PROCESS
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PRACTICES

TECHNICAL REVISION
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Vessels

PIP VEETA001
Tank Selection Guide

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

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1. Scope

This Practice provides guidelines for the selection and specification of aboveground storage tanks.

This Practice describes guidelines for storage of liquid products in tanks at design pressures from atmospheric to 15 psig (103 kPa). This Practice provides guidance for avoiding recurring problems and outlines preferred practices where appropriate. Although this Practice is intended primarily for carbon steel tanks, most of the guidelines are applicable regardless of the material of construction.

Comment: Requirements for specifying and supplying *API 650* tanks are defined in *PIP VESTA002*.

2. References

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 Process Industry Practices (PIP)

- VESFG001 - *Fiberglass Tank and Vessel Selection, Design, and Fabrication Specification, ASME RTP-1 and Section X*
- VESLP001 - *Specification for Low-Pressure, Welded Shop-Fabricated Vessels*
- VESTA002 - *Atmospheric Storage Tank Specification (Supplement to* API Standard 650*)*

2.2 Industry Codes, Standards, Recommended Practices, and Bulletins

- American Petroleum Institute (API)
  - ANSI/API 12B - *Specification for Bolted Tanks for Storage of Production Liquids*
  - ANSI/API 12D - *Specification for Field Welded Tanks for Storage of Production Liquids*
  - ANSI/API 12F - *Specification for Shop Welded Tanks for Storage of Production Liquids*
  - ANSI/API 12P - *Specification for Fiberglass Reinforced Plastic Tanks*
  - ANSI/API 575 - *Inspection of Atmospheric and Low-Pressure Storage Tanks*
  - API 620 - *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*
  - API 650 - *Welded Steel Tanks for Oil Storage*
  - API 651 - *Cathodic Protection of Aboveground Petroleum Storage Tanks*
  - ANSI/API 652 - *Lining of Aboveground Petroleum Storage Tank Bottoms*
  - API 653 - *Tank Inspection, Repair, Alteration, and Reconstruction*
  - API 2000 - *Venting Atmospheric and Low-Pressure Storage Tanks Non-refrigerated and Refrigerated*
  - API 2003 - *Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents*

- API 2516 - *Evaporation Loss from Low-Pressure Tanks*
- API 2517 - *Evaporation Loss from External Floating-Roof Tanks*
- API 2518 - *Evaporation Loss from Fixed-Roof Tanks*
- API 2519 - *Evaporation Loss from Internal Floating-Roof Tanks*

- American Society of Mechanical Engineers (ASME)

  RTP-1 - *Reinforced Thermoset Plastic Corrosion Resistant Equipment*
  - *ASME Boiler and Pressure Vessel Code*
    - *Section VIII, Division 1 - Rules for Construction of Pressure Vessels*
    - *Section X - Fiber-Reinforced Plastic Pressure Vessels*
- American Society for Testing and Materials (ASTM)
  - D 3299 - *Standard Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks*
  - D 4097 - *Standard Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks*
- American Water Works Association (AWWA)
  - D100 - *Welded Steel Tanks for Water Storage*
- Material Technology Institute (MTI)
  - MS-1 Sulfuric Acid
  - MS-2 Formic, Acetic Acid and Other Organic Acids
  - MS-3 Hydrochloric Acid, Hydrogen Chloride and Chlorine
  - MS-4 Hydrogen Fluoride and Hydrofluoric Acid
  - MS-5 Nitric Acid
  - MS-6 Ammonia and Caustic Soda
  - MS-7 Phosphoric Acid
- National Association of Corrosion Engineers (NACE)
  - NACE SP0178 - *Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service*
  - NACE SP0198 - *The Control of Corrosion Under Thermal Insulation and Fireproofing Materials - A System Approach*
  - NACE SP0294 - *Design, Fabrication, and Inspection of Storage Tank Systems for Concentrated Fresh and Process Sulfuric Acid and Oleum at Ambient Temperatures*
  - NACE SP0388 - *Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage*
- National Fire Protection Association (NFPA)
  - NFPA 11 - *Standard for Low Expansion Foam and Combined Agent Systems*
  - NFPA 15 - *Standard for Water Spray Fixed Systems for Fire Protection*
  - NFPA 30 - *Standard for Flammable and Combustible Liquids Code*

- NFPA 780 - *Standard for Standard for the Installation of Lightning Protection Systems*

- Underwriters Laboratories (UL)
  - 142 - *Steel Aboveground Tanks for Flammable and Combustible Liquids*

2.3 Other Documents

- Philip Myers, *Aboveground Storage Tanks,* McGraw Hill, 1997

3. Definitions

bbl (Barrel): A U.S. Customary unit of capacity measure used in the petroleum industry equal to 42 U.S. gallons of oil

manufacturer: The party responsible for fabricating and/or erecting the tank

owner: The party who owns the facility where the tank will be installed and used

purchaser: The party who awards the contract to the Manufacturer. The Purchaser may be the owner or the owner's authorized agent.

4. Tank Type

4.1 Responsibilities

4.1.1 The Purchaser is typically responsible for furnishing the following:

a. Location, including specific climatic data
b. Stored product information (e.g., specific gravity and vapor pressure)
c. Selection of storage type and roof style
d. Desired volume or overall height and diameter requirement
e. Design pressure
f. Maximum and minimum design metal temperature
g. Selection of materials
h. Connection size, style, and location
i. Limits of work (e.g., foundations, piping, painting)
j. Foundation, including soil investigation and design
k. Corrosion allowance

4.1.2 The Manufacturer is typically responsible for providing the following:

a. Tank outline drawing showing material, plate thicknesses, member sizes, etc.
b. Calculations, if specified by Purchaser
c. Other Manufacturer data, if specified by Purchaser
d. Inspection and testing requirements, unless assigned to the Purchaser by the applicable standards (e.g., *API 620*)
e. Foundations, painting, coating, lining, etc., if specified by Purchaser

