

Tank Systems for Refrigerated Liquefied Gas Storage

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Tank Systems for Refrigerated Liquefied Gas Storage

SECTION 1—SCOPE

1.1 General

1.1.1 This standard covers low pressure, aboveground, vertical, and cylindrical tank systems storing liquefied gases requiring refrigeration. This standard provides general requirements on responsibilities, selection of storage concept, performance criteria, accessories/appurtenances, quality assurance, insulation, and commissioning of tank systems.

1.1.2 Additional information and recommendations are given in annexes. These general requirements address issues common to all of these tank systems, issues involving coordination of the components of the tank system, and issues of the tank system acting in an integrated way. The detailed requirements applicable to the metallic and concrete containers respectively are contained in the standards named in 1.4 and 1.5.

1.1.3 The annexes of this standard provide additional information that may be used in the selection and design of refrigerated tank systems. See Table 1 for the status of each annex.

Table 1—Status of Annexes to API Standard 625

Annex	Title	Status
A	Properties of Gases	Information (informative)
B	Recommendations on Foundation Settlement	Recommendations (informative)
C	Commentary on Storage Concepts	Information (informative)
D	Recommendations on Selection of Storage Concept based on Assessment of Risk	Recommendations (informative)
E	Inquiries and Suggestions for Change	Recommendations (informative)

1.2 Coverage

1.2.1 This standard covers tank systems having a storage capacity of 800 cubic meters (5000 bbls) and larger.

1.2.2 Stored product shall be liquids that are in a gaseous state at ambient temperature and pressure and that require refrigeration to less than 5 °C (40 °F) to maintain a liquid phase.

1.2.3 Tank systems with a minimum design temperature of –198 °C (–325 °F) (see note), a maximum design internal pressure of 50 kPa (7 psig), and a maximum design uniform external pressure of 1.75 kPa (0.25 psig) are covered.

NOTE For concrete containers, ACI 376 states it “has been developed with the lowest operating temperature of –168 °C (–270 °F). However lower product temperatures could also be used, provided appropriate additional engineering analysis and justification is performed for each proposed application.”

1.3 Configuration

The tank system configurations covered are described in Section 5.

21 1.4 Metallic Components

18 Metallic components' materials, design, fabrication, inspection, examination, and testing shall be in accordance with API 620 including Annex Q, Annex R, or Annex Y. The applicable annex of API 620 depends on the design metal temperature and the applicable temperature ranges given in these annexes.

21 1.5 Concrete Components

21 Concrete component materials (including nonmetallic barriers), design, construction, inspection, examination, and testing shall be in accordance with ACI 376.

1.6 Boundaries

1.6.1 This standard applies to tank system components attached to and located within the liquid, vapor, and any purge gas containers (but excluding dike walls). Piping connected externally to the liquid, vapor, and any purge gas containers within the following limits shall be constructed according to this standard:

- a) the face of the first flange in bolted flanged connections;
- b) the first threaded joint on the pipe outside the tank wall in threaded pipe connections;
- c) the first circumferential joint in welding-end pipe connections that do not have a flange located near the tank.

1.6.2 The boundary of this standard may be extended as agreed between purchaser and tank system contractor to complete, external, pressure-containing piping connections (such as relief valves in 7.4 and instrumentation in 7.5) which serve only the tank system.

SECTION 2—NORMATIVE REFERENCES

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies. | 21

API Standard 521, *Pressure-relieving and Depressurizing Systems*

API Standard 537, *Flare Details for General Refinery and Petrochemical Service Construction Guidelines* | 13

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

API Standard 650, *API Welded Tanks for Oil Storage*

API 2000, *Venting Atmospheric and Low-pressure Storage Tanks* | 21

API Specification Q1, *Specification for Quality Programs*

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

AGA XK 0101 ², *Purging Principles and Practice*

ANSI K61.1 ³, *American National Standard Safety Requirements for the Storage and Handling of Anhydrous Ammonia*

ASCE 7 ⁴, *Minimum Design Loads for Buildings and Other Structures*

ASME B31.3 ⁵, *Process Piping*

ASME Boiler and Pressure Vessel Code, Section VIII: Rules for Construction of Pressure Vessels Division 1

ASTM A516 ⁶, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

ASTM A553, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 Percent Nickel*

ASTM C165, *Standard Test Method for Measuring Compressive Properties of Thermal Insulations*

ASTM C177, *Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus*

ASTM C240, *Standard Test Methods of Testing Cellular Glass Insulation Block*

ASTM C552, *Standard Specification for Cellular Glass Insulation*

ASTM C549, *Standard Specification for Perlite Loose Fill Insulation*

¹ American Concrete Institute, P.O. Box 9094, Farmington Hills, Michigan 48333, www.aci-int.org.

² American Gas Association, 400 N. Capitol St., NW, Suite 450, Washington, D.C. 20001, www.aga.org.

³ American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org.

⁴ American Society of Civil Engineers, 1801 Alexander Bell Dr., Reston, Virginia 20191, www.asce.org.

⁵ ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

⁶ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM C764, *Standard Specification for Mineral Fiber Loose-Fill Thermal Insulation*

EN14620-1⁷, *Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and –165 °C — Part 1: General*

EN 14620-4, *Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and –165 °C — Part 4: Insulation*

IBC⁸, *ICC International Building Code*

ISO 9001⁹, *Quality Management Requirements*

NFPA 58¹⁰, *Liquefied Petroleum Gas Code*

NFPA 59, *Utility LP – Gas Plant Code*

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*

NFPA 497, *Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

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

OSHA 29 CFR 1910¹¹, *Subpart D, Walking-Working Surfaces*

⁷ European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, Belgium, www.cen.eu.

⁸ International Code Council, 500 New Jersey Avenue, NW, 6th Floor, Washington, D.C. 20001, www.iccsafe.org.

⁹ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

¹⁰ National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

¹¹ U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210, www.osha.gov.

SECTION 3—TERMS AND DEFINITIONS

3.1 General

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

3.2 Definitions

3.2.1 Storage Concepts

3.2.1.1

double containment tank system

See 5.3.

3.2.1.2

double containment-with-penetrations tank system

See 5.5.

3.2.1.3

full containment tank system

See 5.4.

3.2.1.4

full containment-with-penetrations tank system

See 5.5.

3.2.1.5

membrane containment tank system

See 5.6

3.2.1.6

membrane containment Type M-CC with penetrations tank system

See 5.7

3.2.1.7

single containment tank system

See 5.2

3.2.1.8

tank system

Equipment designed for the purpose of storing refrigerated liquified gas consisting of one or more containers, together with all other necessary components within the scope of this standard.

3.2.2 Components

3.2.2.1

annular space

The space between a) the primary cylindrical liquid container and the primary cylindrical product vapor container or b) the primary cylindrical liquid container and the cylindrical purge gas container of a double wall tank.

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3.2.2.2**base heating system**

A heating system provided in the base slab or soil below the tank system to prevent freezing of the soil and frost heave.

3.2.2.3**base slab**

A continuous concrete base supporting the tank system. This base may exist either at grade or elevated and may be either supported by soil or piles.

3.2.2.4**corrugation**

Patterned ridges on the membrane designed to allow for shrinkage and movement under all loadings of the membrane (see Figure 1).

