Draft for SCAST Ballot

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Title of Standard

TANK SYSTEMS FOR
REFRIGERATED, LIQUIFIED GAS STORAGE

API Standard 625
First Edition, (Date Later)
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SECTION 1 - Scope

1.1 General

This standard is for low pressure, aboveground, vertical, cylindrical, tank systems storing liquefied gases requiring refrigeration. This standard provides general requirements and guidance on selection of storage configuration, materials, design, construction, testing, and commissioning of tank systems including insulation, foundations and appurtenances. 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. However, the detailed requirements applicable to the metallic and concrete containers respectively are contained in the standards named in 1.4 and 1.5. It is a mandatory requirement of this standard that the applicable portions of these named standards are satisfied.

1.2 Coverage

This standard covers tank systems having storage capacity in excess of 800 cubic meters (5000 bbls) storing liquids which are in a gaseous state at ambient temperature and pressure and require refrigeration to less than 5°C (40°F) to maintain a liquid phase. The minimum design temperature is -198°C (-325°F), the maximum design internal pressure is 50 kPa (7 psig), and the maximum design uniform external pressure is 1.75 kPa (0.25 psig).

1.3 Configuration

Various configurations are addressed in Section 5.0. All configurations consist of a primary liquid and vapor containment constructed of metal, concrete, or a metal/concrete combination and when required a secondary liquid containment.

1.4 Metallic Containers

Metallic container materials, design, fabrication, inspection, examination, and testing shall be in accordance with API 620 including either Appendix R or Appendix Q. The applicable appendix of API 620 depends on the design metal temperature and the applicable temperature ranges given in these appendices.

1.5 Concrete Containers

Concrete container materials, design, construction, inspection, examination, and testing shall be in accordance with ACI 376. Metallic components that are an integral part of concrete containers are addressed by ACI 376 (e.g. prestressing/reinforcing steel and metallic liners of concrete walls & roofs)

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 Contractor to complete external, pressure containing piping connections (such as in 7.3 and 7.4) which serve only the tank system.

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SECTION 2 – References

Note to balloters: API staff has agreed to prepare Section 2 which simply lists all the standards, codes and specifications cited in API 625. They will do this as a routine publishing function. This ballot is included simply to state that fact and to keep the agenda item numbers in line with the section numbers.
SECTION 3 - Definitions

3.1 General

The definitions contained in this chapter shall all apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used.

3.2 Definitions

3.2.1 Storage Concepts

3.2.1.1 Double Containment Tank System

See Section 5.2.

3.2.1.2 Full Containment Tank System

See Section 5.3

3.2.1.3 Refrigerated Tank System

The combination of a primary liquid container, together with secondary liquid container (if any), insulation, vapor container, appurtenances, instrumentation, and all other elements within the scope of this standard.
3.2.1.4 Single Containment Tank System

See Section 5.1.
3.2.2 Components

3.2.2.1 Annular Space

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

3.2.2.2 Base Heating System

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

3.2.2.3 Base Slab

The base slab is a continuous concrete base supporting the tank system. This base may be either at grade or elevated and may be either supported by soil or piles.

3.2.2.4 Dike Wall

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

3.2.2.5 Elevated Foundation

A foundation with base slab supported by either 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.

3.2.2.6 Load Bearing Insulation

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

3.2.2.7 Primary Liquid Container

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

3.2.2.8 Primary Vapor Container

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

3.2.2.9 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.
3.2.2.10 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.)

3.2.2.11 Refrigerated Temperature Roof

A 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.)

3.2.2.12 Secondary Liquid Container

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

3.2.2.13 Suspended Deck

Structure suspended from the fixed roof for supporting the internal insulation above the primary liquid container.

3.2.2.14 Thermal Corner Protection

A thermally insulating and liquid tight structure in the bottom annular section of a tank system to protect the secondary liquid container against low temperatures in the event of leakage from the primary container.

3.2.2.15 Vapor Barrier

A barrier to prevent entry of water vapor (moisture) and other atmospheric gases into insulation or into the secondary container. This also prevents the product vapor escaping from the secondary container.

3.2.2.16 Warm Product Vapor Container

Parts of a tank system that contain product vapor, but 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.)

3.2.3 Levels and Volumes
3.2.3.1 Design Liquid Level

Maximum liquid level that will be experienced during operation of the tank used for the static shell thickness determination.
3.2.3.2 Maximum Liquid Capacity

The total volumetric liquid capacity of the tank 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 of product available between the maximum normal operating level and the tank bottom that could be stored in the tank system.

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 usable volume of product, the volume available between the maximum normal operating level and minimum operating level that could be stored in the tank system.

3.2.3.7 Overfill Protection Margin

Capacity (tank height or volume) between the maximum normal operating level and the design liquid level. (see section 6.2)

3.2.3.8 Seismic Freeboard

The designed height above the maximum normal operating level to minimize or prevent overflow or damage to the roof due to sloshing of the liquid contents during a seismic event.

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 at the top of completed tank system in its design condition.
3.2.4.3 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.

3.2.4.4 Minimum Design Temperature (Design Metal temperature)

See Section 6.3.6.

3.2.4.5 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.

3.2.4.6 Roll-over

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.

3.2.4.7 Set Pressure

The pressure at which the pressure relief device first opens.

3.2.4.8 Set Vacuum

The internal tank pressure below ambient pressure at which the vacuum relief device first opens.

3.2.5 Seismic

3.2.5.1 Aftershock Level Earthquake (ALE)

See Section 6.4.2.

3.2.5.2 Operating basis Earthquake (OBE) or Operating Level Earthquake (OLE)

See Section 6.4.2.

3.2.5.3 Safe Shutdown Earthquake (SSE) or Contingency Level Earthquake (CLE)

See Section 6.4.2.
3.2.5.4 Seismic Sloshing Wave Height

Height of wave in the stored liquid due to seismic ground movement.
SECTION 4—Responsibilities

4.1 General

The owner/purchaser shall provide the specification defining the tank design from design information specified below. The contractor shall be responsible for the design, supply, fabrication, construction, inspection, and testing of the tank system. The interface issues, such as pre-commissioning and other transition items shall be resolved by the agreement between owner/purchaser and contractor.

4.2 Design Information

4.2.1 Information by owner/purchaser.

The owner/purchaser shall provide following information:

4.2.1.1 Scope of work for contractor (including items determined in 4.2.3)
4.2.1.2 Tank type (see Section 5)
4.2.1.3 Net working capacity
4.2.1.4 Tank location on plot plan
4.2.1.6 Environmental data (including, minimum/maximum ambient temperatures)
4.2.1.7 Site geotechnical and seismic data (including soil properties, allowable solid bearing and predicted settlements after soil remediation and foundation type selected)
4.2.1.8 Process Flow Diagrams (PFDs), Piping & Instrumentation Diagrams (P&IDs)
4.2.1.9 Properties of the stored product, including density at the design temperature, toxicity, flammability
4.2.1.10 Design pressure/vacuum, maximum/minimum operating pressure
4.2.1.11 High/low pressure alarm set point
4.2.1.12 Design Boil-off rate (at maximum normal operating level)
4.2.1.13 Minimum design temperature of primary containment
4.2.1.14 Natural environmental loads (such as earthquake, wind)
4.2.1.15 Type of cathodic protection system (if applicable)
4.2.1.16 Product filling/emptying rates
4.2.1.17 Spillage handling requirements (as per 6.3.2 and 7.8, if applicable)
4.2.1.18 Required rollover prevention provisions (as per 7.4.4, if applicable)
4.2.1.19 Piping and instrumentation requirements (as per 7.2 and 7.4)
4.2.1.20 Corrosion allowances
4.2.1.21 Hazard protection system requirements (such as water spray, gas detection, if any)
4.2.1.22 Accidental loads determined by assessment of risk (such as fire, pressure wave, projectile impact, if any)
4.2.1.23 Overfill protection margin (refer to 6.2)
4.2.1.24 Minimum normal operating level basis

4.2.2 Information by Tank Contractor

The contractor shall provide following information:

4.2.2.1 Tank maximum liquid capacity
4.2.2.2 Internal diameter and height of inner tank (ambient temperature)
4.2.2.3 Design liquid level
4.2.2.4 Normal maximum/minimum operating liquid level
4.2.2.5 High/low level alarm

4.2.3 Agreement by tank owner/purchaser and contractor

The following issues shall be agreed by both sides:

4.2.3.1 Applicable Codes, Standards
4.2.3.2 Contractor's involvement in risk assessment
4.2.3.3 Materials of tank construction
4.2.3.4 Pre-commissioning and Commissioning procedures, including purging, drying and cooldown
4.2.3.5 NDE applied to non-hydrostatically tested components
4.2.3.6 Settlement prediction and inspection method
4.2.3.7 Emergency relief valve discharge flow rate
4.2.3.8 Pressure relief and vacuum set points
SECTION 5—Selection of Storage Concept

5.0 General

Three different main storage concepts are addressed in this standard. Sections 5.1, 5.2, and 5.3 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. Other storage concepts falling outside those defined herein may be possible but are not addressed in this standard and require thorough evaluation by the owner and authority having jurisdiction. 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).

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

5.1 Single Containment Tank System

5.1. 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 comprised of an
inner and outer container, designed and constructed so that only the inner container is required to be liquid-tight and contain the liquid product.

5.1.2 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 inner container.

5.1.3 The primary liquid container shall be of low-temperature-metal or prestressed concrete. The outer tank is normally carbon steel and vapor tight and is referenced in this standard in various contexts as the warm vapor container or the purge gas container.