4.2 Selection Factors

4.2.1 For selecting the type of tank for a specific service, the following factors should be considered:

a. Vapor pressure, flash point, and temperature of stored product

b. Frequency of turnover (i.e., filling and emptying) and consequent value of vapor losses from filling and breathing

c. Vapor control (including means of vapor recovery and conservation) required because of toxicity, value of product, air pollution restrictions, or applicable federal and local regulatory requirements

d. Fire hazards, both to tank and to adjacent facilities or to property of others

e. Initial capital and maintenance costs

f. Corrosiveness of stored product or the product vapor on the materials used in tank construction

g. Susceptibility of stored product to degradation, decomposition, or contamination from, or as influenced by, the surrounding atmosphere, the period of storage, or the materials used in tank construction

h. Amount of product to be stored

i. Static charge hazards

j. Requirements to enable the measurement of liquid including appurtenances and strapping of the tank for the preparation of gauge tables. Appurtenances should enable the following:

(1) Measuring the liquid level height in the tank

(2) Measuring the average temperature of the liquid contents of the tank

(3) Obtaining average/representative samples of the liquid contents of the tank

(4) Measuring the liquid level height of any water or other foreign material that can be present

k. Inert gas blanketing facilities

4.2.2 For evaluating the effect of evaporation losses and the influence the losses can have on the selection of the type of tank for a specific service: the following API bulletins should be used for guidance: *API 2516*, *API 2517*, *API 2518*, and *API 2519*.

4.2.3 If applicable, modifications of existing tanks should be considered in comparison with the purchase of new tanks. Modifications of existing tanks, such as the following, can often provide essential storage, vapor recovery, or vapor conservation facilities at less cost and in less time:

a. Enlarging the roof-to-shell weld or otherwise strengthening a cone roof to permit increasing the vent valve setting

Comment: Enlarging the weld can eliminate the “frangible joint” character of *API 650* tanks. The addition of emergency vents and other safety features can become necessary. The Manufacturer should be consulted regarding the effect of enlarging the weld on the tank rating. Caution should also be exercised to make sure that the internal pressure is not raised high enough to lift the shell off the foundation.

b. Installing a floating diaphragm in a fixed roof tank to prevent vapor loss or contamination

c. Installing a floating roof

4.3 Industry Codes and Other Sources of Information

4.3.1 General

4.3.1.1 The codes and standards described in this section are commonly used for tank applications.

4.3.1.2 See Table 2.1.2 in Myers (1997) for a more complete listing of tank-related codes and standards.

4.3.1.3 See *PIP VESTA002* for additional requirements applicable to tanks covered by *API 650*.

4.3.2 *API 620* provides construction requirements (i.e., material, design, fabrication, erection, and testing) for large, low-pressure carbon steel, vertical, aboveground tanks with a single vertical axis of revolution. Metal temperatures not greater than 120ºC (250ºF) and design pressures not greater than 103 kPa (15 psig) are covered. Key annexes are the following:

a. Annex C: Tank foundations

b. Annex K: Tank-venting devices

c. Annex L: Seismic design requirements

d. Annex Q: Cryogenic services from -51ºC to -168ºC (-60ºF to -270ºF)

e. Annex R: Low-temperature services from 4ºC to -51ºC (+40ºF to -60ºF)

4.3.3 *API 650* provides construction requirements (i.e., material, design, fabrication, erection, and testing) for large, welded, vertical cylindrical, aboveground, closed and open top welded steel and aluminum storage tanks with atmospheric internal pressure less than or equal to 17.2 kPa (2.5 psig). Key annexes are the following:

a. Annex A: Simplified rules for tanks with thicknesses not exceeding 12.5 mm (1/2 inch)

b. Annex AL: Aluminum tanks

c. Annex B: Tank foundations

d. Annex C: External floating roofs

e. Annex E: Seismic design requirements

f. Annex F: Special designs with small internal pressures up to 17.2 kPa (2.5 psig)

g. Annex G: Aluminum dome roofs

h. Annex H: Internal floating roofs

i. Annex I: Leak protection and foundation systems to protect against tank bottom leakage

j. Annex J: Shop-built tanks not greater than 6.1 m (20 feet) in diameter

k. Annex M: Operating temperatures between 90ºC and 260ºC (200ºF and 500ºF)

l. Annex S: Stainless steel tanks

m. Annex V: External pressure design

n. Annex X: Duplex Stainless Steel Storage Tanks

4.3.4 *API 12D* provides construction requirements (i.e., material, design, fabrication, and testing) for vertical, cylindrical, aboveground, closed top, field-welded steel storage tanks in various standard sizes (i.e., diameters of 4.7 m to 16.8 m (15 feet 6 inches to 55 feet)) and capacities (i.e., 79.5 m^3 to 1590 m^3 (500 to 10,000 barrels)) for internal pressures approximating atmospheric.

4.3.5 *API 12F* provides construction requirements (i.e., material, design, fabrication, and testing) for shop-fabricated vertical, cylindrical, aboveground, closed top, welded steel storage tanks in various standard sizes (i.e., diameters of 2.4 m to 4.7 m (7 feet 11 inches to 15 feet 6 inches)) and capacities (i.e., 14.3 m^3 to 119.2 m^3 (90 to 750 barrels)) for internal pressures approximating atmospheric.

4.3.6 *API 653* provides requirements for carbon and low-alloy steel tanks built to *API 650* and *API 12C*. *API 653* provides minimum requirements for maintaining the integrity of welded or riveted, non-refrigerated, atmospheric pressure, aboveground storage tanks after the tanks have been placed in service. *API 653* also describes the maintenance inspection, repair, alteration, relocation, and reconstruction of such tanks.

4.3.7 *API 650 Annex AL* provides material, design, fabrication, erection, and testing requirements for vertical, cylindrical, aboveground, closed and open top, welded storage tanks constructed of specific aluminum alloys.

4.3.8 *ASME Section VIII, Division 1*, provides mandatory requirements, specific prohibitions, and nonmandatory guidance for pressure vessel materials, design, fabrication, examination, inspection, testing, certification, and pressure relief. Vessels with operating pressures greater than 103 kPa (15 psig) are within the scope of *ASME Section VIII, Division 1*, but vessels with lower pressures can be stamped if required by the Purchaser.

4.3.9 *AWWA D100* provides requirements for design, manufacture, and procurement of welded steel tanks for the storage of water, including reservoir tanks, standpipes, and elevated tanks.

4.3.10 *UL 142* provides requirements for carbon and stainless steel atmospheric to 3.5 kPa (0.5 psig) horizontal and vertical tanks in sizes from 0.227 kl to 189 kl (60 gal to 50,000 gal) intended for aboveground storage of noncorrosive, stable flammable, and combustible liquids that have a specific gravity not greater than that of water.

