-seal lifter roofs have a flexible membrane connected to the tank wall and a skirt on the roof edge. In these two lifter-type roofs, the roof is free to move up and down within limits as the tank is filled and emptied or when a change in temperature causes vaporization of the stored product. These types of lifter-roof tanks are less commonly found in service today than in the past.

4.2.3.5.3 Breather-type Roof Tanks

In the breather-type roof, a number of methods are used to provide expansion space for vapors without using a loose external roof. The plain breather-type tank (shown in Figure 16) has a flat roof that is essentially a flexible steel membrane that is able to move up and down within rather narrow limits. The balloon-type roof (shown in Figure 18) is a modification of the plain breather-type roof that is capable of a greater change of volume. A tank with a vapor-dome roof (shown in Figure 17 and Figure 19) uses an added fixed dome with a flexible membrane attached to the walls that is free to move up and down. This type of vapor roof may be designed to provide for any desired change in volume. Vapor recovery systems may use this type of tank.

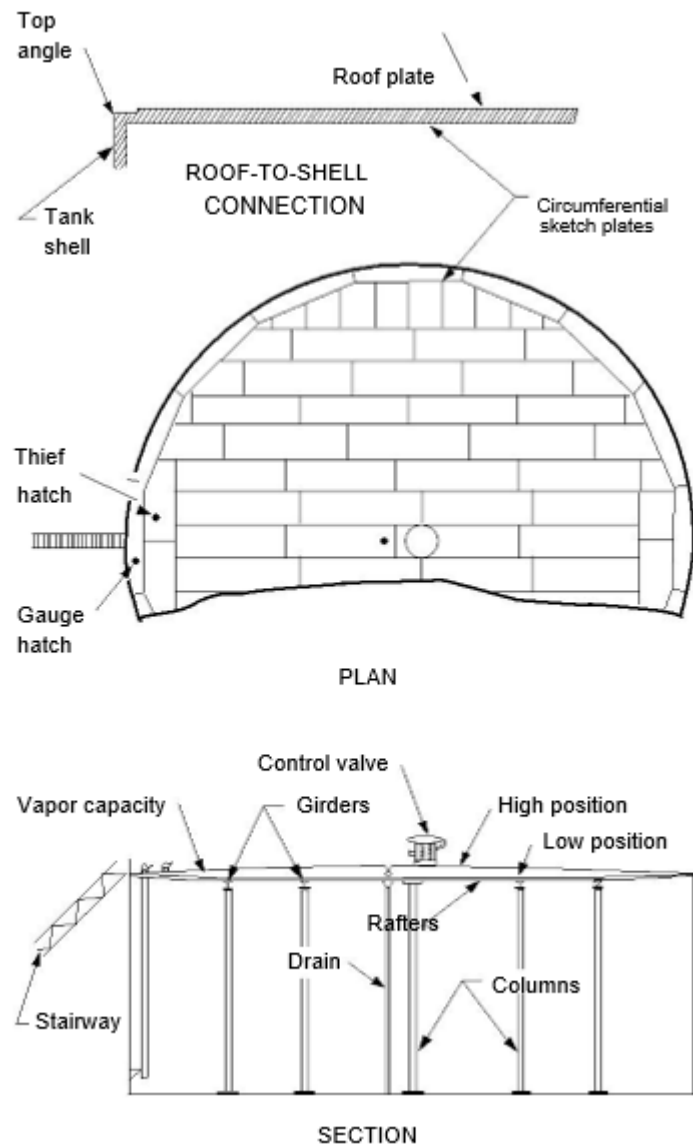


Figure 16—Plain Breather Roof Tanks

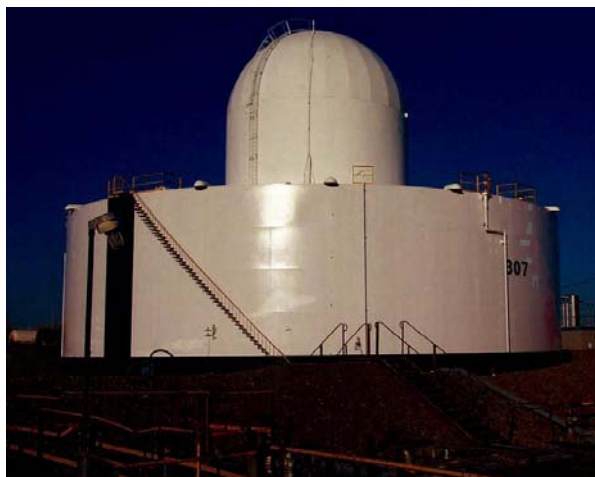


Figure 17—Tank with Vapor Dome Roof

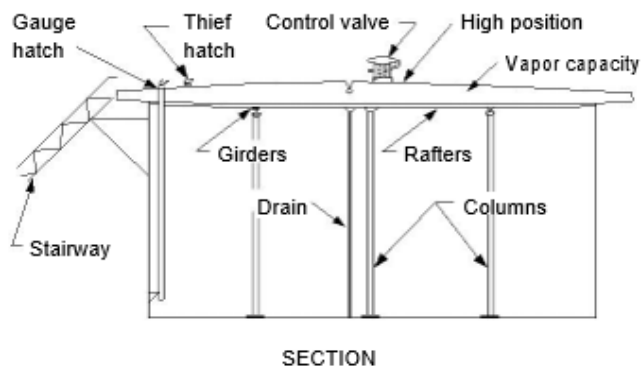
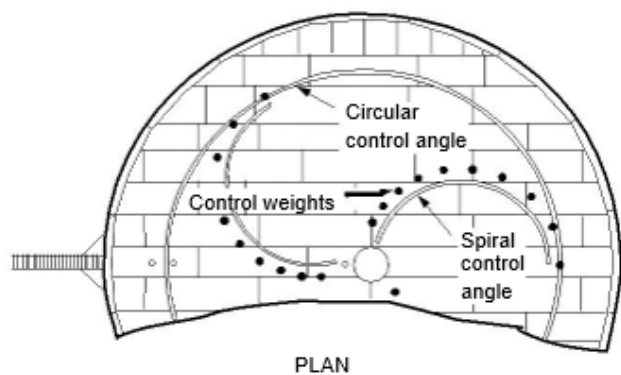
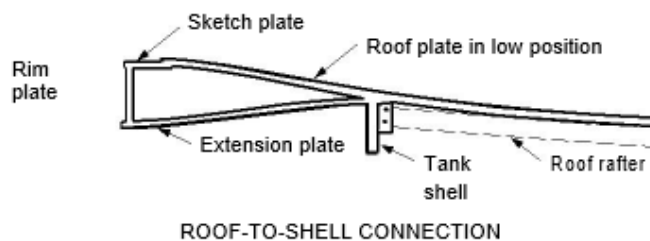


Figure 18—Balloon Roof Tank

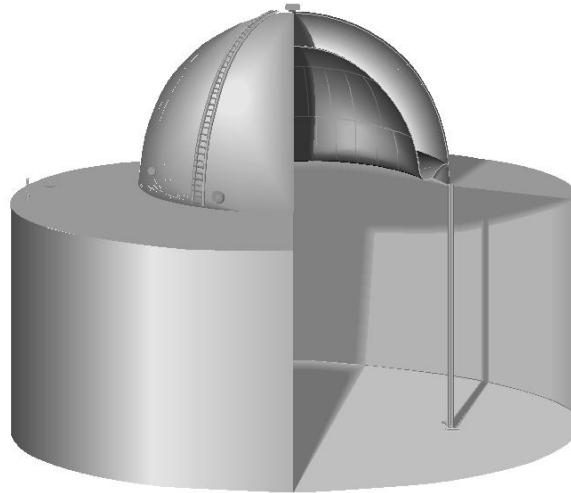