5.1.4 A single containment tank system is surrounded a secondary containment (normally a dike wall) and is designed to retain liquid in the event of leakage (see 5.1.5).

5.1.5 Some variants of single containment concepts having a single tank are in Figures 5-1 and 5-2:

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**FIG. 5-1**
Single Containment Tank System
Single Wall with Steel Primary Container and Suspended Insulation Deck
5.1.6 Some variants of single containment concepts having inner and outer containers are in Figures 5-3 and 5-4.
FIG. 5-4

Single Containment Tank System
Double Wall with Steel Primary Container and Steel Purge Gas Container
5.2 **Double Containment Tank System**

5.2.1 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.

5.2.2 The primary liquid container shall be of low-temperature-metal or prestressed concrete.

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

5.2.4 The secondary liquid container shall be constructed from metal and meet the relevant requirements of API 620 or of pre-stressed concrete and meet the relevant requirements of ACI 376.

5.2.5 Variants of double containment concepts using single tanks and independent primary liquid and vapor containers are in Figures 5-5 and 5-6:

![Diagram of Double Containment Tank System](image)

**FIG. 5-5**

Double Containment Tank System

Steel Primary Container and Steel Secondary Container
5.3 Full Containment Tank System

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

5.3.2 The primary liquid container shall be of low-temperature metal or prestressed concrete.

5.3.3 The secondary container shall be capable of both containing the liquid product and of controlled venting of the vapor resulting from evaporation in the event of product leakage from the primary liquid container.

5.3.4 The secondary liquid container and roof shall be constructed from metal and meet the relevant requirements of API 620 or of pre-stressed concrete and meet the relevant requirements of ACI 376.

5.3.5 Where concrete outer tanks are selected, vapor tightness during normal service shall be assured through the incorporation of a warm temperature metallic or polymeric vapor barrier. Under inner tank leakage (emergency) conditions, the material of the secondary concrete tank vapor barrier material will be exposed to cryogenic conditions. Vapor barrier liners are not expected to remain vapor tight in this condition; however, the concrete shall be designed to remain liquid tight and retain its liquid containment ability. Product losses due to the permeability of the concrete are acceptable in this case.
5.3.6 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 6.7.

5.3.7 Some variants of full containment concepts are in Figures 5-7 through 5-9:
FIG. 5-8
Full Containment Tank System
Steel Primary Container, Concrete Secondary Container, and Steel Roof

LEGEND:
1 - PRIMARY LIQUID CONTAINER (LOW TEMP STEEL)
2 - SECONDARY LIQUID CONTAINER (CONCRETE)
3 - VAPOR CONTAINER (ROOF)
4 - CONCRETE FOUNDATION
5 - SUSPENDED DECK W/ INSULATION
6 - INSULATION (ANNUAL SPACE)
7 - PRODUCT VAPOR CONTAINER (LINER)
8 - BOTTOM INSULATION
9 - SECONDARY LIQUID CONTAINER (LOW TEMP STEEL)
10 - THERMAL CORNER PROTECTION
11 - MOISTURE VAPOR BARRIER
12 - PUMP COLUMN
FIG. 5-9
Full Containment Tank System
Steel Primary Container, Concrete Secondary Container, and Concrete Roof
5.4 Guidance on Selection of Storage Concept

The storage concept shall be selected by the PURCHASER based on an assessment of risks in which the characteristics of the storage concept are considered in the context of jurisdictional regulations and the plan for the overall facility. Discussion of the implications of a release of liquid product from the primary liquid container of the various types of storage concepts along with some other distinctives of each type is found in Appendix C. Guidance information on performing an assessment of risk and using it to select the storage concept is provided in Appendix D.
SECTION 6 - Design and Performance Criteria

6.0 General

This section provides requirements for design of refrigerated tank systems to meet the performance criteria prescribed in 6.3 when subjected to applicable normal and abnormal design loads defined in 6.4. Guidelines for performing the seismic analysis are presented in 6.5.

6.1 Spacing Requirements

Determination by Owner/Purchaser of spacing of refrigerated gas storage tank systems from adjacent property and adjacent tanks should consider the following:
- Radiant heat flux from a liquefied flammable gas pool fire contained by the tank system secondary liquid containment. The secondary liquid containment of an adjacent tank system shall maintain its ability to contain liquid.
- Dispersion of gas evolved from liquefied flammable gas contained by the tank system secondary liquid container to a non-flammable mixture.

Guidance for satisfying the above can be found in Appendix D.

6.2 Liquid Levels and Volumes

Liquid levels and volumes used in this standard for design of the tank system are defined in section 3 and as further noted below. Figure 6-1 provides a graphical representation of the relationship of the terms used.
- Freeboard: a nominal freeboard of 300mm (1'-0) above the design liquid level shall be included in the height of the tank to prevent overfill and provide for free vapor flow below the deck during venting. The height of the tank may need to be increased further to satisfy seismic freeboard requirements.
- Seismic Design Liquid Level is defined in Section 6.5.8.
- Seismic Freeboard is defined in Section 6.5.9.
- Overfill Protection Margin is capacity defined by the owner / purchaser in terms of tank height, volume, or trip times between the maximum normal operating level and the design liquid level to accommodate process shutdown prior to reaching the design liquid level. Refer to API 2350 for further information.
- Minimum Normal Operating Level as defined by the owner / purchaser may be determined as the minimum level for pump restart, or may be the minimum pump down level including reduced pumping rates.
- Heel is the unusable volume of liquid below the minimum normal operating level. A minimum heel of 150mm (6") is required to maintain the operating temperature of the tank.
6.3 Performance Criteria

6.3.1 Normal Operating

The primary liquid container shall contain the liquid under all normal operating loads and conditions. Refer to section 5 for further definition of the meaning of primary liquid containment for various storage concepts.

The primary vapor container shall be vapor tight during normal operation. Further it shall have adequate pressure capacity above normal operating pressure to prevent venting during normal operating conditions.

6.3.2 Abnormal and Emergency Conditions

The primary liquid container shall be designed to maintain liquid containment under the abnormal and emergency conditions specified herein. However, if for any unforeseen condition the primary containment is not maintained then the secondary liquid containment shall contain the liquid.

The secondary liquid container shall be designed and sized to contain the maximum normal operating capacity of the primary liquid container.

Vapor containment requirements for abnormal and emergency conditions vary depending upon the storage concept specified; see Section 5.

Refer to ACI 376 Sections 4.1 and 4.2 for detailed criteria related to leak tightness of concrete primary and secondary containers.
6.3.3 Commissioning and Decommissioning

The tank system shall allow the criteria in Section 10 to be met. In addition, the tank system shall be capable of being decommissioned including purging to a gas to air mixture considered safe for personnel access.

6.3.4 Boil-off

The tank insulation system shall limit the boil-off rate to below the rate required by the plant design or maximum specified by the owner. The boil-off rate, normally specified in percent per day of maximum liquid capacity assuming a pure product, (unless otherwise specified by owner) shall be based on climatic conditions as specified for the project.

Climatic conditions normally considered in the design include:

- Highest recorded average temperature (over 24 hour period)
- No wind
- Solar radiant heat flux

6.3.5 Roll-Over

For stored products subject to rollover condition, the tank system shall provide a means to prevent rollover. See section 7.4.4 for active management of the stored product when rollover conditions are determined to be applicable.

6.3.6 Design Temperature

- Primary and secondary liquid containers and process lines carrying liquid or gas.
  - Minimum design temperatures shall be selected no higher than the pure product boiling temperature at one atmosphere (See Appendix A). However, design conditions such as introduction of sub-cooled product may require a lower design temperature.

- Refrigerated temperature roofs and suspended decks
  - Minimum design temperatures shall be equal to the design temperature for the primary liquid container.

- Warm vapor containers
  - Minimum design temperatures shall be equal to the lowest one day mean ambient temperature for the geographic location.

- Purge gas containers, not subject to containment of product vapor:
  - Minimum design temperatures shall be equal to the lowest one day mean ambient temperature for the geographic location.
• Local areas of the warm vapor container (e.g. process nozzle thermal distance piece connections to the vapor container) which may be subjected to temperatures below ambient conditions.
  - Minimum design temperature for these locations shall take this local cooling effect into consideration.

6.3.7 Differential Movements

The design of the tank system shall provide for differential movements between tank components resulting from differential design temperatures and erection vs. operating temperature. Components that are restrained from free differential movement shall be designed to incorporate adequate flexibility to maintain structural integrity.

6.3.8 Foundation Settlement

Design conditions for the storage tank system foundation, including the supporting soil, shall include predicted settlements. The following components shall be designed for predicted settlements (both short term and long term):

- the bottom insulation system
- the metal or concrete primary and secondary liquid container
- post-tensioning system
- the various tank attachments including connecting piping
- piles or other structural support systems

Annex B provides guidance for evaluating settlements.

6.3.9 Protection from Freezing of Soil

Where freezing of liquid in the soil under the tank foundation is possible and could cause heaving of the soil, the tank foundation design shall include a means to maintain the soil at a temperature above 0°C (32°F), or provide an elevated foundation to separate the cooling effect of the tank from the supporting soil.

6.3.10 Seismic Performance

Tank systems shall be designed for three levels of seismic motion. The magnitudes of the seismic ground motions are defined in Section 6.4.2 and sliding resistance requirements are defined in Section 6.5.10. In addition, the design shall meet the requirements of the applicable local building codes. The primary liquid container shall contain the seismic sloshing wave as defined in Section 6.5.9.

a. Operating Basis Earthquake (OBE): The tank system shall be designed to continue to operate during and after OBE event.

b. Safe Shutdown Earthquake (SSE): The tank system shall be designed to provide for no loss of containment capability of the primary container and it
shall be possible to isolate and maintain the tank system during and after SSE event

c. Aftershock Level Earthquake (ALE): The tank system, while subjected to ALE, shall provide for no loss of containment from the secondary container while containing the primary container volume at the maximum normal operating level.