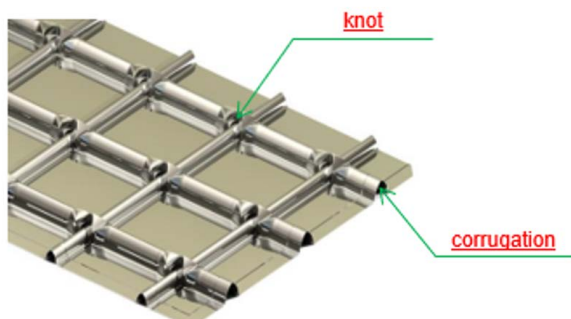


Figure 1—Example of Corrugations on the Membrane

3.2.2.5**dike wall**

A structure remote from the tank system used to establish an impounding area for the purpose of containing any accidental spill of stored liquid. Sometimes this structure is referred to as a bund wall.

3.2.2.6**elevated foundation**

A foundation with base slab, supported either by piles or piers (stub columns), located at an elevation above grade, leaving an air gap between the grade and the bottom of the base slab.

3.2.2.7**knot**

The intersection of the membrane corrugations that provides two-directional flexibility (see Figure 1).

3.2.2.8**load-bearing insulation**

Insulation with special compressive strength properties used for thermal insulation and for transferring the load to the load-bearing structure.

3.2.2.9**membrane**

Parts of a membrane containment tank system that form a liquid- and vapor-tight barrier during normal operation (see Figure 1).

3.2.2.10**membrane tank outer container**

The parts in a membrane containment tank system that carry liquid load during normal operation and may contain liquid in the event of liquid leakage from the membrane.

3.2.2.11**moisture barrier**

A barrier to prevent entry of water vapor and other atmospheric gases.

3.2.2.12**OBE basis operating level**

The design liquid level used for operating basis earthquake (OBE) design.

3.2.2.13**penetration**

A permanent opening, other than a manway, that is placed in a liquid, vapor, or purge gas container.

3.2.2.14**primary liquid container**

Parts of a single, double, and full containment tank system that contain liquid during normal operation.

3.2.2.15**primary vapor container**

Parts of a tank system that contain the product vapor during normal operation.

3.2.2.16**pump column**

A pipe column to house a combined vertical pump and close-coupled electric motor. The column itself protrudes through the outer tank roof.

3.2.2.17**purge gas container**

Parts of a tank system that contain only purge gas and are not expected to function after exposure to product temperature. (This includes outer container of double roof single containment tank system.)

3.2.2.18**refrigerated temperature roof**

A structural roof that contains product vapor and is near the liquid product temperature during normal operation. (This includes inner roofs of double roof tanks and single roofs of tanks with external roof insulation.)

3.2.2.19**ring beam**

A circular load-bearing component under the shell of the primary liquid container.

3.2.2.20**roof space**

The space between the refrigerated temperature roof and the purge gas container roof.

3.2.2.21**secondary liquid container**

Parts of a double and full containment tank system that contain the liquid in the event of leakage from the primary liquid container.

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3.2.2.22**suspended deck**

- 21 | Structure suspended from the fixed roof, used for supporting the internal insulation above the primary liquid container.

3.2.2.23**thermal corner protection**

- 21 | A liquid-tight protection system located at the base of a membrane tank container or secondary liquid container, used to moderate thermal gradients at that location.

3.2.2.24**thermal protection system**

- 21 | A thermally insulating and liquid-tight system to protect the membrane tank outer container or the secondary liquid container against low temperatures in the event of leakage through the membrane or primary liquid container, respectively. The thermal protection system in the bottom annular section is functionally equivalent to the thermal corner protection system.

3.2.2.25**warm product vapor container**

- 21 | Parts of a tank system that contain product vapor and prevent entry of water vapor and other atmospheric gases during normal operation but that are not expected to function after exposure to refrigerated product temperature. (This includes roofs over suspended insulation deck and the outer container of a double wall, open top single containment tank system.)

3.2.2.26**membrane attachment anchors**

- 21 | Attachment device to provide a rigid point support of the insulation to the membrane tank outer container (see 9.8).

3.2.3 Levels and Volumes**3.2.3.1****design liquid level**

- 21 | Maximum liquid level that will be experienced during operation of the tank.

3.2.3.2**maximum liquid capacity**

The total volume between the design liquid level and the tank bottom. (This is also referred to as total liquid capacity in API 620.)

3.2.3.3**maximum normal operating capacity**

The volume between the maximum normal operating level and the tank bottom.

3.2.3.4**maximum normal operating level**

Maximum liquid level that will be experienced during normal operation of the tank.

3.2.3.5**minimum normal operating level**

Minimum liquid level that will be maintained during normal operation of the tank.

3.2.3.6**net working capacity**

The volume between the maximum normal operating level and minimum normal operating level.

3.2.3.7**overfill prevention margin**

Capacity (tank height or volume) between the maximum normal operating level and the design liquid level (see 6.3).

21**3.2.3.8****freeboard**

The height above the maximum design liquid level required to accommodate operational and upset conditions.

21**3.2.3.9****seismic freeboard**

The height above the operating liquid level required to accommodate seismic-induced sloshing waves.

3.2.3.10**heel**

The height of liquid below the minimum normal operating level.

14**3.2.4 Process****3.2.4.1****boil-off**

The process of vaporization of refrigerated product by heat conducted through the insulation surrounding the tank.

3.2.4.2**design pressure**

The maximum gauge pressure permissible in the vapor space above the product of a tank system in its design condition.

3.2.4.3**flame spread index**

A number, obtained according to NFPA 255, which is a comparative measure, derived from visual measurements, of the spread of flame vs time.

3.2.4.4**hazard**

An event having the potential to cause harm, including ill health and injury; damage to property, product or the environment; production losses; or increased liabilities.

3.2.4.5**minimum design temperature (design metal temperature)**

See 6.4.6.

3.2.4.6**purging**

The replacement of one gas/vapor by another in an enclosed tank system by displacement, by dilution, by diffusion or by combinations of these actions.

3.2.4.7**rollover**

Uncontrolled mass movement of stored liquid, correcting an unstable state of stratified liquids of different densities and resulting in a significant evolution of product vapor.

3.2.4.8**set pressure**

The gauge pressure at which the pressure relief device first opens.

3.2.4.9**set vacuum**

The gauge pressure at which the vacuum relief device first opens.

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3.2.4.10**lowest one-day mean ambient temperature**

Meteorological data for the specific site.

NOTE This information for U.S. locations is presented in API 620, as well as other options for locations not covered in that standard.

3.2.5 Seismic**3.2.5.1****aftershock level earthquake****ALE**

See 6.5.2.

3.2.5.2**operating basis earthquake****OBE**

or

operating level earthquake**OLE**

See 6.5.2.

3.2.5.3**safe shutdown earthquake****SSE**

or

contingency level earthquake**CLE**

See 6.5.2.

3.2.5.4**seismic sloshing wave height**

Height of wave in the stored liquid due to seismic ground movement.

3.2.6 Organizations

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3.2.6.1**purchaser**

The owner of the tank system or the owner's designated agent.

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3.2.6.2**tank system contractor**

The party having the responsibility for design, supply, fabrication, construction, examination, and testing the tank system unless otherwise agreed per 4.1.2.