4.4 Types of Tanks

4.4.1 Atmospheric Storage Tanks

4.4.1.1 Fixed Roof Tanks

1. Fixed roof tanks should be used for the following applications:
   a. For storage of nonvolatile, low-vapor-pressure materials with true vapor pressure less than 5.2 kPa (abs) (0.75 psia) at all operating conditions. The limit of 5.2 kPa (abs) (0.75 psia) for true vapor pressure is approximate. The air pollution regulations for the proposed tank site should be reviewed to determine the actual allowable limit for the vapor pressure with fixed roof tanks.
   b. In conjunction with internal floating roofs if climatic conditions prevent the use of external floating roofs alone.
   c. For the storage of volatile, high-vapor-pressure materials if adequate provisions for control of vapor emissions are provided.
2. If the vapor pressure of the product at maximum rundown or storage temperature is greater than or equal to 75.8 kPa (abs) (11.0 psia), a pressure storage, refrigerated storage, or vapor recovery system should be provided for the tank. For smaller diameter tanks, a vapor-blanketing system may be used even if the vapor pressure is below 75.8 kPa (abs) (11.0 psia).
3. For smaller diameter tanks, a fixed roof with vapor blanketing may be considered in lieu of a floating roof.
4. The three types of self-supporting fixed roof designs (i.e., cone, dome, and umbrella) are competitive in sizes less than 15.2 m (50 feet) in diameter and about 2385 m^3 (15,000 barrels). For larger tanks, column-supported cone roof tanks provide the least expensive storage and require minimal maintenance.
5. For vapor recovery and variable vapor space conservation systems (see Section 4.4.1.5) that require pressures up to 3.4 kPa (abs) (0.5 psig), dome and umbrella roofs are often the most economical types of tanks.
6. Self-supporting roofs have a steeper slope and are typically used for smaller diameter tanks.
7. Tanks in accordance with *API 12D*, *API 12F*, and *UL 142* may be purchased "off the shelf" economically in capacities not greater than 1590, 79.5, and approximately 30.2 m^3, respectively (10,000 barrels, 500 barrels, and 190 barrels).
8. *API 12B* bolted tanks can be readily assembled and disassembled without welding hazards. Bolted tanks can provide the best option for storage capacities of equal to or less than 1590 m^3 (10,000 barrels) where requirements vary (e.g., oil leases). Bolted tanks are subject to leaks but can be simply maintained and repaired. *API 12B*

is no longer published or maintained by API and is cited here for reference only.

4.4.1.2 Floating Roof Tanks

1. Floating roof tanks include the following types:
   a. Open top, external floating roof (i.e., external floater)
   b. Closed top (i.e., fixed roof) with an internal roof or deck, which floats on the surface of the stored product (i.e., internal floater). Internal floating roof tanks can have the following types of over-pressure protection:
      (1) Circulation vents in the fixed roof for natural ventilation of the tank space
      (2) Pressure/vacuum vents to protect the tank from over-pressure or over-vacuum. Tanks using pressure/vacuum vents are called closed floating roof tanks. Closed floating roof tanks permit collection of emissions for further treatment if required.
2. If the true vapor pressure of the stored product is between 5.2 kPa (abs) and 75.8 kPa (abs) (0.75 psia and 11.0 psia), a floating roof tank should be provided. The upper limit of 75.8 kPa (abs) (11.0 psia) is approximate. The air pollution regulations for the proposed tank site should be reviewed to determine the actual allowable upper limit for the true vapor pressure in floating roof tanks.
3. Floating roofs with primary and secondary seals may also have an alternate vapor emission control system.
4. Internal floating roof tanks consist of a fixed roof tank with internal floating roof or deck.
5. The closed top with internal floating roof design provides the following benefits:
   a. Combines vapor control features of a floating roof with the weather protection of a fixed roof
   b. Provides effective insulation for products stored at elevated temperatures
   c. Often competitive with the open top, pontoon-type floating roof in diameters less than 30.5 m (100 feet)
6. The two types of internal floating roofs may be installed in tanks having self-supporting fixed roofs and also in tanks having fixed roofs supported by vertical columns and framing.
7. Internal floating roofs should be in accordance with the minimum requirements of *API 650,* Annex H, and *PIP VESTA002*.

8. Because internal floating roofs are not subject to the same loads as are external roofs, a wide variety of designs and materials are available and costs vary accordingly.
9. Compatibility with stored product should govern the choice of material for the basic roof and seal. For example, if caustic solutions are present, aluminum roofs should be avoided.

4.4.1.3 Lifter, Breather, and Balloon Roof Tanks

1. General
    a. In the past, atmospheric storage was sometimes provided using tanks with lifter or breather roofs or using fixed roof tanks equipped with floating membranes.
    b. Groups of lifter or breather type tanks may be arranged in a connected group having a variable vapor space system by connecting tank vapor spaces. However, a tank should not be connected to another tank using a vapor space connection if different liquids are stored and if mutual contamination or degradation can result from co-mingling vapors.
2. Lifter Roof Tanks
    a. The conventional gas lifter type of gas holder is becoming a rarity because of modern volume control management.
    b. Basic operation of lifter roof tanks is that of nesting shells acting as pistons. The floating shells are loosely cylindrical and may be metallic or a flexible membrane. The tanks are equipped with roof-leveling systems and have guided vertical motion. The roofs are typically metallic and weighted to reduce the amount of anchorage required.
    c. The two basic types of lifter roof tanks are wet seal and dry seal which have the following characteristics:
        (1) The wet seal type has a floating roof and shell that nest into a liquid-containing double wall seal that permits the roof portion to rise and fall as the volume changes.
        (2) The dry seal type drapes a “rubber” membrane between nesting roof sections. The outer container is typically a fixed roof tank having the membrane attached to its cylinder and to a smaller diameter inner roof.
    d. *API 620* states that it does not apply to lift-type gas holders. See *API 575* for additional information on this type of tank.
3. Breather Roof Tanks
    a. The breather roof type of tank is intended to permit a small volume change to accommodate vapor accumulation for internal breathing for storage of volatile liquids. The pressure in the tank is approximately limited to the weight of the roof panels.

b. A supported, flexible metallic roof of flat or slightly concave contour can rise off its structural framing and act as a self-supporting roof as the vapor space pressure increases.

c. An industrial design standard does not exist for breather roof tanks. *API 575* illustrates the salient features of this type of tank.