Figure 19—Cutaway View of Vapor Dome Roof

4.2.4 Vapor Recovery Systems

Vapor recovery systems can be provided on several types of tanks such as a fixed cone roof like Figure 1, umbrella roofs like Figure 2, and vapor dome roofs like Figure 17. Adjustment in relief valve settings will be required to accommodate the operating parameters for the vapor recovery system.

4.3 Low-pressure Storage Tanks

4.3.1 Construction, Materials, and Design Standards

Low-pressure storage tanks are those designed to operate with pressures in their gas or vapor spaces exceeding the 2.5 psi (18 kPa) gauge permissible in API Std 650 but not exceeding the 15 psi (103 kPa) gauge maximum limitation of API Std 620. These tanks are generally constructed of carbon or alloy steel and are usually welded, although riveted tanks in low-pressure service are still found. Rules for the design and construction of large, welded, low-pressure storage tanks are included in API Std 620. Venting requirements are covered in API Std 2000.

API Std 625 addresses tank systems designed for storing refrigerated liquefied gas. A tank system consists of one or more containers together with various accessories, appurtenances, and insulation. The metal storage containers themselves are addressed by API Std 620, Annex R for steel containers for refrigerated products from 40 °F (4 °C) to -60 °F (-51 °C) and by API Std 620, Annex Q for steel containers for -60 °F (-51 °C) to -325 °F (-198 °C). ACI 376 addresses concrete containers for 40 °F (4 °C) to -270 °F (-168 °C).