SECTION 4—RESPONSIBILITIES

4.1 General

4.1.1 The owner/purchaser shall provide the specification defining the tank design from design information specified below.

4.1.2 The tank system contractor shall be responsible for the design, supply, fabrication, construction, examination, and testing of the tank system in accordance with the design information named in 4.2 unless otherwise agreed to by the purchaser and the tank system contractor. 21

4.1.3 The supply of the tank system requires input from multiple specialist subcontractors and vendors. The tank system contractor shall ensure that division and delegation of responsibilities are defined and the tank system is fully integrated.

4.2 Design Information

4.2.1 Information by Purchaser

The purchaser shall provide the following information:

- 1) scope of work for contractor (including items determined in 4.2.3);
- 2) tank type (see Section 5);
- 3) net working capacity;
- 4) tank location on plot plan;
- 5) environmental data (including, minimum/maximum ambient temperatures);
- 6) site geotechnical and seismic data (including soil properties, allowable soil bearing, predicted settlements after soil remediation, and foundation type selected); when a site-specific seismic response spectrum is required per Section L.4.2 in API 620, as a minimum, the site-specific spectrum should be based on the requirements in 6.6.2 in this document; 21
- 7) process flow diagrams (PFDs), piping & instrumentation diagrams (P&IDs);
- 8) properties of the stored product, including density at the design temperature, toxicity, and flammability;
- 9) design pressure/vacuum, maximum/minimum operating pressure;
- 10) high/low pressure alarm set point;
- 11) design boil-off rate (as per 6.4.4);
- 12) minimum design temperature of primary liquid, secondary liquid, warm product vapor, purge gas, and membrane tank outer containers and the membrane (in accordance with 6.4.6); 21
- 13) natural environmental loads (such as earthquake, wind);
- 14) type of cathodic protection system (if applicable);
- 15) product filling/emptying rates;

- 16) spillage handling requirements (as per 6.4.2 and 7.7, if applicable);
- 17) rollover applicability and rollover prevention provisions (as per 7.5.4, if applicable);
- 18) piping and instrumentation requirements (as per 7.3 and 7.5);
- 19) corrosion allowances;
- 20) hazard protection system requirements (such as water spray, gas detection, if any);
- 21) accidental loads determined by assessment of risk (such as fire, pressure wave, projectile impact, if any);
- 22) overfill prevention margin (refer to 6.3);
- 23) minimum normal operating level basis;
- 21 | 24) number of loading and unloading cycles during the lifetime.

4.2.2 Information by Tank System Contractor

The contractor shall provide the following information:

- 1) tank maximum liquid capacity;
- 21 | 2) internal dimensions (diameter and height) of primary liquid container or membrane at ambient temperature;
- 3) design liquid level;
- 4) normal maximum/minimum operating liquid level;
- 5) high/low level alarm.

4.2.3 Agreement by Tank Purchaser and Tank System Contractor

The following issues shall be agreed by both parties:

- 1) applicable codes and standards;
- 2) contractor's involvement in risk assessment;
- 3) materials of tank construction;
- 21 | 4) precommissioning and commissioning procedures, including purging, drying, and cool-down;
- 5) NDE applied to nonhydrostatically tested components;
- 6) settlement prediction and inspection method;
- 7) emergency relief valve discharge flow rate;
- 8) pressure relief and vacuum set points.

SECTION 5—STORAGE CONCEPTS

21

5.1 General

5.1.1 Several different main storage concepts are addressed in this standard. 5.2, 5.3, 5.4, 5.5, 5.6, and 5.7 define and describe each of these concepts. Diagrams of some implementations of these concepts are also provided. These diagrams are not meant to exclude other variations as long as they conform to the concept definitions. 21 18

5.1.2 Other storage concepts falling outside those defined herein may be possible but are not addressed in this standard.

5.1.3 In the diagrams provided, color is used to help illustrate the components that are designed for the low product temperatures (blue metal or gray concrete) and other components that are not so designed (red metal).

5.1.4 For all storage concepts, liquid-tightness of the primary liquid container or the membrane is required. Liquid is not permitted to accumulate outside the primary liquid container or the membrane during normal operation. Tank systems where this is not assured would require consideration of issues such as liquid collection and disposal, potential cold spots, effect on tank venting, etc. This standard has not attempted to address these issues. 21

5.2 Single Containment Tank System

5.2.1 This system incorporates a liquid-tight container and a vapor-tight container. It can be a liquid- and vapor-tight single-wall tank or a tank system composed of an inner and outer container, designed and constructed so that only the primary liquid container is required to be liquid-tight and contain the liquid product. 21

5.2.2 The outer container, if any, is primarily for the retention and protection of the insulation system from moisture (see Section 9) and may hold the product vapor pressure, but is not designed to contain the refrigerated liquid in the event of leakage from the primary liquid container. 21

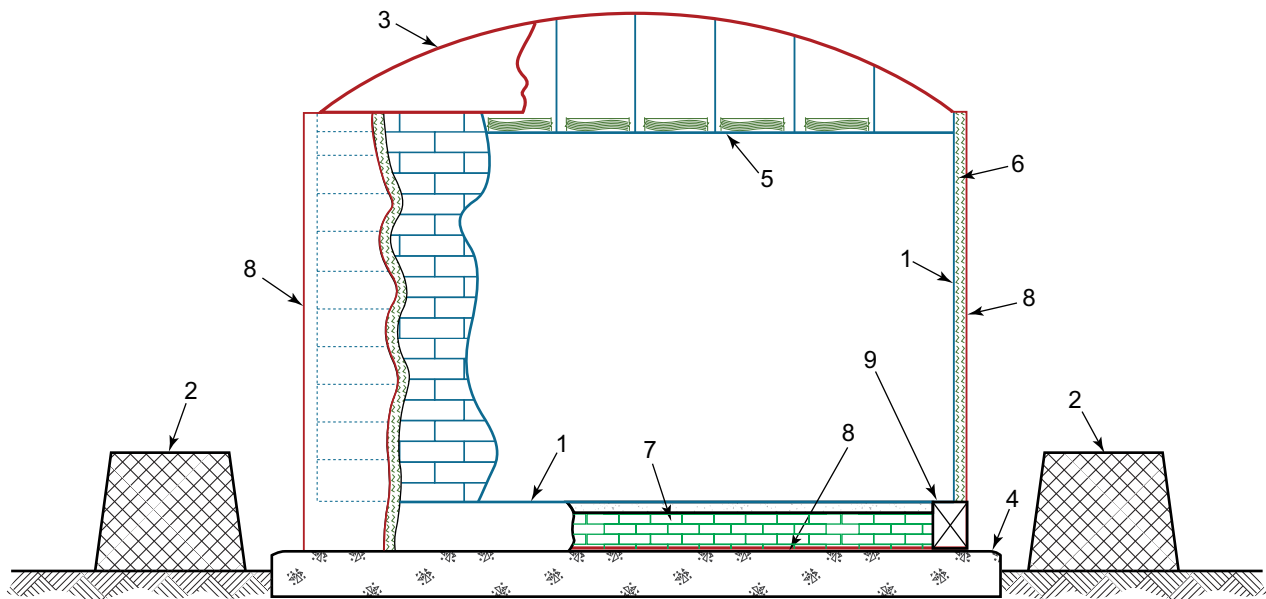
5.2.3 The primary liquid container shall be of low-temperature metal or prestressed concrete. The outer tank (if any) shall be vapor-tight. It is normally made from carbon steel, and it is referenced in this standard in various contexts as the warm product vapor container or the purge gas container.