4. Balloon Roof Tanks

a. The balloon roof type of tank can permit higher vapor volume changes than the breather roof type of tank.

b. The flexible roof is externally stiffened and counterweighted and can withstand greater vapor space pressure than the breather roof type.

c. Balloon roof tanks are anchored. Typical internal design pressures are not greater than 0.43 to 0.86 kPa (1 to 2 ounces per square inch gage).

d. An industrial design standard does not exist for balloon roof tanks. *API 575* illustrates the salient features of this type of tank.

4.4.1.4 Structurally Supported Aluminum Dome Roofs

1. Structurally supported aluminum dome roofs are described in *API 650,* Annex G.

2. The dome roof is an all-aluminum, clear-span, self-supporting space truss with aluminum panels. An integral tension ring takes the primary horizontal thrust. The roof is attached to and supported by the tank at mounting points equally spaced around the perimeter of the top shell.

3. Dome roofs are available in diameters greater than 91.4 m (300 feet).

4. Structurally supported aluminum dome roofs are used for the following applications:

a. Conversion of external floating roof tanks to internal floating roof tanks

b. Cover for new internal floating roofs

c. Replacement of existing, deteriorated steel roofs

4.4.1.5 Vapor Conservation Tanks

1. Vapor conservation tanks (i.e., variable-vapor space tanks) are often used to accommodate the evaporation loss inherent with a cone roof tank, if the expanding air-vapor mix is vented.

2. A vapor conservation device provides a dry air or gas blanket on an existing fixed roof tank. Some alteration to the tank (e.g., heavier top angle) may be required.

3. Types of vapor conservation tanks include the following:

a. Gas holder (e.g., wet seal/dry seal types, single/multiple lift, etc.)

b. Flexible membrane. Membrane or similar type of fabric material is subject to pinhole leaks or tears. Unlike the fabric in a floating roof seal, membrane material can be difficult to inspect and repair.

4. It may be possible to connect other gas-tight cone roof tanks to a vapor storage unit through interconnected piping, forming a vapor-saving system.

4.4.1.6 Vapor Bladder Tanks

1. With the advent of vapor recovery in petroleum distribution systems, vapor domes were retroactively added to existing cone roof tanks to add greater vapor space. Vapor domes were typically small dome cupolas lined with flexible rubber bladders of slightly smaller size than the external roof. Later, full-diameter hemispherical and structurally supported dome roofs were built with suspended rubber bladders of greater volume than the earlier vapor domes.

2. A vapor bladder-type tank that has a ring-type truncated cone can provide greater volume capacity change because of the uniform liner shape transition of the tank, which is attributable to tensioned shroud lines from the bladder to a central internal counterweight.

3. An industrial design standard does not exist specifically for vapor bladder tanks. Myers (1997) and *API 575* provide general descriptions for this type of tank.

4. Although the following standards do not cover all details, typically the available industry standards should be applied as follows:

   a. If vapor bladder tanks are to be used for atmospheric pressure applications, *API 650* should be applied.

   b. If internal pressure is a design load, *API 620* should be applied.

   c. For spherical shapes or for other non-cylindrical shapes, *API 620* should be applied, regardless of the pressure.

4.4.2 Low-Pressure Tanks

4.4.2.1 *API 620* provides design and construction requirements for large, welded, field-erected storage tanks operated at a gas pressure of 103 kPa (15 psig) and less, with a configuration of a single vertical axis of revolution.

4.4.2.2 Depending on design pressure and capacity, low-pressure storage tanks may be any of the following types:

a. Cylindrical with flat bottom and dished or coned roof

b. Cylindrical with both roof and bottom dished or coned

c. Spherical

d. Spheroidal

4.4.2.3 *API 620* also provides design and construction requirements for anchored flat bottom tanks.

4.4.2.4 *API 620,* Annex R provides requirements for tanks used to store refrigerated products with storage temperatures from +4ºC to -51ºC (+40ºF to -60ºF). Typical products stored in *API 620*, Annex R-type tanks include butane and propane. These products are stored at temperatures near their boiling points. For example, commercial propane is stored at +7.6ºC (-45.6ºF).

4.4.2.5 *API 620,* Annex Q provides requirements for tanks used for storage temperatures from -51ºC to -168ºC (-60ºF to -270ºF) and includes stainless steel, nickel alloy, and aluminum materials. Typical products stored in *API 620,* Annex Q-type tanks include ethylene at -103.3ºC (-154ºF) and methane at -162ºC (-259ºF).

4.4.3 Other Storage Containers

4.4.3.1 Vessels

1. Vessels may be used for storage at pressures less than 103 kPa (15 psig) even though *ASME Boiler and Pressure Vessel Code, Section VIII, Division 1*, covers design pressures greater than 103 kPa (15 psig).
2. If the vessel is bullet-shaped, having a horizontal axis of revolution, and formed heads, *ASME Code, Section VIII, Division 1*, provides requirements for design that are more applicable than those of *API 620*.
3. See *PIP VESLP001* for requirements for low-pressure vessels.

4.4.3.2 Fiberglass Vessels and Tanks

1. Fiberglass tanks and vessels are used to contain corrosive and other hazardous materials.
2. *ASME Boiler and Pressure Vessel Code, Section X,* provides the minimum requirements for fabrication of fiber-reinforced thermosetting plastic pressure vessels for general service. Requirements are provided for the following vessel classes:
    a. Class I vessels designed not to exceed the following pressures:
        (1) For bag-molded, centrifugally cast, and contact-molded vessels, 1000 kPa (150 psi)
        (2) For filament-wound vessels, 10,000 kPa (1500 psi)
        (3) For filament-wound vessels with polar boss openings, 20,685 kPa (3000 psi)
    b. Class II vessels limited to diameter and pressure controls (e.g., 3.7 m (144 inches) in diameter and 1380 kPa (200 psig) pressure). Additional restrictions apply, however, that may decrease these limits.
3. *API 12P* provides requirements for material, design, fabrication, and testing for fiberglass-reinforced plastic (FRP) tanks having the following characteristics:

a. Shop-fabricated, vertical, cylindrical tanks

b. Tanks are intended for aboveground and atmospheric pressure service

c. Unsupported cone bottom tanks are not included

4. *ASME RTP-1* provides requirements for the materials of construction, design, fabrication, quality control, and inspection of reinforced thermoset plastic (RTP) vessels operating at pressures not greater than 103 kPa (15 psig) externally and/or 103 kPa (15 psig) internally above any hydrostatic head.