4.3.2 Use of Low-pressure Storage Tanks

Low-pressure storage tanks are used for the storage of the more volatile fluids having a true vapor pressure exceeding the pressure limits of API Std 650 but not more than 15 psi (103 kPa) gauge. Light crude oil, gasoline blending stock, light naphtha, pentane, volatile chemicals, liquefied petroleum gas (LPG), liquefied natural gas (LNG), liquid oxygen, and liquid nitrogen are examples of liquids that should be stored in low-pressure storage tanks.

API Std 620, Annexes R and Q, and ACI 376 provide single-wall and double-wall construction details.

4.3.3 Types of Low-pressure Storage Tanks

4.3.3.1 Cylindrical Tanks

Tanks that have cylindrical shells and cone or dome roofs are typically used for pressures less than about 5 psi (34.5 kPa) gauge. Tank bottoms may be flat or have a shape similar to the roof. Hold-down anchorage of the shell is generally required. For pressures above about 5 psi gauge (34.5 kPa) gauge, hemispheroid, spheroid, and noded spheroid tank types are commonly used. Tanks for this application are now typically constructed as spheres. Such tanks are designed to withstand the vapor pressure that may be developed within a tank having no devices or means to change or relieve the internal volume. As with atmospheric storage tanks, these tanks are provided with relief valves to prevent pressures from rising above design values.

4.3.3.2 Plain and Noded Spherical Tanks

Tanks with a plain spherical roof and tanks with a noded spherical roof are shown in Figure 20 and Figure 21, respectively, and cross-sectional view is shown in Figure 22. Figure 23 shows a plain spheroid, while Figure 24 shows a spherical roof with a knuckle radius or smooth transition at the intersection of the shell and top head.