6.4 Design Loads and Load Combinations

6.4.1 Design Loads

The following types of design loads shall be considered in the design of the containers and foundations. API 620 and ACI 376, Chapter 3 provide guidance on the types of the design loads and load combinations to be used. They include, but are not limited to the following:

Normal Loads:

1. Dead loads
2. Product Pressure and Weight
3. Internal pressure
4. External pressure
5. Construction Specific Loads
6. Testing and Commissioning Loads such as test, vacuum and pneumatic tests
7. Thermally-induced loads experienced during tank purging, cooling and filling
8. Shrinkage and Creep Induced Loads for concrete container
9. Pre-stressed loads for concrete container
10. Live Loads
11. Environmental Loads such as Snow, Wind and ice loading
12. Seismic Loads (OBE, defined in Section 6.4.2)
13. Decommissioning Loads
14. Loads induced by predicted differential settlement

In addition to the normal loads indicated above, the following loads from abnormal events shall be considered in the design.

1. Loads from liquid spill condition (for double and full containment tank systems)
2. Loads based on a assessment of risk such as fire, pressure wave external projectile etc. (when specified by purchaser)
3. Seismic Loads (SSE & ALE, defined in Section 6.4.2)

6.4.2 Seismic Loads

Probabilistic seismic hazard studies are required to determine the seismic ground motions for design of tank-fluid-foundation system. Three levels of the seismic ground motions shall be considered:
a. Operating Basis Earthquake (OBE): The OBE is defined as the seismic ground motion having 10% probability of exceedance within 50 year period, i.e. 475 year recurrence interval. The OBE is also referred to as Operating Level Earthquake (OLE) in API 620, App L.

b. Safe Shutdown Earthquake (SSE): The SSE is defined as the seismic ground motion having 2% probability of exceedance within 50 year period, i.e. 2,475 year recurrence interval. The SSE is also referred to as Contingency Level Earthquake (CLE) in API 620, Appendix L.

c. Aftershock Level Earthquake (ALE): The ALE is defined as half of the SSE.

6.4.3 Load Combinations

The design loads shall be combined to produce load combinations to be used in the analysis and design of the containers. Load combinations are dependent on the material type of the container. See API-620 for guidance on the load combinations for metal containers and ACI-376 for concrete containers.

6.5 Seismic Analysis

6.5.1 General

The tank system shall be designed for three levels of seismic ground motions as defined in Section 6.3.10 and 6.4.2 above. The rules in API 620 Appendix L shall be applied to all steel tanks designed to this standard. The rules of ACI 376 shall be applied to all concrete tanks designed to this standard.

6.5.2 Site-Specific Response Spectra

The site-specific horizontal and vertical acceleration response spectra shall be developed for both OBE & SSE for different damping values of up to 20%.

6.5.3 ALE Design

The ALE earthquake shall be considered only for the seismic design of secondary containment with full liquid condition, assuming that the primary container is damaged after the SSE event.

6.5.4 Tanks Supported on Rock

When the tank foundation is supported on rock-like site (defined as the site class A & B in IBC or ASCE 7), the fixed base condition is considered. In this case, the structural damping values shall be used for determining the seismic responses (SSI is not considered).

6.5.5 Soil-Structure Interaction
When the tank foundation is supported on soil (defined as the site class C to F in IBC or ASCE 7, soil-structure interaction seismic analysis (SSI) shall be considered. In this case, dynamic soil and pile stiffness and damping parameters should be included in the tank model for SSI analysis. Dynamic soil/pile properties are evaluated by considering the effects of seismically induced soil strains and forcing frequencies. System damping for SSI shall be calculated for determining seismic response, and should be limited to 15% for OBE and 20% for SSE.

6.5.6 Response Modification Factors – OBE

In order for the tank system to remain in continuous operation during and after OBE, the elastic method of seismic analysis should be performed. The response modification factor, R, applied in the response spectra design method shall be 1.0.

6.5.7 Response Modification Factors – SSE

The response modification factors for SSE design applying the response spectra design method shall meet those specified in API 620 L Tables L-4Q and L-4R for steel tanks and ACI 376 Section 6 for concrete tanks. Response reduction factors are not applicable for non-linear dynamic analysis methods incorporating fluid-structure and soil-structure interaction.

6.5.8 Seismic Design Liquid Level

The maximum normal operating level shall be applied to all seismic design including freeboard determinations.

6.5.9 Seismic Sloshing Wave Height

The seismic sloshing wave height shall be calculated in accordance with API 620 Appendix L. The seismic freeboard height shall be determined based on the OBE sloshing height plus 300mm (1 ft) allowance or the SSE sloshing height, whichever is larger.

6.5.10 Resistance to Base Shear – Sliding

The rules in API 620 Appendix L shall be applied to determine sliding resistance. In high seismic regions a more extensive analysis may be applied, provided it includes evaluation of the response of the shell, the fluid, and foundation (in the case of a slab) to the fluctuation of liquid pressures in the tank. When applying this approach, the horizontal and vertical seismic response should be applied based on the component combination of 100% and 40%. The case for the 100% vertical plus 40% horizontal load case shall be evaluated in addition to the 100% horizontal plus 40% vertical load case defined by API 620, App L. Alternately, a time history analysis approach may be applied incorporating both horizontal and vertical motions simultaneously.

6.5.11 Evaluation of Damage from an Earthquake
The seismic design may assume that when a tank system is subjected to an earthquake exceeding an OBE magnitude event, the tank system will be evaluated for permanent distortion, continued safe operation, and the need for repairs.

6.5.12 Interaction between Tank and Adjacent Structures

Consideration for flexibility of components connecting the tank system to adjacent structures shall be included in the tank system design.

6.6 Foundation Design

6.6.1 General

Tank systems shall be installed on suitable foundations designed to transmit all loadings to suitable load bearing soil strata. Types of foundation support systems consist of Raft or Mat foundations, pile foundations (steel H-piles, cast in-situ concrete piles or precast prestressed concrete piles) and elevated foundations supported on drilled shafts or vertical walls. ACI 376 Chapter 8 provides guidelines on foundation design.

Foundation support systems are dictated by detailed geotechnical investigation of the location for siting of the Tank Systems. The extent and detail of the soil investigation shall be specified by qualified geotechnical engineers. ACI 376 Section 8.2 gives detailed guidelines on the geotechnical investigations to be performed.

The materials of construction and the foundation type shall be designed to adequately resist the operating and emergency temperature conditions. The foundation shall maintain integrity under normal operating conditions. One method of maintaining the foundation integrity is to utilize the foundation base heating for grade supported mat foundations where subsoil freezing would occur under normal load conditions. Elevated foundations with adequate air gap between the bottom of the foundation and grade shall be considered in cases where base heating methods are not feasible.

6.6.3 Design Codes

The structural concrete design shall be in accordance with ACI 318. The concrete elements include raft or mat foundations, cast in-situ concrete piles or precast prestressed concrete piles, drilled shafts and vertical walls. For concrete elements in direct contact with liquid product, ACI 350 may be utilized. AISC steel construction manual provides guidelines on design of steel H-Pile Sections.

6.6.4 Factors of Safety

In general, the design soil parameters, (i.e., bearing capacity, pile compression and tension capacities etc.), are based on allowable stress design (ASD) approach with an ultimate capacity value divided by a factor of safety. The factor
of safety is based on soil type, variability and soil characterization. The factors of safety presented in Section 8 of ACI 376 can be used as a guide. The actual factor of safety shall be determined on a case by case basis, based on the recommendations of geotechnical engineer in charge of geotechnical investigations. An alternate design approach could be applied by comparing the ultimate factored soil/pile loads with the ultimate soil bearing or pile capacities.

ACI 318 utilizes an ultimate design strength approach for the design of the concrete foundation slabs, piers or piles.

6.6.5 Mat Foundations

If the supporting soil is found adequate with respect to load transfer and settlements then a soil supported mat foundation may be used. Adequate consideration shall be given to the effects of differential settlement, shrinkage, creep and thermal strains.

6.6.6 Pile Foundations

If bearing capacities are not sufficient or estimated settlements are excessive, then the foundation base slab may be supported by piles. Negative skin friction (down drag) and pile interaction (group effects) shall be considered when determining the pile capacity. The pile design shall consider operating loads, tank settlements, thermal cycling, drying shrinkage, creep effects, lateral deformations from wind, OBE and SSE earthquakes.

6.6.7 Anchorage

Anchorage of primary or secondary metallic containment tanks shall consider the following:

- Differential movement between the anchorage and the connection to the container
- Local stresses at the connection to the container
- Differential strength along the length of the anchor due to thermal effects and weld materials
- Connection details where the anchor extends through a containment boundary (such as the secondary containment bottom of a full or double containment tank)
- The anchorage shall exhibit ductile behavior prior to failure. Connections of the anchors to the container and foundation shall be designed for 1.25 times the anchor capacity at the minimum specified yield stress increased to account for thermal increases in material properties at design temperature.

6.7 Thermal Corner Protection System (TCP) for Concrete Tanks

Where required by ACI 376, the design of the wall to slab junction of a concrete container shall consider the effects of differential movement between the wall and base. Design of the junction shall also consider the application of differential
thermal stresses and prestress forces to provide liquid containment in case of a spill.