5.2.4 A single containment tank system is surrounded by a secondary containment (normally a dike wall) which is designed to retain liquid in the event of leakage (see C.2).

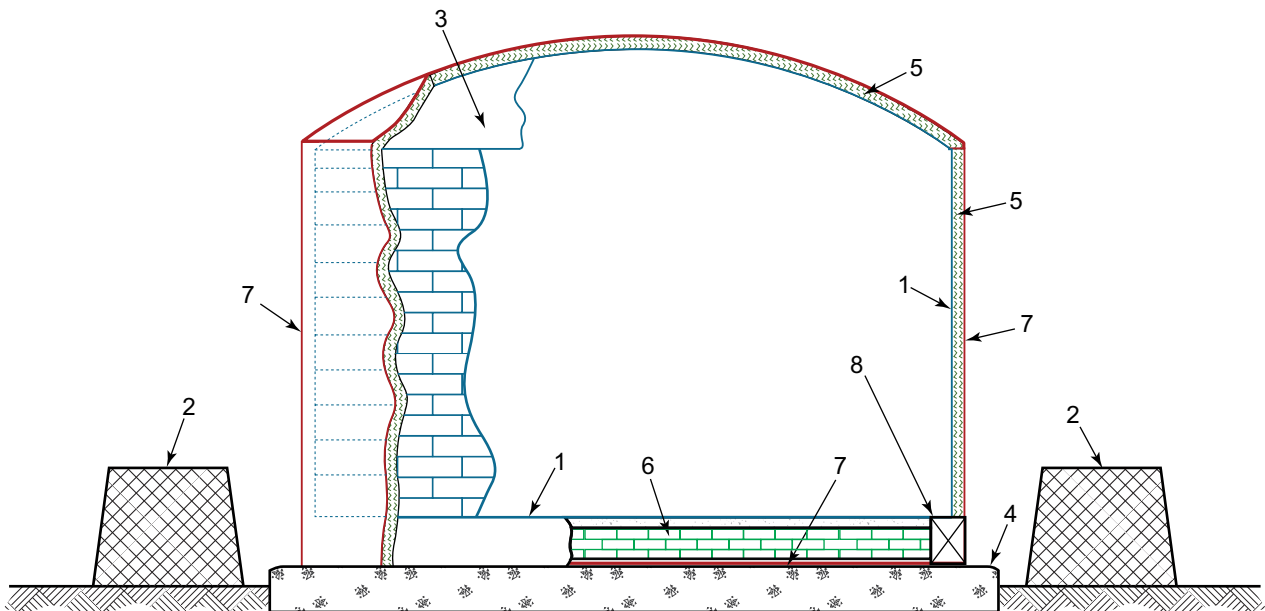
5.2.5 Some variants of single containment concepts having a single tank are depicted in Figure 2 and Figure 3. 21

5.2.6 Some variants of single containment concepts having inner and outer containers are depicted in Figure 4 and Figure 5.

5.2.7 Shell or bottom penetrations that breach the primary liquid container and outer container are allowed.

**Key**

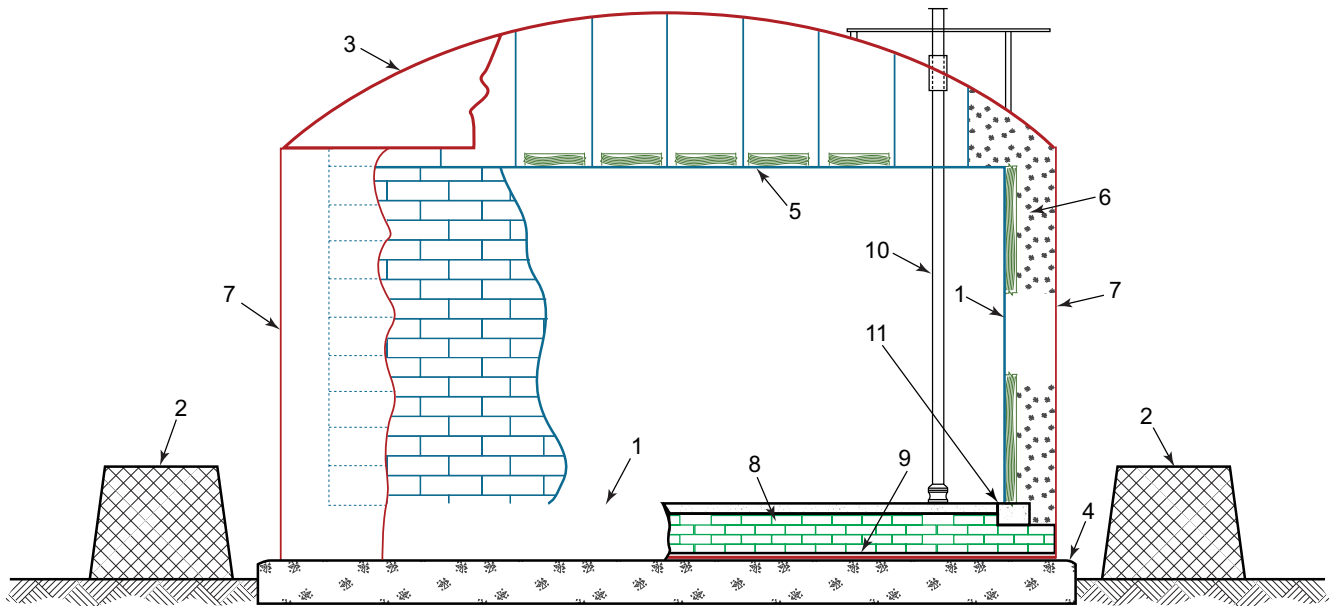
- | | | |
|---|------------------------------------|-------------|
| 1 primary liquid container (low temp steel) | 5 suspended deck with insulation | 9 ring beam |
| 2 secondary containment (dike wall) | 6 insulation (external) | |
| 3 warm product vapor container (roof) | 7 load-bearing insulation (bottom) | |
| 4 concrete foundation | 8 moisture barrier | |

Figure 2—Single Containment Tank System**Single Wall with Steel Primary Liquid Container and Suspended Insulation Deck****Key**

- | | | |
|---|------------------------------------|--------------------|
| 1 primary liquid container (low temp steel) | 4 concrete foundation | 7 moisture barrier |
| 2 secondary containment (dike wall) | 5 insulation (external) | 8 ring beam |
| 3 refrigerated temperature roof | 6 load-bearing insulation (bottom) | |

Figure 3—Single Containment Tank System**Single Wall with Steel Primary Liquid Container and External Insulation****Documents**