5. *ASTM D3299* provides requirements for materials, properties, design, construction, dimensions, tolerances, workmanship, and appearance for cylindrical tanks fabricated by filament winding having the following characteristics:

   a. For aboveground vertical installation

   b. Contain aggressive chemicals at essentially atmospheric pressure (i.e., 3.4 kPa (±0.5 psig)), as classified therein

   c. Made of a commercial-grade polyester or vinyl ester resin

6. *ASTM D4097* provides requirements for materials, properties, design, construction, dimensions, tolerances, workmanship, and appearance for cylindrical tanks fabricated by contact molding having the following characteristics:

   a. For aboveground vertical installation

   b. Contain aggressive chemicals at essentially atmospheric pressure (i.e., 3.4 kPa (±0.5 psig))

   c. Made of a commercial-grade polyester or vinyl ester resin

7. *PIP VESFG001* provides requirements for materials selection, design, fabrication, testing, inspection, and documentation for fiberglass vessels and tanks to be constructed in accordance with *ASME Boiler and Pressure Vessel Code, Section X,* or *ASME/ANSI RTP-1.*

4.4.3.3 Vessels designed in accordance with *ASME Section VIII, Division 1,* provide a good alternative for storage if deflagration or detonation design considerations are required.

4.4.3.4 *NACE SP0294* provides requirements for design, fabrication, and inspection of tanks in concentrated sulfuric acid and oleum service.

4.4.4 Comparison of Tank Types

4.4.4.1 Fixed Roof Tanks

1. Fixed roof tanks have breathing and filling losses.
2. Fixed roof tanks can have vapor space corrosion.
3. Maintenance is simpler for fixed roof tanks.

4. For smaller diameters (i.e., generally less than 15.2 m (50 feet)), fixed roof tanks are typically more economical than other types of tanks.
5. Some fixed roof types can be seal welded if internal lining is required.

4.4.4.2 Self-Supporting Roofs

1. Access to tank appurtenances can be difficult because of roof slope.
2. If a frangible joint cannot be provided, special venting provisions can be required.
3. Internal supports that can interfere with underside access do not exist.
4. Because required framing can be placed on the exterior, seal welding can be performed.
5. Self-supporting roofs cost more than supported roofs.

4.4.4.3 Floating Roof Tanks

1. A floating roof tank is the most effective conservation tank for non-pressure storage.
2. Fire hazard is low for a floating roof tank because of the absence of a vapor zone.
3. If consequent values of vapor losses are considered, external floaters can be cost competitive with cone roofs for larger sizes.
4. Corrosion of exposed, unprotected shell plates can contaminate stored product.
5. External floaters can pose drainage problems.
6. External floaters can be difficult to operate in cold climates.
7. An internal floating roof tank provides the benefits of floating roof emission control and the low cost of maintenance of a fixed roof tank.
8. Monitoring of corrosion of carbon steel floating roofs is required to ensure structural integrity.
9. External floating roof tanks may require emission control on accessories (leg supports, guide poles).

4.4.4.4 Lifter Roofs

1. Lifter roofs are the least expensive roof for high-purity, low turnover-frequency storage.
2. Lifter roofs can serve as variable vapor space reservoirs if connected to other tanks by tank vapor space connections.
3. Industry standards for lifter roof tanks are not available.

4.4.4.5 Breather Roofs

1. Breather roofs provide greater vapor capacity than do lifter roofs.
2. Stored product is fully protected from contamination or vapor dilution.
3. Filling losses are less than for fixed roofs but are not completely eliminated. However, filling losses can be nearly eliminated if the breather roof diaphragm is the same diameter as the tank.
4. Maintenance on roof seal is required.
5. For a breather roof with a membrane bag or guided pistons in the vapor zone, maintenance is required on membrane or pistons.
6. Industry standards for breather roof tanks are not available.

4.4.4.6 Structurally Supported Aluminum Dome Roofs

1. Stored product emissions can be reduced because domes eliminate the wind evaporative effect and lower product temperature by reflecting sunlight.
2. A dome can keep water out of the tank and off the floating roof, thereby lowering the risk of having problems with disposal of water and contamination of sensitive products. Also, in areas subject to snow and ice accumulation, roof drain plugging problems can be reduced. These benefits should be considered for remote tank locations and for tank locations that do not have water treatment facilities.
3. Aluminum construction may be more corrosion resistant than carbon steel; thereby maintenance costs can be reduced.
4. Except for *API-650* Annex G, industry standards do not exist for some dome roof details.
5. By providing a dome roof, some components typically required for an external floating roof can be eliminated.

4.5 Selection of Tank Size

Factors that can affect the size or dimensions of tanks for a particular service include the following:

a. Land costs
b. Soil conditions
c. Regulations for diking and tank spacing
d. Shipping limits
e. Site conditions
f. Type of tank roof used
g. Process/Operation Requirements

5. Tank Components

5.1 General

5.1.1 Tankage should be in accordance with applicable jurisdictional rules and regulations (e.g., EPA and OSHA) or equivalent local, regional, or national regulations.

5.1.2 *API 650* Tank Data Sheets should be used to specify such information as the following:

a. Tank geometry or capacity

b. Metallurgy of components and corrosion allowance

c. Design loads and load combinations

d. Applicable industry code or allowable stresses

e. Other significant information (e.g., climatic design data) which is required by the tank manufacturer to determine plate thicknesses and sizing of other tank components

5.2 Foundations

5.2.1 In most cases, the foundation design and installation are furnished by Purchaser.

5.2.2 The party responsible for furnishing the foundation should prepare or obtain a soil report specifying the allowable soil-bearing pressure. The subsurface investigation and resulting bearing value should be provided by a qualified soils engineer.

5.2.3 Soil-bearing pressure is the primary factor in selecting the proper type of foundation. Typically, the most economical storage cost results from using the tallest tank that the soil can support without excessive settlement. If a low-soil-bearing pressure indicates using less economical tank proportions, alternate foundation schemes should be explored.