For fixed wall to base LNG tanks, a standard solution applies a metallic thermal corner protection expansion joint and a secondary bottom. The TCP may be designed to withstand the full hydrostatic pressure from a full spill, or may transfer a part of the pressure to the wall through load bearing insulation. If a TCP is required, the following shall be considered in the design of the TCP:

- The location of the top of the TCP as related to the prestress force diagram.
- Differential thermal movements between the connection to the wall and secondary bottom including the following conditions: Operating, small spill, full spill, and full spill plus ALE.
- Differential movements due to wall prestress and creep
- Wall rotation due to foundation settlement
- Differential shrinkage between the wall and top of TCP connection
- Erection tolerances between the TCP and the load bearing insulation
SECTION 7 - Accessories and Appurtenances

7.0 General

Accessory and appurtenance considerations for safe operation of the tank are addressed in the following paragraphs.

7.1 Access

7.1.1 Tank Interior Access

Shell manholes shall not be used in the primary liquid container of full containment tanks unless otherwise specified by the Purchaser. In other tank configurations, shell manholes may be provided in the primary liquid container and, when used, shall utilize welded closure details to prevent leakage during service.

7.1.2 Tank Roof Access
A primary system for accessing the tank roof shall be provided. The type of roof access system shall be suited for reliable personnel ingress/egress. Unless otherwise specified by the Purchaser, a second access system shall be provided if the primary tank egress pathway can be obstructed or if the primary system is mechanically operated and powered (e.g., electrical or hydraulic elevator).

Walkways or platforms shall be provided to access all roof appurtenances requiring periodic maintenance such as vents and level gauges and for access to the roof manholes.

7.2 Process Piping

7.2.1 Process Piping - General Requirements

7.2.1.1 Material requirements - Refer to API 620 Sections Q.2.5 or Table R-1 for material selection requirements for process piping components.

7.2.1.2 Nondestructive examination - Refer to API 620 Sections Q.5.7 or R.5.7

7.2.1.3 Configuration requirements

a. Flanged joints in refrigerated liquid and vapor piping systems are not permitted in the space between inner and outer containers.

b. For single containment tanks, process lines may penetrate the roof, bottom, or shell except as restricted by specification or regulation. In-tank valves should be considered when bottom or shell process lines are used. In-tank valves shall be automatically activated on pressure drop due to failure of external piping and shall also be automatically activated during a loss of electrical power and shall be capable of being activated from a remote location.

c. For double or full containment tanks, shell or bottom penetrations that breach the primary and secondary containment are not allowed except when all of the following additional requirements are met:
   i. The penetrations are specified by the Purchaser
   ii. No prohibition exists in applicable regulations
   iii. The penetrations are accounted for in the assessment of risk as per 5.4
   iv. In-tank valves are provided. Refer to 7.2.1.3(b)
   v. A remote dike wall is provided in addition to the secondary containment that is part of the tank system. The volume contained by the dike shall equal 110% of the flow from a full line break prior to closure of the in-tank valve.

7.2.2 Tank Fill Lines

Fill lines may be top and/or bottom-fill type as required by process conditions and roll-over mitigation as per 7.4.4.
7.2.3 Tank Outlet System

When shell or bottom outlets are not provided, pump columns and in-tank pumps are required. Pump columns, extending from above the roof level to near the tank bottom, shall be designed to transport product to the outlet line connection on the roof and to contain the removable pump. The pump columns shall be designed, constructed, and tested in accordance with ASME B31.3 or ASME Section VIII. Pump columns shall be designed for pump removal and replacement during tank operating conditions by transporting the pump through the inside of the pump column.

7.2.4 Purge System

A system shall be provided to facilitate purge and cool down per Section 10.

7.2.5 Cool-Down System

The tank system shall include a separate fill line specifically for cool down of the tank. The system shall have a means for control of the flow to meet the cool down rates defined in Section 10. For products stored at temperatures below \(-51^\circ C (-60^\circ F)\), the cool down line shall incorporate spray nozzles and shall introduce liquid near the top center of the primary liquid containment tank.

7.3 Relief Valves

7.3.1 General

Design and installation of tank pressure and vacuum relief valves shall comply with API620 Sec.9 and API 2000 (and other applicable codes and standards, such as NFPA58, NFPA59, NFPA59A, ANSI K61.1, etc.).

Conditions related to the plant process design determined by the plant process designer shall be evaluated.

Venting requirements of this standard shall be met by relief to atmosphere. If release to atmosphere is not allowed for the product stored, a second set of relief valves shall be provided to flare, set at a lower set pressure.

7.3.2 Pressure Relief Valves

The number and size of pressure relief valves required shall be calculated based on the total product vapor outflow and the applicable set point considering flow losses from the inlet and vent piping of the relief system. In addition, one spare valve shall be installed for maintenance purposes.

The inlet piping shall penetrate the suspended deck where applicable but be located above the level of the top of a primary liquid container, thus preventing cold vapor from entering the warm space between outer roof and suspended deck under relieving conditions.
Required capacity shall be based on the largest single relief flow or any reasonable and probable combination of the following relief flows.

a. Fire exposure  
b. Operational upset  
c. Failures at interconnected facilities  
d. Heat input from pump recirculation, if any  
e. Barometric pressure change  
f. Tank filling  
g. Tank heat leak (boil off)  
h. Roll-over, if required by owners or applicable regulations

In addition to the above conditions, the following conditions should be considered for a full containment tank.

i. Vapor generated due to a primary liquid container leakage (Note: EN14620-1 Section 7.2.2.1 may be referred to for sizing of the relief flow.)  
j. Overfill, if it is required by hazard study.

7.3.3 Vacuum Relief Valves

The number and size of vacuum relief valves shall be calculated based on the total air inflow and set points specified. In addition, one spare valve shall be installed for maintenance purposes.

The vacuum relief valves shall allow air to enter the vapor space. Volumetric change due to temperature change of the air shall be taken into consideration. Required capacity shall be based on the following:

a. Withdrawal of liquid and vapor  
b. Barometric pressure change

7.4 Instrumentation

7.4.1 Level Gauges / Over Fill Protection

The tank shall be equipped with two independent liquid level gauges, which include high level alarms. A separate, liquid level alarm and cutoff device is also required. All level instruments shall be designed and installed so that they can be maintained during operating condition.

7.4.2 Leak Detection

A system for detecting leaks through the primary liquid container shall be provided for all double and full containment tanks. Such a system is required for double-wall single containment tanks only if specified by purchaser or if required by a result of a hazard study. The system may be based on one of the following.

a. Temperature change  
b. Gas detection
c. Differential pressure measurement

7.4.3 Temperature

Temperature monitoring devices for the primary liquid container shall be provided to assist in controlling cool down and to monitor liquid and vapor temperature as required for operation. For controlling cool down, temperature elements shall be located on the inner tank bottom and in a vertical array near or on the inner tank shell.

7.4.4 Roll-Over

Roll-over conditions shall be prevented by active management of the stored fluid. If roll-over is determined to be applicable per Section 6.3.5, a density measurement system shall monitor the density over the full liquid height and give an alarm when predicted roll-over conditions are approached. Active management includes monitoring temperatures/densities and mixing the liquid by appropriate top and bottom filling or by recirculation.

7.4.5 Pressure

Two pressure instruments are required to monitor and control tank pressure. The pressure instruments shall be connected to the space above the design liquid level.

7.5 Foundation Accessories

7.5.1 Foundation Heating (when required by foundation design)

The foundation heating system shall be designed to meet the performance criteria mentioned in 6.3.9. The heating system shall be controlled by temperature sensors, which are installed in the foundation. The foundation heating system shall have 100% redundancy and give an alarm for the system failures.

7.5.2 Foundation Settlement Monitoring

In monitoring the settlement, an independent datum reference point located beyond the influence of local foundations shall be established. Permanent markers shall be provided to facilitate settlement monitoring around the perimeter of the foundation at a minimum of 8 locations not more than 30 feet apart. In addition, for concrete outer wall tanks and for settlement conditions that are expected to approach the design limits set for the tank, provisions shall be made to measure dishing settlement. An inclinometer system can be provided to accomplish this requirement.

7.5.3 Seismic Ground Motion Measurement
As noted in Section 6.5.11, seismic design may assume a damage evaluation is performed for seismic events greater than an OBE event. A seismometer or accelerometer around the tank(s) or in the plant may be required to determine OBE exceedance.

### 7.6 Fire, Gas and Cryogenic Spill

#### 7.6.1 General

Protections for fire, gas and cryogenic spill are required as per 7.6.2 to 7.6.7, if they are specified by the purchaser or per regulations, or as a result of a hazard study.

#### 7.6.2 Fire and Gas Detection

For tanks designed to store flammable products, flammable gas detector(s) should be installed in the area where the potential leakage could occur (e.g. flange joints in the area of the process lines on the tank and tail pipe of PRV).

#### 7.6.3 Fire Protection

All essential appurtenances and equipment on the tank and the platform should be protected against radiant heat flux by means of fixed cooling water spray systems, fire proofing or other relevant method enabling protection against radiant heat flux resulting from external fire.

#### 7.6.4 Heat Detection

Heat detector(s) should be provided to give an alarm so that the water spray system mentioned in 7.6.3 can be activated.

#### 7.6.5 Low Temperature Detection

Low temperature detector(s) should be installed in the area where potential leakage could occur (e.g. flange joints in the area of the process lines on the tank and tail pipe of PRV).

#### 7.6.6 Roof Spill Protection

A cryogenic liquid spill protection system should be provided to prevent roof damage. This system may consist of a separate collection system or utilize roof components, constructed of suitable cryogenic material. For example, a concrete roof may be a part of the spill protection system if it is designed for cryogenic temperature. Design spill parameters shall be per the applicable regulation and any purchaser supplemental requirements.