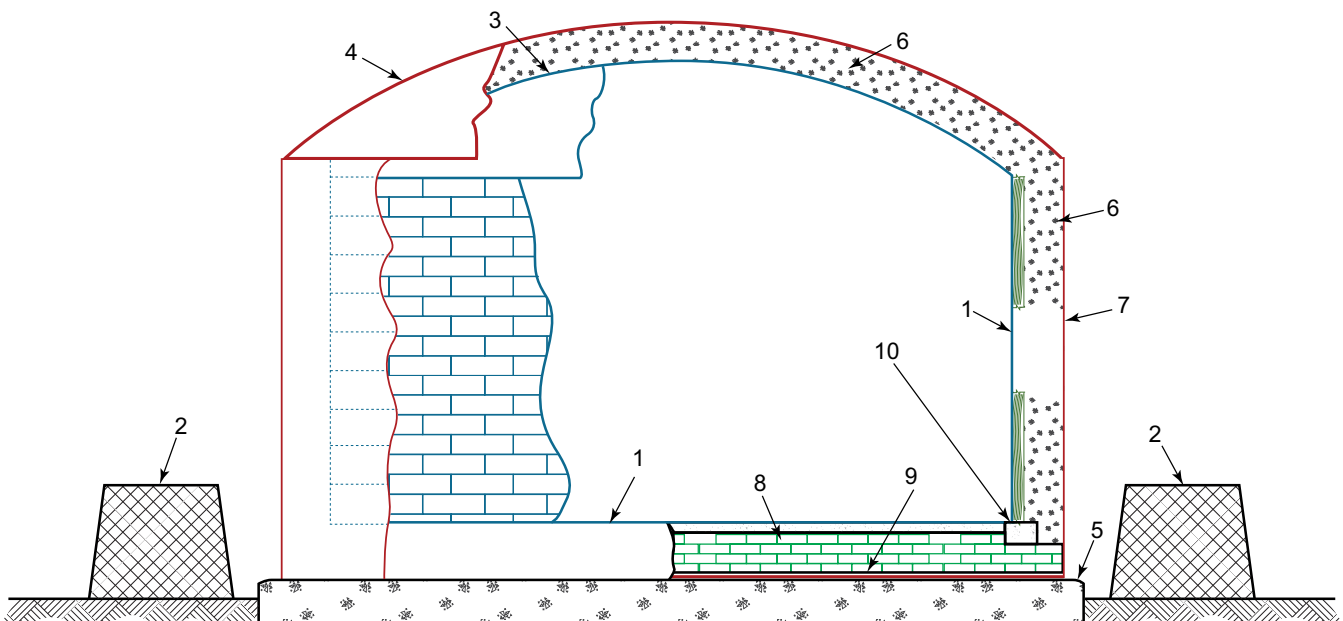
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**Key**

- | | | |
|---|---------------------------------------|---|
| 1 primary liquid container (low temp steel) | 5 suspended deck with insulation | 8 load-bearing insulation (bottom) |
| 2 secondary containment (dike wall) | 6 insulation (annular) | 9 warm product vapor container (bottom) |
| 3 warm product vapor container (roof) | 7 warm product vapor container (wall) | 10 pump column |
| 4 concrete foundation | | 11 ring beam |

Figure 4—Single Containment Tank System
Double Wall with Steel Primary Liquid Container and Steel Vapor Container

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**Key**

- | | | |
|---|---------------------------------------|------------------------------------|
| 1 primary liquid container (low temp steel) | 4 purge gas container (roof) | 7 purge gas container (wall) |
| 2 secondary containment (dike wall) | 5 concrete foundation | 8 load-bearing insulation (bottom) |
| 3 refrigerated temperature roof | 6 insulation (annular and roof space) | 9 purge gas container (bottom) |
| | | 10 ring beam |

Figure 5—Single Containment Tank System
Double Wall with Steel Primary Liquid Container and Steel Purge Gas Container

21

5.3 Double Containment Tank System

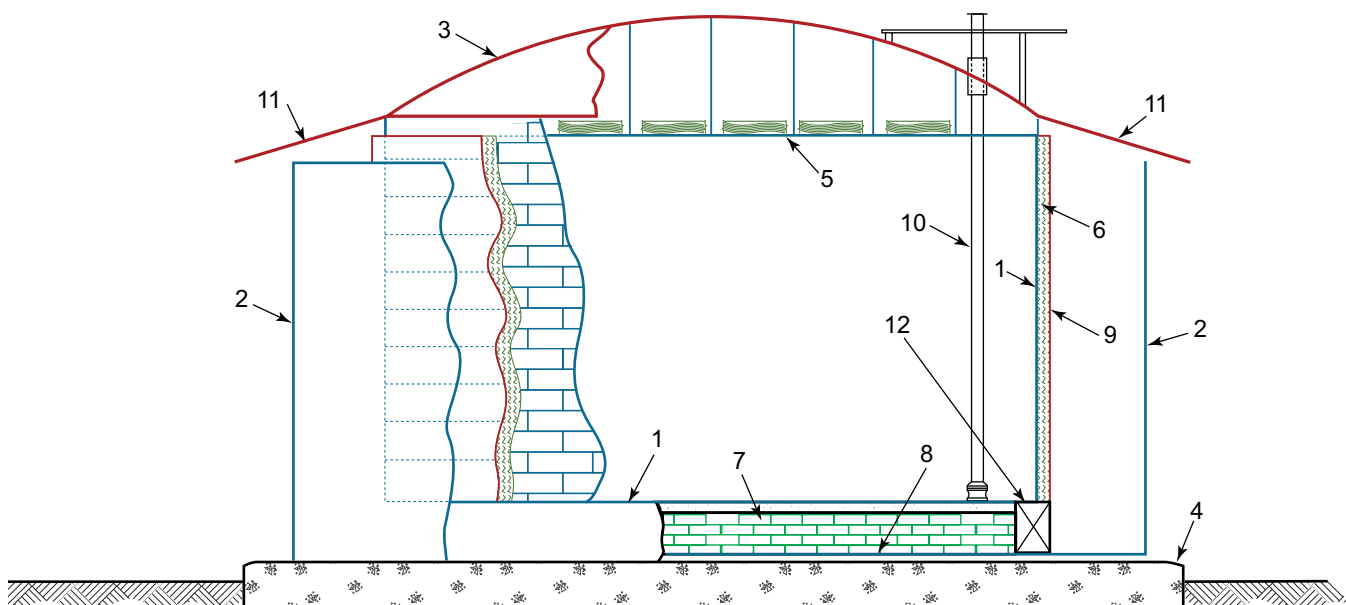
5.3.1 This consists of a liquid- and vapor-tight primary tank system, which is itself a single containment tank system, built inside a liquid-tight secondary liquid container.

- 21 **5.3.2** The secondary liquid container is designed to hold all the liquid contents of the primary liquid container in the event of leaks from the primary liquid container, but it is not intended to contain or control any vapor resulting from product leakage from the primary liquid container. The annular space between the primary liquid container and the secondary liquid container shall not be more than 6 m (20 ft).

5.3.3 The primary and secondary liquid containers shall be constructed either from metal or from concrete.

- 14 **5.3.4** Variants of double containment concepts using single tanks and independent primary liquid and vapor
21 containers are depicted in Figure 6 and Figure 7.