5.2.4 For tanks storing heated or cold products, experienced and qualified expertise is required to assure that adequate foundation design is performed. For proper and economical design of foundations, every site should have a subsurface investigation. Random exploration should not be permitted. Typically for large tanks, a minimum of three borings, equally spaced at 120 degrees on a circumscribing circle 1.5 m (5 feet) outside the foundation should be performed. The soils engineer should specify allowable soil-bearing pressure on the basis of given tank loads and results of the investigation.

5.2.5 Foundation types appropriate for flat bottom tanks typically are included in the following broad categories:

a. Earth foundations, without a concrete ringwall

b. Concrete ringwall, with or without a concrete footing

c. Concrete slab, floating or pile-supported

5.2.6 Typically, foundations for flat bottom tanks can be earthen types without a concrete ringwall.

5.2.7 Concrete ringwall foundation should be considered for larger tanks, particularly floating roof tanks. Uneven settling of a foundation can cause a large tank to go out of round, causing the seal to lose effectiveness or, in some cases, causing a floating roof to jam.

5.2.8 Regardless of foundation type, foundation design should provide for suitable drainage designed to keep the tank bottom dry.

5.3 Bottom

5.3.1 Typically, tank bottom plates for flat bottom tanks are lap welded. However, for tanks installed on grillage, the bottom plates should be butt-welded.

5.3.2 Lap-welded bottom plates should provide a shingle such that the stored product drains in a downward direction, without pockets at overlap weld seam to trap product.

5.3.3 Providing a crowned bottom (e.g., coned up at tank center) can facilitate cleaning and compensate for the extra settlement that can occur at the tank center relative to the outer edge.

5.3.4 The *API 650* Tank Data Sheet should be used to specify the type of bottom configuration, including slope requirement, and state whether undertank leak detection and subgrade protection is required. Bottom slope for crown or cone bottom tanks can vary depending on the intended service of the tank.

5.3.5 Of all major tank components, the bottom is probably the most often repaired or replaced. *API 653* provides a long list of causes of bottom failures that necessitate appropriate corrective action.

5.4 Shell

5.4.1 The shell plate thicknesses are typically determined by the Manufacturer, using design loads, design criteria, tank geometry, and material allowable stresses, as specified by the Purchaser on the *API 650* Tank Data Sheet.

5.4.2 Optional design procedures, included in *API 650* for example, may permit higher design stresses because of a more refined engineering design, greater inspection, and use of shell plate steels with demonstrably improved toughness. Tanks built with an optional design procedure will have thinner shells and therefore reduced resistance to buckling under wind when empty or subjected to external pressure or vacuum. If additional shell stiffness is required, either increased shell plate thickness or intermediate windgirders may be provided.

5.4.3 Anchorage of a tank to a concrete foundation can be required because of internal pressure, wind, seismic loading, prevention of flotation, or possibility of deflagration.

5.4.4 Windgirders used for personnel access may require handrailing past the stairway opening.

5.5 Roof

5.5.1 General

5.5.1.1 Minimum slope of an *API 650* column-supported cone roof is 6.25 cm/m (¾ inch per foot). Increasing this slope should be done with caution. A relatively flat roof can follow the variations resulting from differential settlement. A steeper cone roof can develop buckles.

5.5.1.2 *API 650,* Annex F, provides details of roof-to-shell junction for tanks if an internal pressure has been specified. Otherwise, a frangible joint is preferred if feasible. The purpose of a frangible joint roof seam is to provide a “weak” joint that is designed to fail under excessive internal pressure before failure occurs in the tank shell joints or the shell-to-bottom connection.

5.5.1.3 Roofs that are to be internally coated should be seal welded on inside and outside or should be double butt-welded.

5.5.1.4 If a roof requires an internal lining or coating, consideration should be given to selecting a roof that does not require internal support. This type of roof design minimizes surface area and provides a smooth interior for coating and future maintenance. If the frangible feature is lost, emergency-venting devices should be provided.

5.5.1.5 Although tanks with self-supporting cone, dome, and umbrella roofs are cost competitive with column-supported cone roof tanks in diameters smaller than approximately 15.2 m (50 feet), self-supporting roofs can be required because of the intended tank service (e.g., coating or lining requirements, internal pressure, etc.).

5.5.1.6 Because self-supporting cone roofs do not require framing, the roof diameter is limited. *API 650* limits roof slope to 2:12 minimum and 9:12 maximum. *API 650* limits roof plate thickness to 5 mm (3/16 inch) minimum and 13 mm (1/2 inch) maximum. Manufacturer would probably butt weld roof plates at thicknesses greater than 9 mm (3/8 inch). The steeper roof slope affects the capability to support personnel on the roof and therefore can add to the cost of walkways and platforms.

5.5.2 Dome and Umbrella Roofs

5.5.2.1 Dome Roof

1. A dome roof is formed to the surface of a spherical segment.
2. Dome plates are dished and supported only at the periphery. Framing is typically required only for construction purposes and can be removed after erection.

5.5.2.2 Umbrella Roof

1. An umbrella roof consists of wedge-shaped sections formed in one direction (not dished).
2. Permanent framing may be required on umbrella roofs.

5.5.2.3 Framing

1. If service conditions require that the tank be internally lined or coated, any roof framing required should be placed on the exterior.

2. If external framing is required, consideration should be given to seal welding the members to avoid crevice corrosion, rust streaks, and paint discoloration.
3. External framing can be a tripping hazard.

5.5.3 External Floating Roof

5.5.3.1 External floating roofs in open top tanks are designed to float directly on the product. The types of external roofs are pan, single deck (i.e., pontoon), and double deck.

5.5.3.2 Pan type floating roofs without bulkheads are unstable and the use of pan type roofs is not permitted by *API 650*.

5.5.3.3 Single Deck Floating Roofs

1. Single deck roofs consist of a deck supported by annular pontoons. Many variations exist but most are designed to float directly on the stored product.
2. The single center deck of a pontoon floating roof can be designed to balloon upward if the stored product boils, thereby retarding further vapor formation. The deck can be designed to slope downward under water load and thereby permit water withdrawal through the drains.
3. Single deck pontoon roofs with compartmental annular pontoons have load-carrying capacity and flotation capability that provide stability.
4. If severe wind conditions occur, or if the tank diameter is very great, the center deck of a single deck roof can flex significantly, thereby causing fatigue cracks in welds. Providing stiffeners or seal welding from both sides of the deck may be required to reduce flexing.
5. The single deck can be susceptible to vapor loss on stored products having high vapor pressures.
6. Of the external floating types, the single deck roof is preferred because of lower initial cost. However, for tank diameters less than approximately 12 m (40 feet), double deck pontoons are typically more cost effective than the single deck type.