#### 7.6.7 Cold Protection of Miscellaneous Components

Components, such as pipe supports and equipment, whose continuous usage is essential to plant safety, should be resistant to or protected against cryogenic liquid if they are subject to exposure.
7.7  Electrical

7.7.1  Lightening Protection

Lightning protection shall be provided in accordance with NFPA 780 (and NFPA 59A as applicable).

7.7.2  Grounding / Earth

Tank grounding shall meet the requirements of NFPA 780.

7.7.3  Aviation Lighting

Aircraft warning lights shall be supplied when required by FAA or applicable local/international rules and regulations or when specified by the purchaser.

7.8  Miscellaneous

7.8.1  A means for handling roof top equipment requiring periodic maintenance, such as in-tank pumps, shall be provided.

7.8.2  Perlite Fill Nozzles

Perlite fill nozzles in the roof shall be provided when applicable.
SECTION 8 – Quality Assurance and Quality Control

8.0 Introduction

Tank system construction in accordance with this standard consists of various subactivities such as design, procurement, fabrication, construction and testing for all subsystems such as the foundation, tanks, piping, insulation, electrical and instrumentation systems etc. A quality management system shall be utilized to ensure that the work performed meets quality requirements.

Quality management systems consist of Quality Control (QC) and Quality Assurance (QA) activities.

QC is a system of routine activities developed to measure and controls the quality of the work as it is being performed. The QC system is designed to provide routine and consistent checks to ensure correctness and completeness and identify corrective responses.

QA consists of a series of systematic planned activities implemented in a quality system so that quality requirements are met. QA includes review procedures for the implementation of QC.

ISO 9001 and API Specification Q1 provide guidance for establishing QA and QC plans.

8.2 NDE, Testing and Tolerances
Nondestructive Examination (NDE) activities during tank system construction shall be performed to ensure that the quality requirements of the work are met. Testing such as hydrostatic and pneumatic tests, loop checks of the electrical work, foundation level measurements etc. are mandated by construction standards to ensure construction integrity. Tolerances are imposed by the construction codes such that design considerations are not violated.

The QA/ QC requirements for construction contained in applicable design and construction standards such as API-620, ACI 318, ACI 376 and ASME B31.3 shall be followed during construction. In addition to the standards, additional requirements may be imposed by regulatory codes such as NEC and NFPA 59A.
SECTION 9 – Insulation

9.1 System Design

The insulation system shall be designed to:

a. Not fail under the specified or calculated static and dynamic loads.
b. Maintain product boil-off at or below the specified limit at the specified climatic conditions.
c. Maintain components (such as those of an outer tank) at or above their minimum design temperature.
d. Minimize condensation and icing.
e. Prevent soil freezing (in combination with the tank foundation heating system for foundations on grade).
f. Prevent ingress of moisture (in combination with other tank components).
g. Be purged (loose fill and blanket insulation) during commissioning and decommissioning.

9.2 Materials

9.2.1 Tests of materials are required to ensure that their properties (thermal conductivity, strength, density, etc.) are adequate, except for Perlite which is field tested. See 10.8 for specifications.

9.2.2 A detailed testing, installation and inspection plan shall be submitted by the tank manufacturer to the purchaser.
9.2.3 Insulation shall be protected, particularly from moisture, during shipment, storage, installation, tank hydrotest and in service.

9.2.4 For liquid oxygen tanks, insulation shall be non combustible.

9.3 Load Bearing Bottom and Thermal Corner Protection (TCP) Insulation

9.3.1 System Design

9.3.1.1 The insulation must be designed for static and dynamic compressive and shear loads. These loads include weight, earthquake, and tank movement due to commissioning and decommissioning and filling and emptying.

9.3.2 Materials

9.3.2.1 Materials for bottom and TCP insulation include brittle materials (cellular glass), materials subject to creep but with closed cells (polyvinyl chloride, etc.) and, for ring beams, high load bearing materials. For concrete ring beams, refer to ACI 376.

9.3.2.2 Tests of materials subject to creep are required to establish their acceptability.

9.3.3 Design

9.3.3.1 Structural design of insulation shall be based on allowable stress or limit state. For limit state design, follow EN 14620–4 Annex C.

9.3.3.2 For brittle materials the minimum safety factors based on fully effective interleaving materials are:

a. Normal operation – 3.0 relative to nominal compressive strength
b. Hydrotest – 2.25 relative to nominal compressive strength
c. OBE Earthquake – 1.25 relative to lower specification limit compressive strength
d. SSE Earthquake – 1.0 relative to lower specification limit compressive strength

9.3.3.3 For brittle materials with open surface cells an interleaving material shall be applied to develop the compressive strength of the material. System tests shall have established the effectiveness of the material used and the bearing capacity shall be reduced by that effectiveness. Interleaving materials other than asphalt Type III or IV shall be tested or shall have been previously tested to include the following:

a. Blocks shall be selected from the same production run.
b. Halves of a minimum of ten blocks shall be used for the control tests and the other halves for the interleaving material.
c. Control tests shall be per ASTM C240 to duplicate the tests basis of the material manufacturer.
d. Tests with the interleaving material shall be per ASTM C240 except for sample preparation.
e. Each compressive strength grade shall be tested separately.

9.3.3.4 For materials subject to creep, the permissible load shall be established in accordance with EN 14620-4, Section 6.3.2.2.2.

9.3.3.5 The thermal design of the ring beam and any underlying insulation shall minimize temperatures which are lower under the ring beam than under the bottom insulation.

9.3.4 Installation

9.3.4.1 Insulation joints shall be staggered with minimum gaps.

9.3.4.2 Insulation shall be installed over a leveling layer of concrete or sand and topped with a layer of concrete or sand or other material. Sand shall be clean, free flowing, non-plastic, free of organic matter, have a maximum chloride content of 500 ppm, and no greater than 5% shall pass a number 200 sieve. Sand shall also have a maximum installed moisture content of 5% by weight, (measured immediately prior to covering with insulation or bottom plate).

9.3.4.3 For brittle materials, an interleaving material shall be applied between layers, above the top layer and below the bottom layer. The material shall be butted and not lapped except that the interleaving material above the top layer may be lapped.

9.4 External Wall and Roof Insulation

9.4.1 System Design

External wall and roof insulation systems include rigid insulation covered by a weatherproofing and vapor barrier or by sealed jacketing that acts as a vapor barrier. Refer to NFPA 59A Section 7.2.5 for requirements applicable to external insulation regardless of product stored.

9.4.2 Design

9.4.2.1 The insulation shall have a weatherproofing or jacketing chosen to resist site conditions such as marine or polluted atmospheres and be attached to resist wind.

9.4.2.2 The attachment of the insulation and vapor barrier shall be designed to accommodate the dimensional changes of the tank.

9.4.2.3 Steel tanks (except stainless steel) shall be painted or coated prior to insulating.
9.5 Internal Wall Insulation

9.5.1 System Design

Internal wall insulation systems include:

a. Loose fill (e.g. Perlite) in the annular space.
b. Insulation applied to the outer surface of the inner wall or the inner surface of the outer wall, or both.
c. These may also be used between double dome roofs.

9.5.2 Materials

For loose fill insulation, tests shall be conducted during production and installation of the material (see 9.2.1 and 9.2.2).

9.5.3 Design and Installation of Loose Fill Insulation

9.5.3.1 For metal inner tanks, a compaction control system typically consisting of a resilient blanket on the inner tank wall shall be installed to limit pressure on the inner tank due to filling/emptying and commissioning/decommissioning. Where this is not installed, (e.g. liquid oxygen tanks) the inner tank shall be designed for the uncontrolled Perlite pressure. The purchaser shall specify the number of commissioning/decommissioning cycles. The manufacturer shall demonstrate by calculations or tests that the design pressure is conservative.

9.5.3.2 The method of supporting and attaching any blanket insulation to prevent failure due to loose fill drag friction shall be submitted by the manufacturer to the purchaser. The outer layer shall have a high tensile facing.

9.5.3.3 Loose fill shall be compacted to the specified density by vibration during installation.

9.5.3.4 A loose fill volume above the annular space extending to the outer roof shall be provided. This volume shall not be less than 4% of the loose fill volume in the annular space. A partition shall be provided on suspended deck designs unless loose fill is also used on the suspended deck.

9.5.3.5 Loose fill filling nozzles shall be provided so that loose fill may be added in service. This also applies to loose fill between double dome roofs.

9.5.4 Design of Sprayed-on Insulation Attached to the Walls

9.5.4.1 Insulation shall not disbond from the wall on contact with spilled product.
9.5.4.2 The insulation attachment shall be designed to accommodate the tank movements.

9.6 **Suspended Deck Insulation**

9.6.1 If loose fill is used, deck seams must be sealed.

9.6.2 For products and atmospheric conditions where condensation can occur in the space above the deck, the insulation shall be designed so that it cannot be affected by the condensation.

9.7 **Penetration and Internal Piping Insulation**

9.7.1 Roof nozzle connections with internal cold vapor or liquid process piping shall be provided with thermal distance pieces where required to hold the roof to near ambient temperature at the point of penetration. Insulation shall be provided between the thermal distance pieces and the cold line.

9.7.2 Cold vapor or liquid process piping between the roof and a suspended deck shall be insulated.

9.8 **Specifications for Insulation**

The following ASTM specifications shall be used in the supply and testing of insulation.