5.3.5 Shell or bottom penetrations that breach the primary or secondary liquid container are not allowed.



Key

- | | | |
|---|---|--------------------|
| 1 primary liquid container (low temp steel) | 5 suspended deck with insulation | 9 moisture barrier |
| 2 secondary liquid container (low temp steel) | 6 insulation (external) | 10 pump column |
| 3 warm product vapor container (roof) | 7 load-bearing insulation (bottom) | 11 rain shield |
| 4 concrete foundation | 8 secondary liquid container (low temp steel) | 12 ring beam |

Figure 6—Double Containment Tank System
Steel Primary Liquid Container and Steel Secondary Liquid Container

5.4 Full Containment Tank System

- 21 **5.4.1** This consists of a liquid-tight primary liquid container and a liquid- and vapor-tight secondary liquid container. Both are capable of independently containing the product stored.

- 21 **5.4.2** The secondary liquid container shall be capable of both containing the liquid product and controlling the vapor release in the event of product leakage from the primary liquid container.

5.4.3 The primary and secondary liquid containers shall be constructed either from metal or from concrete.

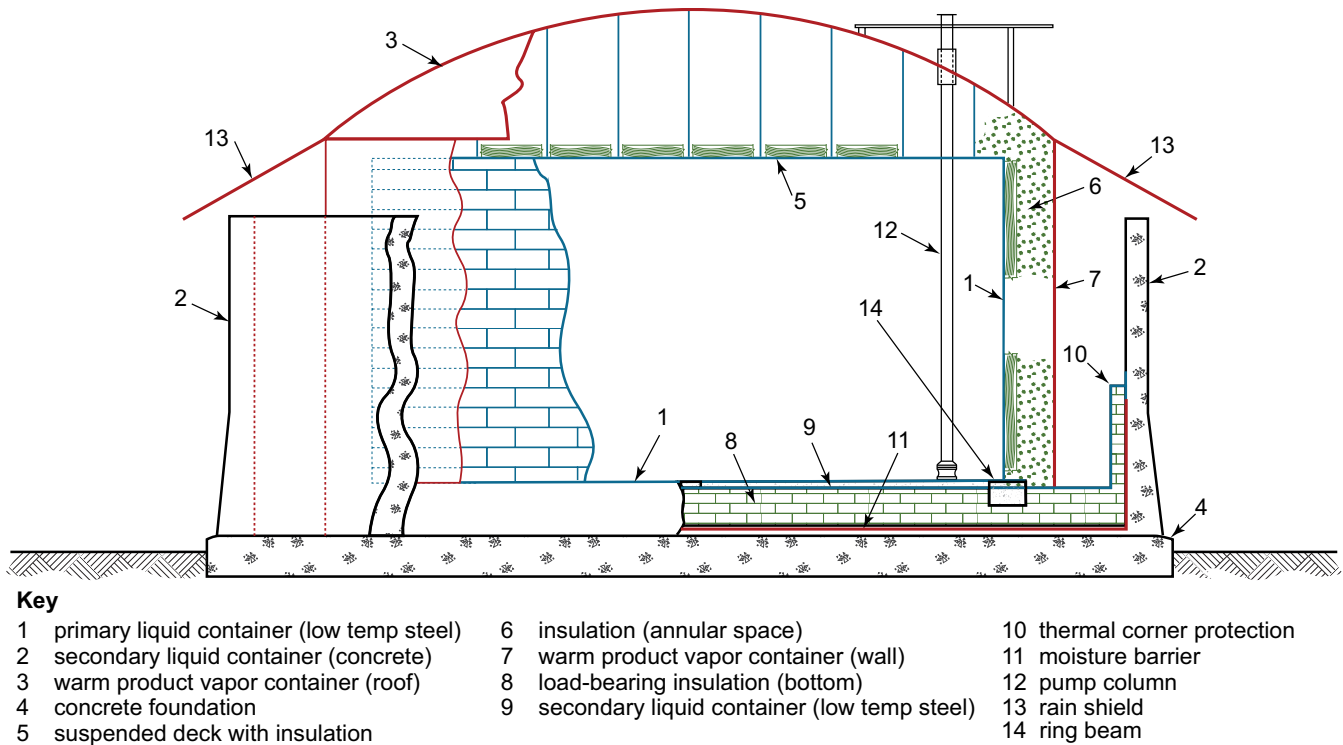


Figure 7—Double Containment Tank System
Steel Primary Liquid Container, Steel Vapor Container, and Concrete Secondary Liquid Container

21

5.4.4 Vapor tightness of the tank system during normal service is required. Under primary liquid container leakage (emergency) conditions, tank system product vapor losses due to secondary container permeability are acceptable.

21

5.4.5 ACI 376 addresses various base-to-wall joint details. For certain low-temperature products, significant design issues arise at monolithically-connected outer tank base-to-wall joints due to the mechanical restraint offered by the base. To mitigate these issues, it is normal practice to include a secondary liquid containment bottom and thermal corner protection to protect and thermally isolate this monolithic area from the cold liquid and provide liquid tightness. Refer to ACI 376 for the design and detailing of such areas. The diagrams in this section approximately depict such details. Details of this subject are in 6.8 of API 625.

21

5.4.6 Some variants of full containment concepts are depicted in Figure 8, Figure 9, Figure 10, and Figure 11.

5.4.7 Shell or bottom penetrations that breach the primary or secondary liquid container are not allowed.

14

5.5 Double or Full Containment-with-Penetrations Tank System

21

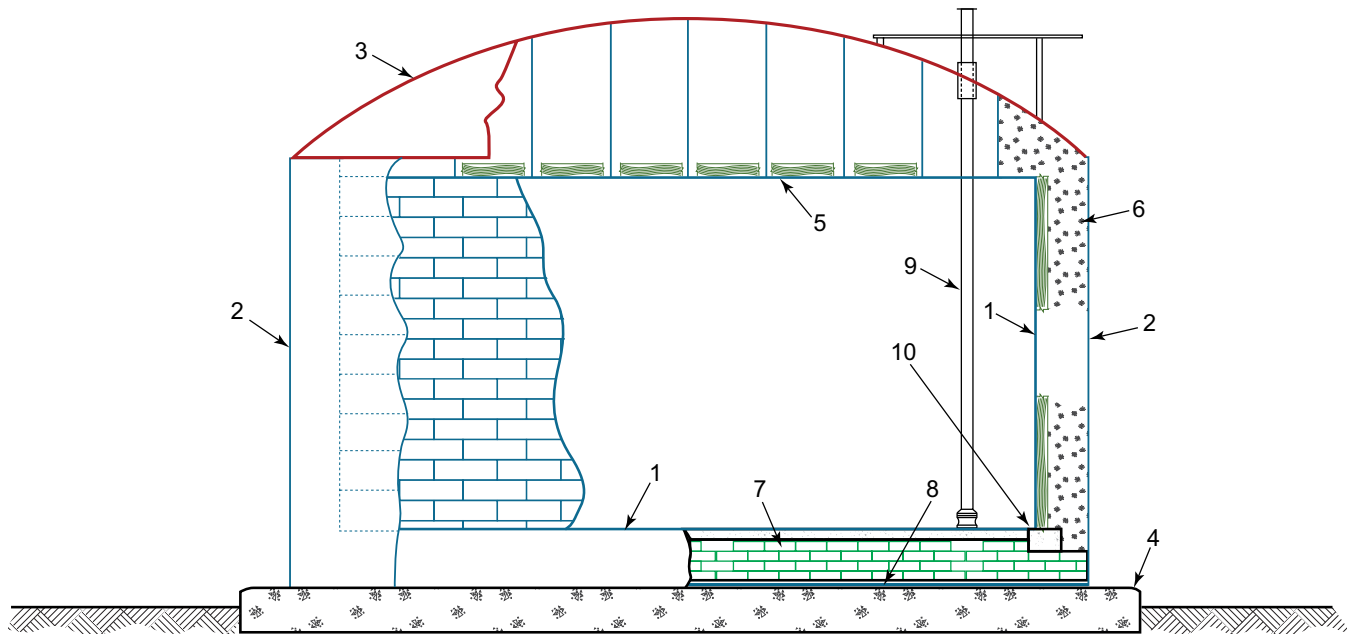
This concept meets the requirements of double or full containment tank systems defined in 5.3 and 5.4, respectively, except shell or bottom penetrations and manways that breach the primary or secondary containment are allowed when all of the following additional requirements are met.