5.5.3.4 Double Deck Floating Roofs

1. Double deck floating roofs have two complete decks over the liquid surface.
2. Double deck floating roofs provide the following benefits:
   a. Insulation (which retards boiling of product)
   b. Simplified drainage
   c. A clear and maintenance-free deck
   d. Stability during constant steady winds
   e. Good performance in high-rainfall conditions

5.5.4 Internal Floating Roof

5.5.4.1 The types of internal roofs are as follows:

a. Metallic (typically aluminum or stainless steel) roofs on floats

b. Single deck or double deck metallic roofs

c. Other internal roofs using metallic or plastic sandwich panels

d. Composite glass-reinforced panels with self-buoyant cores

5.5.4.2 Either the required net working capacity or the tank dimensions should be clearly specified on the *API 650* Tank Data Sheet.

5.5.4.3 Each tank manufacturer can have different freeboard measurements because of the following design requirements:

a. Seal device configurations

b. Fixed roof framing arrangements

c. Provisions for foam makers, foam dams, and secondary seals

5.5.4.4 Any one or a combination of the following conditions or substances could cause severe agitation of the stored product, causing splashing of liquid onto the roof around the seals, and possible sinking of the roof:

a. Butane-blending procedures

b. Hydrocarbons with high vapor pressures

c. Gaseous products

d. Mixing operations

5.5.4.5 The service conditions for the tank should be clearly specified on the *API 650* Tank Data Sheet.

5.5.4.6 Existing cone roof or preferably self-supporting roof tanks can be altered to internal floaters with the addition of an internal roof. The following should be considered before installing an internal floating roof in an existing tank:

a. Condition of tank (e.g., out of roundness, severe buckles, riveted shell, out of level, internal shell attachments, etc.)

b. Internal framing (e.g., type of columns, column seals, removal of internal bracing)

c. Manway size and location (e.g., requirements for additional manways and platforms to provide installation and maintenance access for the internal floating roof)

d. Roof inlet nozzles (e.g., nozzles should be modified to provide an extension)

5.5.4.7 Requirements for operating space for internal roof accessories (e.g., secondary seal, foam chambers, foam dam) can reduce tank capacity.

5.5.5 Structurally Supported Aluminum Dome Roof

In many cases, a structurally supported aluminum dome roof is used in a retrofit situation (e.g., converting an existing open top floating roof tank to an internal floater). Typically, the upper shell of the existing tank requires some reinforcement to accommodate the point loads imposed by the dome roof.

6. Tank Accessories

6.1 Floating Roof Seals

6.1.1 A seal or sealing system is designed to close the annular rim-shell space.

6.1.2 Properly designed sealing systems provide the following protections:

a. Maintain the gap between the floating roof and the shell

b. Maintain normal roof movement

c. Provide protection from weather (i.e., wind, rain, lightning) and fire

6.1.3 Seal systems should be designed in accordance with existing jurisdictional regulations.

6.1.4 Evaporative loss from floating roof seals can be reduced by the following techniques:

a. Installing a primary seal with a low rim seal loss factor

b. Reducing gaps in the primary seal

c. Reducing gaps in the secondary seal

6.1.5 Because liquid-mounted primary seals lack the large rim vapor space below the primary seal, liquid-mounted primary seals have lower vapor losses than vapor-mounted primary seals.

6.1.6 Rim-mounted secondary seals effectively reduce rim seal vapor losses by decreasing the wind-related convection effect on the evaporative loss from the primary seal. Secondary seals also reduce the potential for fires caused by lightning.

6.1.7 Seal types are grouped in two broad categories:

a. Metallic

b. Non-metallic

6.1.8 The most common seal types are mechanical shoe seals and resilient toroidal envelope seals (i.e., liquid-filled or foam logs).

6.1.9 Primary seals are always required on floating roofs. Secondary seals can also be required for special service conditions or because of air pollution regulations.

6.1.10 Manufacturers typically provide manufacturer standard primary and secondary seals. However, some Manufacturers can provide a wide spectrum of seal configurations.

6.2 Nozzles and Manways

6.2.1 Typically, pipe connections through the shell are located in the first shell course.

6.2.2 Typically, piping loads on shell connections are calculated. However, *API 650,* Annex P, provides design information regarding first-course shell connections subjected to external pipe loading.

6.2.3 Nozzles and manways should not be located in weld seams. However, with agreement between Purchaser and Manufacturer, *API 650* permits locating connections on weld seams with added configuration and examination requirements.

6.2.4 For existing tanks, *API 653* provides rules for minimum weld spacing at shell penetrations.

6.2.5 *AWWA D100* requires two manways in the first ring of the tank. *API 650* requires the Purchaser to determine the size and number of shell and roof manways.

6.3 Vents

6.3.1 Venting requirements should be determined in accordance with the following standards for the types of tanks shown:

a. For nonrefrigerated aboveground tanks, *API 2000,* Section 1 and *NFPA 30*

b. For refrigerated aboveground and underground tanks, *API 2000*, Section 2

6.3.2 Additional venting capacity on fixed roof hot-oil tanks or tanks in similar service should be considered.

6.4 Mixers

6.4.1 For blending operations, fixed angle mixers can be used.

6.4.2 For sediment and water control, variable-angle mixers should be considered. However, an increased number of fixed angle mixers may also be considered.

6.4.3 Each mixer should have a dedicated manway or nozzle connection.

6.4.4 Other types of mixing devices (e.g., vertical roof agitators, eductors) may also be considered.

6.5 Drains

6.5.1 Two types of primary drainage systems can be used to remove water from the top of an external floating roof:

a. Closed system: Using pipe or hose, water cannot come in contact with stored product

b. Open drain: Water flows down through the stored product

6.5.2 For single deck floating roofs with closed drainage systems, typically a check valve should be provided at the upper end of the drainage system to prevent stored product from flowing onto the deck in case of a leak in the drain piping. Closed drainage systems for double deck floating roofs should not require a check valve.