9.8.1 **Cellular Glass**

- C165 Standard Test Method for Measuring Compressive Properties of Thermal Insulations
- C240 Standard Test Methods of Testing Cellular Glass Insulation Block
- C552 Standard Specification for Cellular Glass Insulation

9.8.2. **Perlite**

- C549 Standard Specification for Perlite Loose Fill Insulation

9.8.3. **Resilient Glass Fiber Blanket**


9.8.4 Materials subject to creep (polyvinyl chloride, etc.)

Specifications for these materials shall be proposed by the manufacturer and approved by the purchaser.
Note: Information on Perlite is available at www.perlite.org
SECTION 10 - Post Construction Activities

10.1 Scope

This section provides requirements and guidance for post construction activities necessary for the safe startup of storage tank systems covered in this standard. Activities include pressure testing, purging and cool down.

- Requirements for concrete structures are provided within ACI 376.
- Requirements for metal structures are provided in API 620.

10.2 General

All construction activities, inspections, testing and cleaning (all sand, sludge and standing water shall be removed) of the tank shall be completed. All instrumentation shall be calibrated and verified prior to final closure of the tank. All electrical systems including the foundation heating system shall be verified as operational. A drying / purging and cool down procedure shall be prepared by the Tank Contractor for incorporation into the detailed plant purge and cool down procedure.

10.3 Hydrostatic and Pneumatic Testing

10.3.1 Testing of Primary Liquid and Vapor Containers

Requirements for hydrostatic and pneumatic testing of the primary liquid and vapor containers are provided within API 620 and ACI 376.
10.3.2 Testing of Secondary Liquid Containers

Hydrostatic testing of secondary liquid containers of double and full containment tank systems is not required unless explicitly specified by the purchaser. When specified for specific projects, hydrostatic testing of secondary liquid containers shall include the following.

- Hydrostatic testing of the primary container must be completed prior to the secondary container test and shall not be drained prior to filling and emptying the secondary container.

- Verification of primary bottom leak tightness must be made during testing of the primary liquid container. The bottom insulation system must be protected from exposure to water during secondary container testing.

- Water test height for the secondary container shall, as a minimum, be set at a height that produces a liquid pressure in the base of the container equivalent to 1.25 times the pressure produced to contain the full primary container contents at design liquid level.

- Water quality for the secondary container shall meet the water requirements in API 620.

10.3.2 Pressure Testing of Pump Columns

Pump columns shall be pressure tested, hydrostatically or pneumatically, in accordance with the standard used for their design (see paragraph 7.2.3). Pump columns shall be installed prior to hydrostatic testing of the primary liquid container. Pump column internal pressure testing shall be performed with the primary liquid container empty, and the pump column shall be empty when the primary liquid container is hydrostatically tested.

10.3.3 Pressure Testing of Piping

Piping shall be pressure tested as required by API 620 Appendix Q or Appendix R.

10.4 Drying / Purging

10.4.1 Immediately following the hydrostatic test of the tank, residual standing water shall be removed.

10.4.2 Excessive free water within the insulation system can cause the insulation system to perform below its design basis and, in the case of cellular glass load bearing insulation could cause damage to the insulation system. Erection procedures shall incorporate provisions that eliminate collection of excessive moisture within the insulation system.

10.4.3 Excessive moisture in the tank atmosphere will be naturally removed from the gas when the gas temperature drops below the dew point of the gas. Therefore,
removal of most moisture from the gas within the tank will be achieved through the process of nitrogen and warm gas purges discussed below. The dew point values in Table 10.1 can be used as an indication for when detrimental moisture has been adequately removed. It is not necessary to lower the dew point below 32°F (0°C). If the recommended dew point is reached at the end of the nitrogen purge and if the nitrogen purge is followed by a warm product purge, it is not necessary to take subsequent readings.

10.4.4 A nitrogen purge shall reduce the oxygen level in the tank to a level that will allow the product to be introduced without creating a combustible gas mixture. The O₂ end point value in Table 10.1 is a value that is considered safe for ethylene per AGA Principles and Practice – 2001. Percent oxygen in nitrogen gas end points for all other gasses covered by this standard could be safely set at a higher level but the dew point values listed will normally be harder to achieve than the 8% O₂ level.

10.4.5 A warm product purge to between 80% and 90% product gas normally follows the nitrogen purge and is completed prior to tank cool down. If liquefied gas is introduced directly into a nitrogen environment, the initial introduction can cause the temperature of the liquid to drop below the product design temperature and the design metal temperature. Material selection and tank design must consider this lower temperature if a warm product purge is not performed.

10.4.6 An exception to the O₂ values in Table 10.1 is ammonia storage. Anhydrous ammonia storage is susceptible to stress corrosion cracking (SCC). Water additions have been shown to reduce the SCC process and any free moisture exposed to ammonia vapor will combine with the ammonia. The percent O₂ at time of liquid accumulation is also important to reduce the SCC process. Therefore, the O₂ level achieved prior to cool down (liquid accumulation) is recommended to be lower than the value in Table 10.1 and should be as low as practical.

10.4.7 When the tank is not cooled down immediately following completion of the purging a small positive pressure should be maintained to prevent ingress of oxygen and moisture. When the cool down is delayed more than 2 weeks, the purge dew point end point for the annular space, as measured at the end of the nitrogen purge, should be reduced from the values in Table 10.1 by 5°C to stabilize the moisture levels in the tank.

10.4.8 Purge dew point levels recommended for primary concrete containers are found in ACI 376.

Table 10.1
Recommended Drying and Nitrogen Purging End Points for Steel Tanks

<table>
<thead>
<tr>
<th>Section</th>
<th>Dew Point at 1 atm</th>
<th>O₂ Concentration Level (Vol %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner tank and Dome space</td>
<td>-5°C (+23°F) Max.</td>
<td>8% Max.</td>
</tr>
<tr>
<td>Annular space (internally insulated double wall suspended deck tanks)</td>
<td>+10° C (+50° F) Max.</td>
<td>8% Max.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Bottom Insulation Space</td>
<td>No measurement necessary</td>
<td>No measurement necessary</td>
</tr>
<tr>
<td>Annular Space of a double wall double roof tank</td>
<td>No measurement necessary</td>
<td>No measurement necessary</td>
</tr>
</tbody>
</table>

10.5 Cool Down

10.5.1 Cool down shall be performed after the tank purge has been completed. A cool down procedure shall be developed to provide a controlled process. During the initial introduction of liquid product, it is important to insure that the storage tank cools as uniformly as possible. Sharp thermal gradients can cause permanent local distortions and potential crack growth. The cool down rate for the primary liquid container shall be controlled to a maximum average of 5°C/h (9°F/h) and shall not exceed 8°C/h (15°F/h) during any one hour.

10.5.2 For thermal gradients and cool down procedures related to concrete tanks, see ACI 376.

10.5.3 The cool down can be considered complete when a minimum of 150 mm (6 inches) of liquid product is maintained in the storage tank. At this point the bottom TEs and TEs in the first 3 meters (10 ft) of the vertical TE array will be reading approximately product storage temperature.
SECTION 11 — MARKING

11.1 Nameplates

11.1.1 A tank system made in accordance with this standard shall be identified by a nameplate identifying the constituents of the system similar to that shown in Figure 11-1. Every tank system requires the contents of Figure 11-1a on its nameplate. A tank system having more than one container requires a longer nameplate with the additional content of Figure 11-1b for each additional container. The nameplate shall indicate, by means of letters and numerals not less than 4 mm (5/32 in.) high, the following information. At the purchaser’s request or at the contractor’s discretion, additional pertinent information may be shown on the nameplate.

A. API Standard 625.
B. The edition of API Standard 625
C. The addendum number of API Standard 625.
D. The Storage Concept. This is Single Containment, Double Containment, or Full Containment as defined in Section 5.
E. The year the tank system was completed.
F. Maximum Normal Operating Capacity as illustrated in Fig 6-1 in m³ (42-gallon barrels).
G. The number assigned to the tank system according to the numbering system for equipment at the facility.
H. The name of the contractor with overall responsibility for the tank system.
I. The number assigned to the tank system by contractor (may be the same contract number for construction of multiple tank systems)
J. The type of container. This shall be “Primary Liquid Container”, “Secondary Liquid Container”, “Warm Vapor Container”, or “Purge Gas Container”.

K. The standard of construction for a particular container. (i.e. API Standard 620 or ACI 376)

L. The nominal diameter in meters (feet and inches of the cylindrical shell.

M. The edition of the standard of construction for a particular container.

N. The nominal height, in meters (feet and inches)

O. The addendum of the edition of the standard of construction for a particular container.

P. The design specific gravity of the stored liquid.

Q. The minimum design temperature in degrees Celsius (Fahrenheit) as per 6.3.6.

R. The design pressure (gage) in addition to any liquid head. In the case of an open top liquid container, indicate “N/A”.

S. The design liquid level in meters (feet and inches) as illustrated in Fig 6-

T. The design external pressure (gage). In the case of an open top liquid container, indicate “N/A”.

U. The water level to which the container was filled during hydrotest.

V. The pressure applied to the container during test in addition to any liquid head.

W. The material used for the container. (e.g. “ASTM A516-70N steel”, “ASTM A553 Type 1 steel”, “pre-stressed concrete”, etc)

11.1.2 All nameplates shall be attached to the outside wall of the tank system where they are readily visible. For attachment to metal containers, the nameplates shall be attached to the tank shell on the first shell course. A nameplate that is placed directly on the shell plate or reinforcing plate shall be attached by continuous welding or brazing all around the nameplate. A nameplate that is riveted or otherwise permanently attached to an auxiliary plate of ferrous material shall be attached to the tank shell plate or reinforcing plate by continuous welding. The nameplate shall be of corrosion-resistant metal.

For concrete tanks, the name plate should be attached to an auxiliary plate of coated or galvanized ferrous material that is embedded in concrete.