- a) the penetrations are specified by the purchaser;
- b) no prohibition exists in applicable regulations;
- c) the penetrations are accounted for in the assessment of risk as per 5.8;

14

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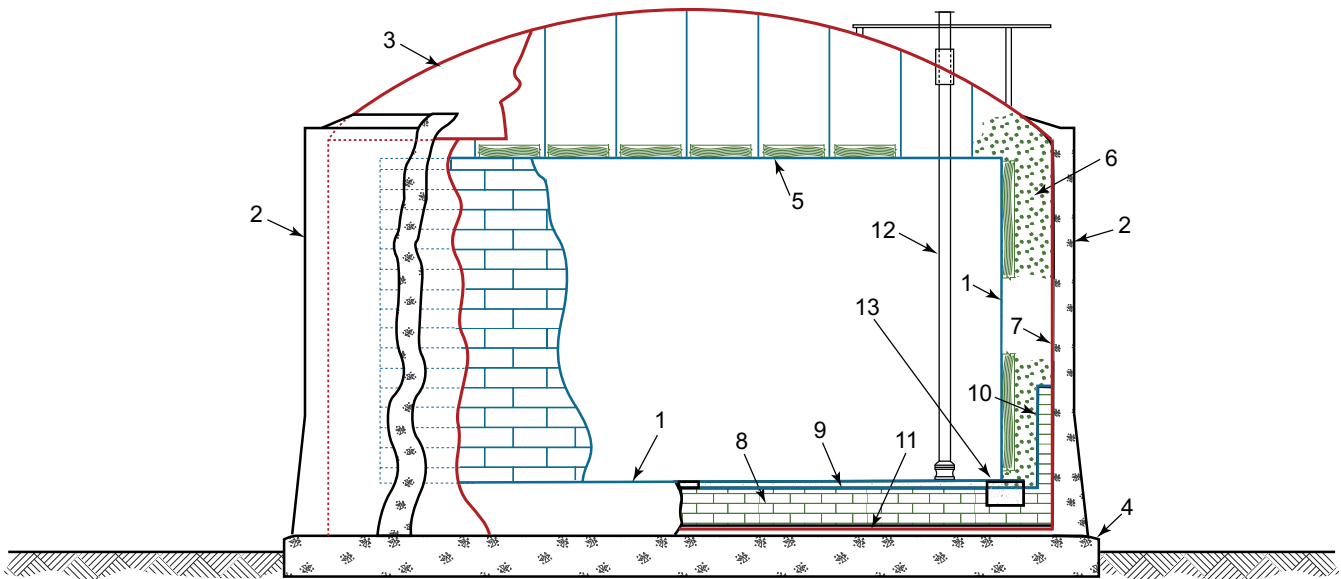
- 21 d) in-tank valves are provided (refer to 7.3.1.4.2 b) for all penetrations except the following:
- dead end lines (such as drain lines) in secondary liquid container that do not exceed 4-inch NPS, nor exceed 18-inch projection;
 - instrumentation cable glands through the secondary liquid container;
- 14 e) a remote dike wall is provided in addition to the secondary containment that is part of the tank system. The volume
21 contained by the dike shall be equal to 110 % of the flow from a full line break prior to closure of the largest in-tank valve.
- 21 **5.6 Membrane Containment Tank System**
- 5.6.1** This is an integrated tank system consisting of the metallic membrane, load-bearing thermal insulation, and self-standing membrane tank outer container.
- 5.6.2** The membrane shall be liquid tight and vapor-tight during normal operation.
- 5.6.3** The tank system shall be vapor-tight during normal operation. The tank system may use a suspended deck with insulation with vapor contained by the structural roof. Alternately, the tank roof may have a vapor-tight membrane and insulation lining as in 5.6.1
- 5.6.4** The membrane shall incorporate either a design with corrugations to accommodate thermal contraction or materials with acceptably small thermal contraction.
- 21 **5.6.5** The load-bearing insulation transfers all hydrostatic loads and other loadings onto the membrane tank outer container.



Key

- | | | |
|---|------------------------------------|---|
| 1 primary liquid container (low temp steel) | 5 suspended deck with insulation | 8 secondary liquid container (low temp steel) |
| 2 secondary liquid container (low temp steel) | 6 insulation (annular space) | 9 pump column |
| 3 warm product vapor container (roof) | 7 load-bearing insulation (bottom) | 10 ring beam |
| 4 concrete foundation | | |

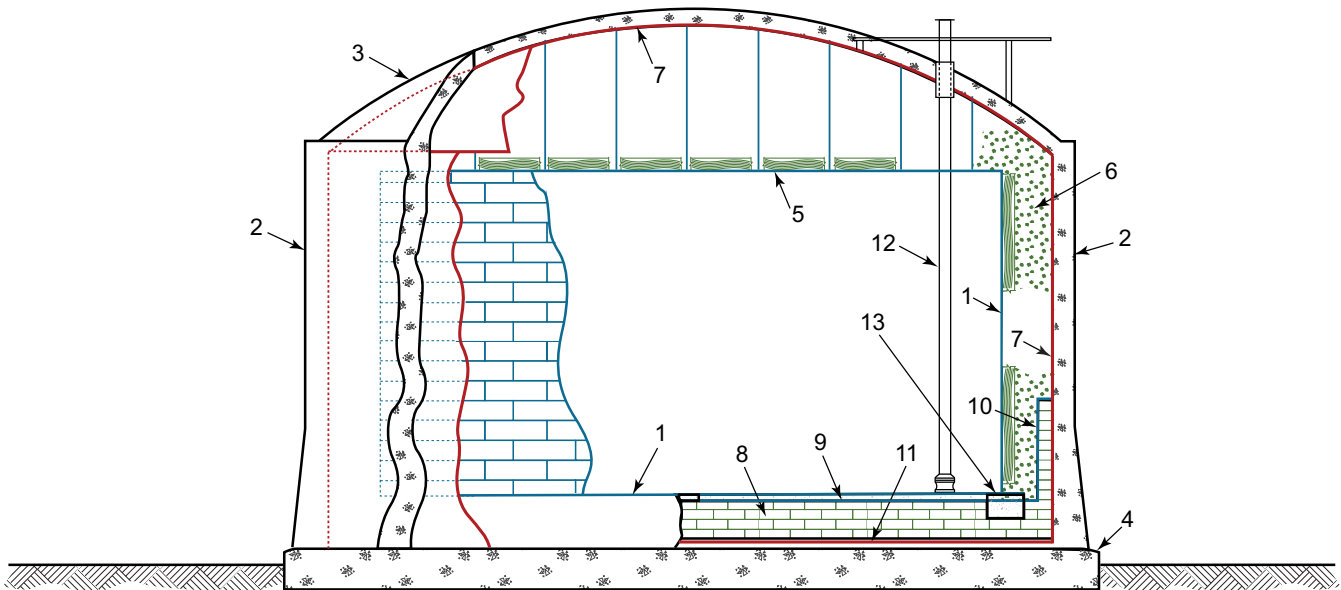
Figure 8—Full Containment Tank System
Steel Primary Liquid Container, Steel Secondary Liquid Container, and Steel Roof