6.5.3 The outlet for a closed drainage system should have a gate valve, which is kept closed, except when draining the roof, to prevent loss of stored product in case of a leak in the drain piping.

6.5.4 Emergency drains, which drain directly into the stored product, should be provided for double deck floating roofs to prevent excessive water accumulation.

6.6 Swinglines

6.6.1 Swinglines (i.e., floating suction lines) facilitate filling or withdrawing stored product from a designated or variable level other than near the bottom of tanks.

6.6.2 Two types of swinglines are as follows:

a. Floating swingline: Places the end of an articulated pipe near the product surface. This type can be used on floating or fixed roof tanks.

b. Simple swingline: Consists of a single internal pipe and a swing joint. A winch is used to adjust the position.

6.7 Platforms, Walkways, and Stairways

6.7.1 The type of stairway (i.e., helical or straight along a radius) should be indicated on the *API 650* Tank Data Sheet.

6.7.2 If roof slope on a cone roof tank is greater than 1:12 or if snow or ice conditions are expected, platforms should be considered at all roof connections.

6.7.3 Access between tanks, if required, may be provided by a crosswalk. The crosswalk and connections should be designed to accommodate differential movement between tanks.

7. Protection and Verification

7.1 Designing for Corrosion Protection

When designing vessels to hold corrosive liquids it may be necessary to take into consideration issues relating to specific chemicals (i.e., velocity in nozzles, heat treatment, etc.). The MTI (Material Technology Institute) MS series lists some of those considerations.

7.2 Fire and Lightning Protection

7.2.1 General

7.2.1.1 Fire protection should be in accordance with *NFPA 11*, *NFPA 15*, and *NFPA 30*.

7.2.1.2 Lightning protection should be in accordance with *API 2003* and *NFPA 780*.

7.2.1.3 Fireproofing of supports (e.g., legs on a sphere) should be in accordance with *ASTM C-33* and *ASTM C-150*.

7.2.2 Foam Systems

7.2.2.1 Cone or Fixed Roof Tanks

1. Foam protection should be considered for the stored product liquid surface in fixed roof tanks.

2. See *NFPA 11* for information on foam systems.

3. Foam protection methods typically used for fixed roof tanks are as follows:
    a. Shell-mounted foam chambers
    b. Portable tower/monitor
    c. Subsurface (i.e., base injection)

7.2.2.2 Floating Roof Tanks

1. Foam protection systems for floating roof tanks are typically designed to extinguish fires in the seal area.
2. Foam protection methods typically used for floating roof tanks are as follows:
    a. Shell-mounted foam chambers
    b. Catenary system using fixed piping on the floating roof with foam discharge outlets into the seal area
    c. System using rigid and flexible piping inside the tank and mounted on the roof with foam discharge piping directed to the seal area
3. For external floating roofs, foam dams should be attached to the top deck. A foam dam traps foam around the periphery of the roof to extinguish a rim fire.
4. Depending on roof type, a foam dam is typically attached to the top of the outer rim of internal floating roofs. Upper travel of roof is reduced by a foam dam.

7.2.3 Deluge Systems

7.2.3.1 Use of water deluge for tanks can be required for any of the following reasons:

a. Fire protection
b. Safety rules
c. Jurisdictional regulations

7.2.3.2 Tanks are typically protected by a water deluge system consisting of spray nozzles or a circular weir that permits a uniform film of water to flow over the tank surface.

7.2.3.3 Deluge systems can cause corrosion problems under insulation.

7.3 Painting and Internal Coating/Lining

7.3.1 Because corrosion of internal tank surfaces can occur after a hydrotest and before the tank is placed in service, the use of a corrosion inhibitor should be considered.

7.3.2 Tanks in the following services are commonly internally coated:

a. Condensate
b. Demineralized water

c. Neutralization

d. Caustic

e. Potable water

f. Clarified water

g. Wastewater

7.3.3 Internal lining of aboveground storage tank bottoms should be in accordance with *API 652* and *NACE SP0178*.

7.3.4 Surface conditions affect paint performance and future maintenance. Accordingly, seal welding and grinding can be required, especially on interior surfaces.

7.3.5 Seal welding is especially important in areas that are difficult to inspect and maintain (e.g., interior attachments and underside of external windgirders and stiffeners).

7.3.6 Grinding welds so that the welds are smooth, and especially flush, is an expensive process. The cost is based on the weld preparation required for a particular lining or coating system. Grinding samples should be prepared to show the required weld smoothness. It is recommended that weld surface conditions be defined using the *NACE SP0178* visual comparator.

7.3.7 Fiberglass or other composite linings for tank bottoms and lower shells should be specified based on the expected corrosion conditions and required tank life. Thick film linings are commonly used in crude oil storage tanks. Other proprietary systems are also available.

7.3.8 Depending on the exterior skin temperature of a tank that is covered with insulation it may be necessary to coat the external surface of the tank to prevent external stress corrosion cracking (ESCC). The primary source for ESCC to occur is water entering between the insulation and tank surface. A protective coating has shown to be an effective way of mitigating corrosion under insulation. *NACE SP0198* is suggested as a guideline for when to select a protective coating.

7.4 Cathodic Protection

Cathodic protection should be considered to minimize corrosion of interior wetted surfaces and bottom plate's exterior surface. *NACE SP0388* and *API 651* are suggested guidelines for the application of internal and external cathodic protection.

7.5 Testing

7.5.1 Testing that involves the bottom, shell, and roof should be considered for every new tank.

7.5.2 Floatation and leak tests for the following types of tank roofs should be in accordance with the standards shown:

a. For external floating roofs, *API 650*, Annex C

b. For internal floating roofs *API 650*, Annex H

c. For structurally supported aluminum dome roofs, *API 650*, Annex G

7.5.3 Testing of tanks that have been repaired, altered, or reconstructed should be in accordance with *API 653*.

7.5.4 The following issues related to test water should be considered:

a. Temperature and quality of test water

b. Potential danger of corrosion from test water. Special procedures should be applied considering the material of construction of the tank or tank components and the corrosiveness of the test water.

c. Supply and disposal of test water (typically the responsibility of the Purchaser)

d. See *API 650* for a list of issues related to test water.