Figure 20—Plain Hemispheroids

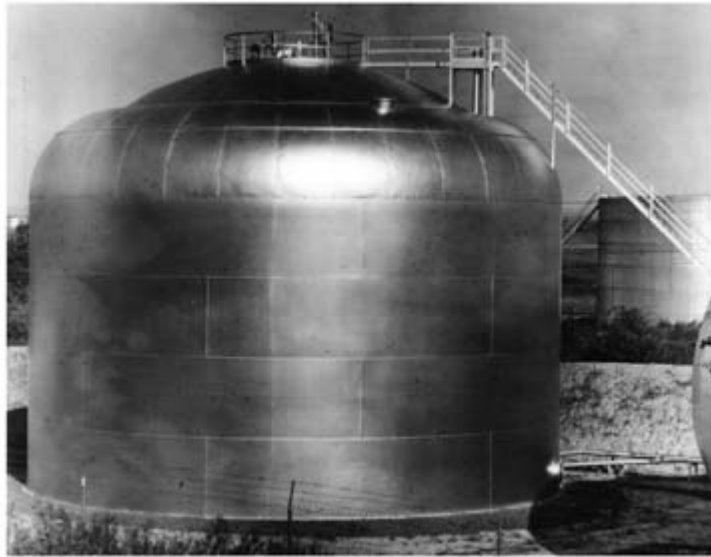


Figure 21—Noded Hemispheroid

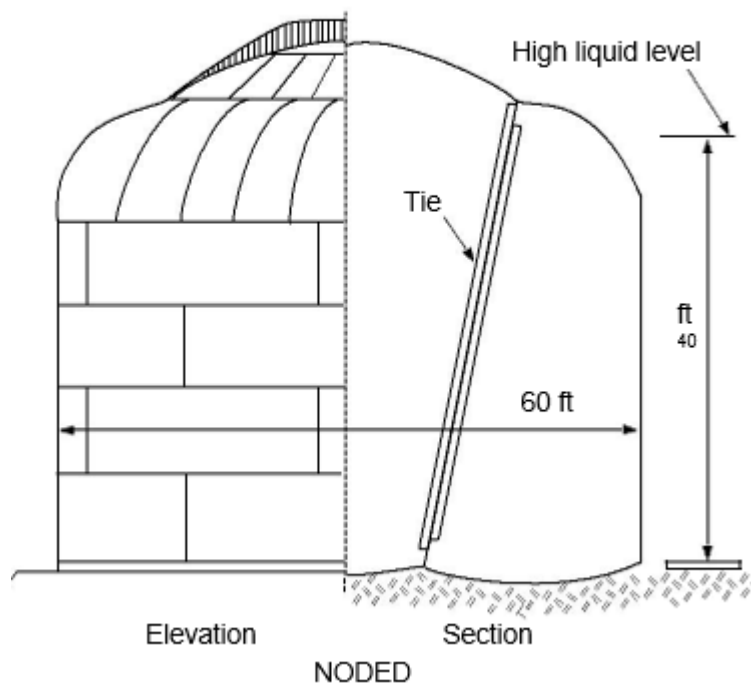


Figure 22—Drawing of Hemispheroid

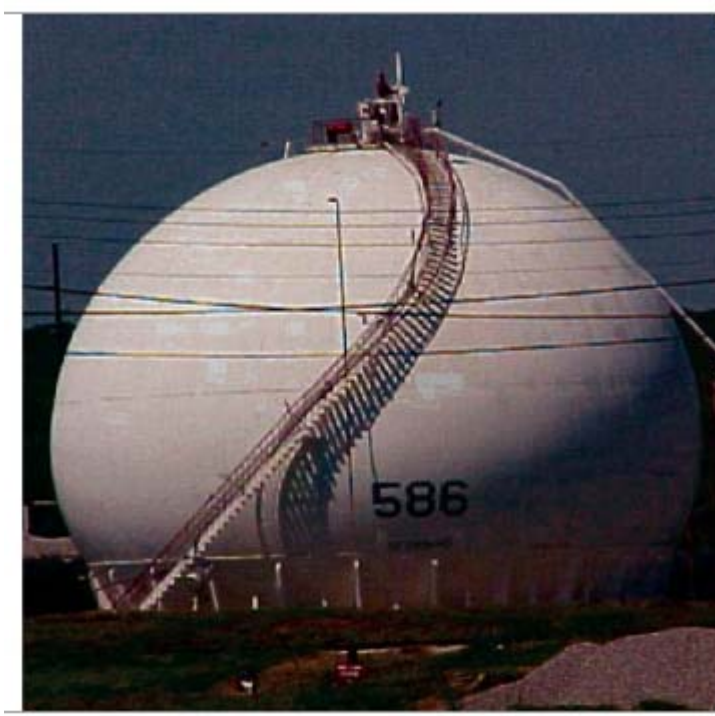


Figure 23—Plain Spheroid

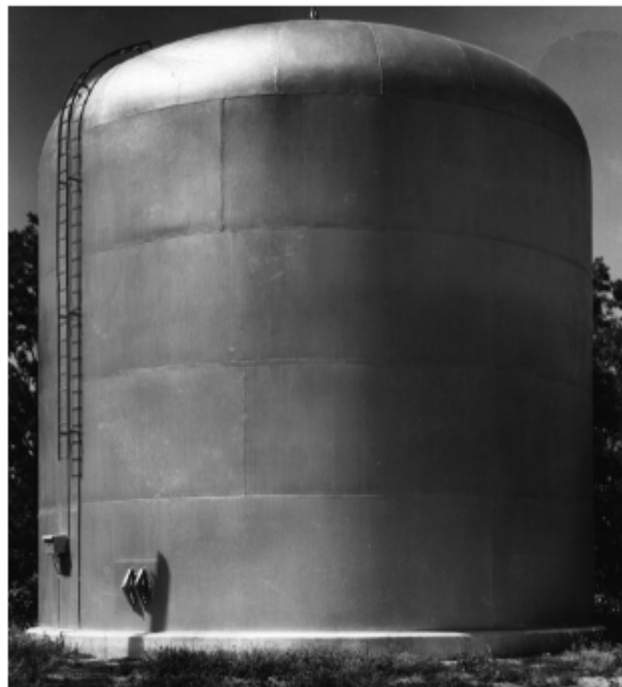


Figure 24—Plain Hemispheroid with Knuckle Radius

4.3.3.3 Spheroids

The spheroid uses elements of different radii, resulting in a somewhat flattened shape as shown in Figure 20. The noded spheroid, shown in Figure 25, is used for larger volumes, and internal ties and supports help to distribute the shell stresses. Figure 26 shows a cross-section of a noded spheroid. Noded spheroids are no longer constructed; they have been replaced either by spheres or by vertical cylindrical storage tanks as referenced in API Std 620.