**Key**

- | | | |
|---|--|--|
| 1 primary liquid container (low temp steel) | 6 insulation (annular space) | 10 thermal corner protection |
| 2 secondary liquid container (concrete) | 7 warm product vapor container (liner) | 11 warm product vapor container (bottom) or moisture barrier |
| 3 warm product vapor container (roof) | 8 load-bearing insulation (bottom) | 12 pump column |
| 4 concrete foundation | 9 thermal protection system | 13 ring beam |
| 5 suspended deck with insulation | | |

Figure 9—Full Containment Tank System
Steel Primary Liquid Container, Concrete Secondary Liquid Container, and Steel Roof

21

**Key**

- | | | |
|---|--|--|
| 1 primary liquid container (low temp steel) | 6 insulation (annular space) | 10 thermal corner protection |
| 2 secondary liquid container (concrete) | 7 warm product vapor container (liner) | 11 warm product vapor container (bottom) or moisture barrier |
| 3 roof (concrete) | 8 load-bearing insulation (bottom) | 12 pump column |
| 4 concrete foundation | 9 thermal protection system | 13 ring beam |
| 5 suspended deck with insulation | | |

Figure 10—Full Containment Tank System
Steel Primary Liquid Container, Concrete Secondary Liquid Container, and Concrete Roof

21

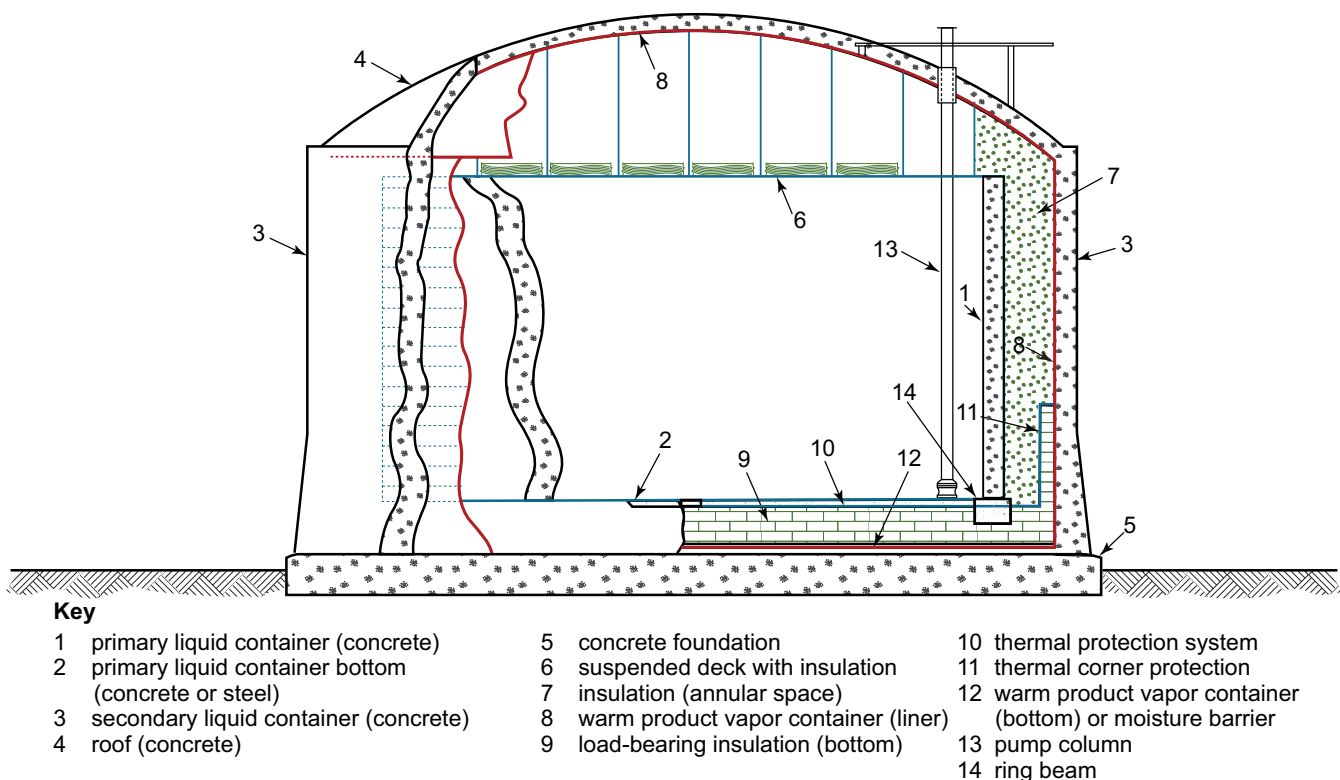


Figure 11—Full Containment Tank System
Concrete Primary Liquid Container, Concrete Secondary Liquid Container, and Concrete Roof

5.6.6 The membrane tank outer container provides structural function for all normal and applicable abnormal design conditions.

5.6.7 The membrane tank outer container shall be self-standing and may be of metal, concrete, or metal/concrete combination.

5.6.8 If the membrane outer tank container is not moisture tight, a moisture barrier preventing entry of water vapor and other atmospheric gases shall be required to keep the insulation layer between the membrane and the outer tank dry.

5.6.9 The membrane containment tank system may be one of the two possible types. The purchaser shall select the type of the membrane tank outer container in accordance with 5.8.

5.6.9.1 Type M-1: The membrane tank outer container for this type is not designed to contain the product in the event of a leak from the membrane and no thermal protection system is provided. This tank system is surrounded by a secondary containment, normally a dike wall, which is designed to retain liquid in the event of leakage. Under normal conditions, the membrane tank outer container also acts as a purge gas container. One variation of this type is depicted in Figure 12. Shell or bottom penetrations that breach the membrane or membrane tank outer container are allowed.

5.6.9.2 Type M-CC: The membrane tank outer container for this type is designed to contain the product in the event of a leak from the membrane. The membrane tank outer container shall be capable of both containing the liquid product and controlling the vapor release in the event of leakage from the membrane. Under membrane leakage (emergency) conditions, tank system vapor product losses due to container permeability are acceptable. Under normal conditions, the metallic membrane tank outer container also acts as a purge gas container. Some variants of this type are depicted in Figure 13 and Figure 14. Shell or bottom penetrations that breach the membrane or membrane tank outer container are not allowed.