11.2 Certification

Upon completion of all tests and inspections on each tank system, the contractor shall certify to the purchaser, by a letter such as that shown in Figure 11-2, that the tank system has been constructed in accordance with the applicable requirements of this standard.

11.3 Report

The contractor shall prepare a report to the purchaser summarizing all the data on the tank system, and shall attach to the report drawings, charts and records as necessary. The content of this report shall be as agreed between purchaser and contractor.
**Figure 11-1.a General Information and Primary Liquid Container Nameplate**

<table>
<thead>
<tr>
<th><strong>API STANDARD 625</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EDITION</td>
<td>B</td>
</tr>
<tr>
<td>ADDENDUM</td>
<td>C</td>
</tr>
<tr>
<td>STORAGE CONCEPT</td>
<td>D</td>
</tr>
<tr>
<td>YEAR COMPLETED</td>
<td>E</td>
</tr>
<tr>
<td>MAXIMUM NORMAL</td>
<td>F</td>
</tr>
<tr>
<td>OPERATING CAPACITY</td>
<td>G</td>
</tr>
<tr>
<td>PURCHASER TK. NO.</td>
<td>H</td>
</tr>
<tr>
<td>CONTRACTOR SER. NO.</td>
<td>I</td>
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</table>

**PRIMARY LIQUID CONTAINER**

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>CONST. STD</td>
<td>K</td>
</tr>
<tr>
<td>NOMINAL DIA.</td>
<td>L</td>
</tr>
<tr>
<td>EDITION</td>
<td>M</td>
</tr>
<tr>
<td>NOMINAL HEIGHT</td>
<td>N</td>
</tr>
<tr>
<td>ADDENDUM</td>
<td>O</td>
</tr>
<tr>
<td>DESIGN SPECIFIC GRAVITY</td>
<td>P</td>
</tr>
<tr>
<td>MIN. DESIGN TEMP</td>
<td>Q</td>
</tr>
<tr>
<td>DESIGN PRESSURE (PSI)</td>
<td>R</td>
</tr>
<tr>
<td>DESIGN LIQ. LEVEL</td>
<td>S</td>
</tr>
<tr>
<td>DESIGN EXT. PRESSURE</td>
<td>T</td>
</tr>
<tr>
<td>HYDROSTATIC TEST LEVEL</td>
<td>U</td>
</tr>
<tr>
<td>TEST PRESSURE</td>
<td>V</td>
</tr>
<tr>
<td>CONTAINER MATERIAL</td>
<td>W</td>
</tr>
</tbody>
</table>
Figure 11.1.b – Additional Container Nameplate

<table>
<thead>
<tr>
<th>J</th>
<th>CONTAINER</th>
</tr>
</thead>
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<td>CONST. STD</td>
<td>K NOMINAL DIA.</td>
</tr>
<tr>
<td>EDITION</td>
<td>M NOMINAL HEIGHT</td>
</tr>
<tr>
<td>ADDENDUM</td>
<td>O DESIGN SPECIFIC GRAVITY</td>
</tr>
<tr>
<td>MIN. DESIGN TEMP</td>
<td>Q DESIGN PRESSURE (INT)</td>
</tr>
<tr>
<td>DESIGN LIQ. LEVEL</td>
<td>S DESIGN EXT. PRESSURE</td>
</tr>
<tr>
<td>HYDROSTATIC TEST LEVEL</td>
<td>U TEST PRESSURE</td>
</tr>
<tr>
<td>CONTAINER MATERIAL</td>
<td>W</td>
</tr>
</tbody>
</table>
Contractor’s Certification for a Tank System Built to API Standard 625

To
(name and address of purchaser)

We hereby certify that the tank system constructed for you at (Location)

And described as follows:

(Serial or contract number, single/ double/ full containment, diameter, height, capacity etc.)

meets all applicable requirements of API Standard 625, ______________ Edition, ______________ Addendum, Dated ____________________, including the requirements for design, materials, fabrication, and construction.
The tank system is further described on the attached as-built data sheet dated ____________________.

Contractor
Authorized Representative
Date
Appendix A – Properties of Gases

This informational appendix provides useful reference data. Sources of the values given are as follows. LFL / UFL Flammability Limits are from NFPA 497. All other values are verified by HYSYS, (Process modeling analysis computer program by AspenTech). Unless otherwise noted, physical property values have been calculated based on the following conditions: Temperature = 70°F and Pressure (atmospheric) = 14.7 psi.

Note that all values are for pure gasses. Actual stored liquid gases may contain a combination of several gasses. Design values to be used on specific tank designs may be somewhat different and shall be provided according to the responsibilities outlined in Section 4.
Table A -1a Physical Properties of Gases (SI)

<table>
<thead>
<tr>
<th>GAS</th>
<th>Chemical Formula</th>
<th>MOLECULAR WEIGHT</th>
<th>BOILING POINT AT 1 ATM (°C)</th>
<th>SPECIFIC HEAT (Cp) (Mass Heat Capacity) at conditions defined above (kJ/kg °C)</th>
<th>CRITICAL POINT TEMP (°C)</th>
<th>CRITICAL POINT PRESS (kPa abs)</th>
<th>VAPOR DENSITY at conditions defined above (kg/m³)</th>
<th>VAPOR DENSITY at (1 ATM) BOILING POINT (kg/m³)</th>
<th>LIQUID DENSITY at (1 ATM) BOILING POINT (kg/m³)</th>
<th>GAS/LIQUID RATIO (1 ATM BOILING POINT)</th>
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<tbody>
<tr>
<td>Air</td>
<td>28.95</td>
<td>0.99</td>
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<td></td>
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<td></td>
<td></td>
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<td>Ar 39.95</td>
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<td>-122.5</td>
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<td>1.69</td>
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<td>1389.79</td>
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<td>Methane</td>
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<td>420.04</td>
<td>624</td>
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<td>Ethylene</td>
<td>C₂H₄ 28.05</td>
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<td>Propylene</td>
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<td>Anhydrous</td>
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<td>Iso-butane</td>
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<td>2.69</td>
<td>601.50</td>
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Table A -1b Physical Properties of Gases (US Customary Units)
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<th>GAS</th>
<th>Chemical Formula</th>
<th>MOLECULAR WEIGHT</th>
<th>BOILING PT at 1 ATM (°F)</th>
<th>SPECIFIC HEAT (Cp) (Mass Heat Capacity) at conditions defined above (BTU/lb°F)</th>
<th>CRITICAL POINT TEMP (°F)</th>
<th>CRITICAL POINT PRESS (psi abs)</th>
<th>VAPOR DENSITY at conditions defined above (lb/cu ft)</th>
<th>VAPOR DENSITY at (1 ATM) BOILING POINT (lb/cu ft)</th>
<th>LIQUID DENSITY at (1 ATM) BOILING POINT (lb/cu ft)</th>
<th>GAS/LIQUID RATIO</th>
<th>ATM / E POI</th>
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</thead>
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<tr>
<td>Air</td>
<td></td>
<td>28.95</td>
<td>0.24</td>
<td>0.08</td>
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APPENDIX B - Foundation Settlement

B.0 General

The effects of foundation settlement must be considered in the design of the tank system including individual tank system components. Depending on the combination of loads, temperature, time and settlement effects, foundation settlement can result in unacceptable stress levels and/or distortions in the tank system. Differential settlement between the tank system and adjacent structures can also affect the design of interconnecting components. The term foundation includes any combination of soil improvement and deep or shallow bearing structures.

Tank settlement patterns and resultant tank distortions can be very complex and unpredictable. Important factors that can affect how a tank reacts to settlement include heterogeneous soils (both vertically and horizontally), variable as-built distortions, short vs. long term movements, and sensitivity of structural details to movement.

B.1 Predicted Settlements

Predicted settlements shall be determined as part of the site specific geotechnical study (4.2.1.7). Soil improvement, as determined necessary by design of the tank system, may be provided to reduce the predicted settlements.

B.2 Settlement Types
Settlement can be separated into four specific types: uniform settlement, global tilt, differential center-to-edge settlement and differential circumferential settlement. Actual settlement typically is a combination of these settlement types and their effects on the tank system can be additive. Values provided below are based on experience and intended as guidance for steel tanks. Design of concrete tanks may require different limits. Refer to ACI 376 for further guidance. Variations from these values below or those provided in ACI 376 are acceptable if accounted for in the design of the tank system and interconnecting components.

B.2.1 Uniform Settlement

The amount of acceptable uniform settlement is dependent upon piping and structural connections between the tank system and adjacent structures.

B.2.2 Global Tilt

Global tilt (also addressed as planar tilt) is associated with rigid body rotation of the superstructure caused by non-uniform soil across the width of the structure. While large tanks may be able to accommodate significant uniform tilt without damage, other components usually require lower values of tilt.

Predicted global tilt, measured in inches, of a flat bottom tank shell should be limited to 5 times the tank diameter divided by the tank height. Tilt is often restricted to lesser values as a result of the same issues addressed in B.2.1 for uniform settlement metricate.

B.2.3 Differential Center-to-Edge Settlement

Tank systems constructed to this standard have self supporting roofs. Differential settlement between the center and the edge does not affect the roof. While bottom plate can accommodate significant settlement, tank internals supported by the bottom and the bottom insulation system inherent in these tank systems cannot. Significant short or long term settlement of the bottom can crack or damage the bottom insulation system which would increase the heat leak of the structure, potentially causing freezing of the soil under the tank.

Predicted differential settlement between the edge of the tank and the center should be limited to the radius of the tank divided by 240.