Figure 25—Noded Spheroid

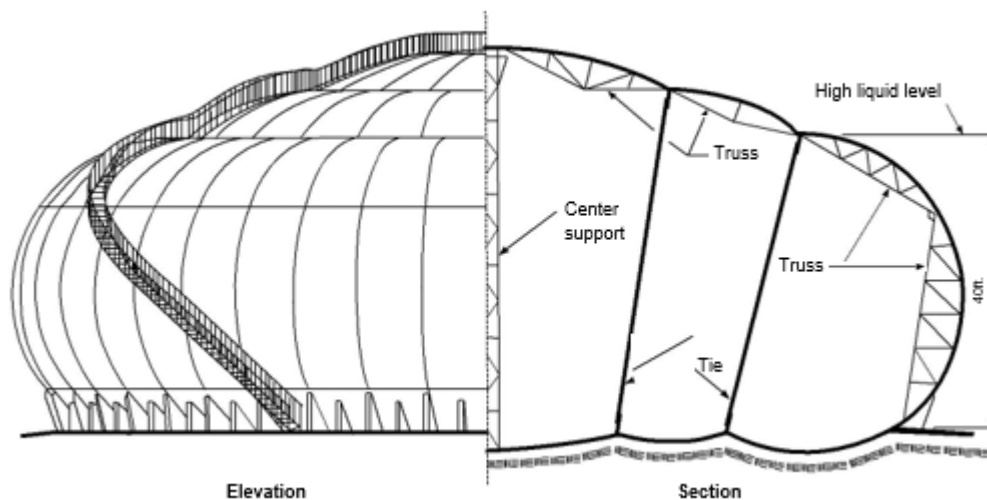


Figure 26—Drawing of Noded Spheroid

4.3.4 Tank Systems for Refrigerated, Liquefied Gas Storage

API Std 625, Section 5 defines and describes various storage concepts for refrigerated liquefied gas tank systems. These include single, double, and full containment concepts. Some of these concepts are briefly described as follows.

4.3.4.1 Single Containment—This system incorporates a liquid-tight container and a vapor-tight container. There are several variants to the single containment concept such as the following.

- 1) Single wall—Single low-temperature steel or concrete tank containing the cold liquid with warm vapor-containing roof, suspended deck with insulation, and external wall insulation. (See API Std 625, Figure 5.1.)
- 2) Single wall—Single low-temperature steel or concrete tank containing the cold liquid with low-temperature vapor-containing roof, external roof insulation, and external wall insulation. (See API Std 625, Figure 5.2.)
- 3) Double wall—Single low-temperature steel or concrete tank containing the cold liquid with a warm vapor-containing roof, suspended deck with insulation, annular space insulation, and warm vapor-containing outer tank (concrete or steel). (See API Std 625, Figure 5.3.)
- 4) Double wall—Single low-temperature steel or concrete tank containing the cold liquid with low-temperature vapor-containing roof, external roof insulation, annular space insulation, and warm vapor-containing outer tank (concrete or steel). (See API Std 625, Figure 5.4.)

4.3.4.2 Double Containment—An inner tank (low-temperature steel or concrete) containing the cold liquid surrounded by a secondary containment tank of steel or concrete that holds any leaked liquid but not any leaked vapor. There are several variants to the double containment concept such as the following.

- Low-temperature steel or concrete primary liquid container, secondary low-temperature steel or concrete secondary liquid container, suspended deck with insulation, warm vapor-containing roof, and insulation on primary liquid container shell. (See API Std 625, Figure 5.5.)

4.3.4.3 Full Containment—An inner tank (low-temperature steel or concrete) containing the cold liquid surrounded by a secondary containment tank of steel or concrete that holds any leaked liquid and provides for a controlled release of vapor. There are several variants to the full containment concept as follows.

- 1) Low-temperature steel or concrete primary liquid container, secondary low-temperature steel or concrete secondary liquid container, suspended deck with insulation, warm vapor-containing roof, and annular space insulation between the liquid containers. (See API Std 625, Figure 5.7.)
- 2) Concrete primary liquid container, concrete secondary containment, and concrete roof. (See API Std 625, Figure 5.10.)

5 Reasons for Inspection and Causes of Deterioration

5.1 Reasons for Inspection

5.1.1 General

The basic reasons for inspection are to determine the physical condition of the tank and to determine the type, rate, and causes of damage mechanisms and associated deterioration. This information should be carefully documented during each inspection (see Section 10 for a list of example documentation). The information and data gained from an inspection contribute to the planning of future inspections, repairs, and replacement and yield a history that should form the basis of good quality permanent inspection records.

5.1.2 Process Safety and Environmental Protection

One of the primary reasons to conduct periodic scheduled inspections is to identify deficiencies that could result in a process safety incident, such as loss of containment, which could lead to fire, toxic exposure, or other environmental hazard. These deficiencies should be addressed as soon as practical through evaluation, further inspection, or repair.