B.2.4 Differential Circumferential Settlement

Irregular settlement of soils around the periphery of a tank can cause out-of-roundness and localized distortions and buckles in a tank. These can affect the stability or the performance of the tank.

Predicted differential settlement around the periphery of the tank should be limited to 1:1000 i.e. 10mm in an arc of 10 meters (3/8 inch in an arc of 30 feet).
APPENDIX C—Commentary on Behavior of Storage Concepts

C.0 General

This appendix discusses the implications of a release of liquid product from the primary liquid container of the various storage concepts along with some other distinctives of each type.

C.1 Single Containment Tank System

C.1.1 Leakage or failure of the primary liquid container may lead to spreading of liquid over the surrounding area resulting in extensive vapor formation. To limit the spreading of the liquid and vapor cloud formation, secondary containment in the form of dikes are provided. Either low dikes remote from the tank or higher dikes close to the tank may be used provided that the theoretical spill volume is retained. However, the distance of the dikes from the primary liquid container influences the vapor cloud formation and this may have an impact on the layout of the facility including spacing and location of the tanks.

C.1.2 Penetrations through secondary liquid containment (dikes) are not recommended. To ensure integrity of the spill containment, pipe work should be detailed to go over dikes rather than through them. Where pipe work penetrates the dikes below the liquid levels, particular attention should be paid to the location, detailing and design to ensure that the product is retained.
C.2 Double Containment

C.2.1 The “double containment” or “double integrity” concept evolved from single containment and lowers the risks and consequences of a traveling vapor cloud and potential pool fires following a primary liquid container leakage or failure.

C.2.2 In order to reduce both the wetted area and surface area of a spilled pool of liquid product, the low dikes at fairly large distances (used with single containment tank systems) are replaced with close proximity high dikes. Therefore the double containment tank is essentially a single containment tank system with the addition of close proximity dikes. In this standard the secondary containment wall shall be no more than 6 m (20 feet) from the primary liquid container.

C.2.3 One additional change from the single containment concept is that piping penetrations are not permitted through the primary liquid and secondary liquid containers below the liquid level unless additional criteria of 7.2.1.3c are satisfied.

C.2.4 The secondary liquid container may be of metal or prestressed concrete. When improved resistance to external threats and hazards is specified, prestressed concrete may be used.

C.3 Full Containment

C.3.1 The full containment concept evolved from double containment and has the following advantages:

- Controls or prevents the release of product vapors following (postulated) primary liquid container leakage or failure.
- Greater ability to resist external threats such as blast, fire and impact compared to of single and double containment tanks.
- Reduced land requirements relative to single and double containment tanks.

C.3.2 The primary liquid container has historically been constructed of welded metal plates with suitable low temperature characteristics. Concrete primary tanks with metallic liners have been constructed. Tanks using only pre-stressed concrete have been used for liquid oxygen service.

C.3.3 The secondary liquid container may be of metal or prestressed concrete; however when improved resistance to external threats and hazards is specified, it is generally achieved through the adoption of pre-stressed reinforced concrete.

C.3.4 The roof of a pre-stressed concrete outer tank may be constructed from metal or concrete. However the metal roof is more susceptible to damage from leakage at product flanges and external hazards (see Appendix D.2.2.3). Where these hazards are specified it is common to adopt a concrete roof.
Additionally where a concrete roof is provided, a complete roof collapse may not be considered credible.
APPENDIX D
Guidance on Selection of Storage Concept Based on Assessment of Risk

D.0 Scope

This appendix provides guidance to the PURCHASER on making the selection of the storage concept from among the three main concepts and their variations which are presented in Section 5. Per Section 5.4, the selection is to be based on an assessment of risk. The risk is a function of not only the storage concept itself but also the way the tank system relates to many other aspects of the overall facility. Therefore, while the guidance provided is mostly focused on the storage concept, it also touches as necessary on other aspects of the facility and its surroundings.

D.1 Introduction and Background

D.1.1 By definition refrigerated liquefied gas facilities can in the event of an upset or emergency event release gases that present a significant threat to human life, the environment and surrounding communities. This is especially true for cryogenic liquids where the volume of their gases can be up to 600 times the volume of the liquid. Depending on the liquefied gas stored and the rate of leakage, the potential result following a loss of primary containment is generation of vapor clouds that can drift beyond the facility.

D.1.2 Plans for the proposed facility should specifically address the impact of gas clouds and radiant heat flux on plant facilities and adjacent properties. Intrinsic within this approach is the selection of storage concept, separation distances,
and proximity to property lines, site topography; soil conditions, and ground water conditions. A review of the site may identify constraints or provide opportunities to utilize specific features of site to the benefit of the facility i.e. natural topography may allow the selection of single containment.

D.1.3 Key drivers known to influence storage concept selection are as follows.

- Product to be stored
- Availability of land
- Proximity to residential developments and habitable areas
- Influence/impact of adjacent process plant and equipment
- Hazards as discussed in D.2.2.4 and D.2.2.5.

D.1.4 The possible effect of a liquid spill from any portion of the facility should be considered. This is particularly relevant where there is a conduit through which the liquid product can flow beyond the secondary liquid containers. Appendix C provides information on effects of liquid spills from the various tank concepts.

D.1.5 The determination of vapor generation and dissipation is complex and dependent on many parameters including relative gas to air densities, meteorological conditions, terrain, rate of release and the amount of entrained liquid droplets dispersed into the vapor cloud.

D.1.6 When liquid product spills, evaporation takes place. The amount of evaporation in the very first moments depends primarily on the exposed surface in contact with the cryogenic liquid.

D.1.7 Initially most refrigerated vapors are heavier than air and sink due to their low temperature. However as heat is drawn from the environment some hydrocarbons become less dense and when warmed eventually become lighter than air. Propane, ethylene and heavier vapors remain denser than air, even when warmed to ambient temperatures. Refer to Appendix A for data relevant to these considerations.

D.1.8 Depending on atmospheric and environmental conditions the resulting gas cloud may drift across or away from the facility prior to being dispersed below its lower flammable limit where ignition is no longer possible. The area wetted in the case of a spill may be limited in order to reduce the size and travel distance of a gas cloud. The exposed wetted area is directly linked to the selection of containment concept.

D.1.9 The rate of heat generation from a large pool of burning liquefied gas is significantly higher than that of a similar pool of another oil product. Again in order to limit the radiant heat flux on the surroundings to acceptable levels it may be necessary to reduce as much as possible the area of the pool of spilled liquefied gas though the selection of containment concept.

D.2 Assessment of Risk
D.2.1 General

D.2.1.1 Per Section 5.4, the storage concept shall be selected by the PURCHASER based on an assessment of risks in which the characteristics of the storage concept and the influence of external, internal and environmental hazards are considered in the context of jurisdictional regulations and the plan for the overall facility. The risk assessment shall demonstrate that the risks to property and life are acceptable, both inside and outside the plant boundary.

D.2.1.2 One method to achieve this is by means of a staged risk assessment that clearly identifies the hazards, failure conditions, probabilities of occurrence and consequences thereof.

D.2.2 Hazard Identification

D.2.2.1 The assessment of risk process commences with identification of the hazards that can be grouped into external and internal threats.

D.2.2.2 All containment systems shall be designed with the assumption that the primary tank may leak or fail and gradual filling of the secondary container may take place. For metallic tanks where the material is selected and tested in accordance with this standard the possibility of sudden failure “unzipping or zip failure” of the inner tank is not a normal design consideration. Where extra protection from brittle fracture is desired, general practice is increase the toughness requirements of the primary container rather than design for zip. Design for zip failure, on the other hand, implies a requirement that the outer tank or wall be designed to withstand the consequent impact loading.

D.2.2.3 Additional hazards that should be considered by the purchaser when selecting a containment concept are in D.2.2.4 and D.2.2.5. These lists are not exhaustive and a risk assessment should be performed by responsible parties to identify the critical hazards that influence the concept selection and plant layout.

D.2.2.4 External Hazards

- Environmental hazards including earthquake, lightning, wind loading including hurricane/typhoons, flooding, snow and ice loading, tsunamis and seiches.
- Ground conditions, weak strata, liquefiable layers, lateral spreading, and presence of caverns, voids and defects.
- Flying objects, and equipment following a process incident
- Pressure waves due to vapor cloud ignitions from the process plant, adjacent plant, process equipment and carriers including facilities located outside the boundary limits.
- Operational and upset conditions including spillage and leakage of product
- Maintenance hazards;
Fire hazards from adjacent tanks, dikes, relief valves, sumps, jet fires and plant areas
Proximity of tanks to external uncontrolled sources of ignition such as ground flares, flares.

D.2.2.5 Internal Hazards

- Leakage of product from the inner tank
- Overfilling of the tank
- Over/Under pressurization of the tank due to process upset
- Roll-over leading to over pressurization of the tank
- Major leak i.e. the complete failure of the inner tank
- Minor leak i.e. partial leakage from the inner tank due to a postulated defect
- Fatigue and cyclic loading of key components e.g. annular plates
- Corrosion
- Failure of pipe work attached to the tank bottom/sides
- Instrumentation failures

D.2.3 Safety Improvement

Where the assessment of risk identifies risks that exceed acceptable limits then positive measures (action) should be taken to reduce the level of risk to an acceptable level. Typical mitigation measures may be as follows;

- Selection of alternative containment concepts i.e. migration from single containment double or full containment.
- Improvements to process equipment selection
- Substitution of a metal roof on a full containment tank with a concrete
- Increase in safety distances (separation distances) to limit impact in respect of vapor dispersion and radiant heat flux
- Elimination of ignition sources
- Selection of alternate layouts and site locations
- Inclusion of protection systems to shield critical equipment from hazard