



Tentative Interim Amendment

NFPA® 59A

Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)

2016 Edition

Reference: Various

TIA 16-1

(SC 15-12-4 / TIA Log #1187R)

Note: Text of the TIA was issued and approved for incorporation into the document prior to printing.

1. *Add new entries to Subsection 2.3.12 to read as follows:*

EN14620-1 through 5, (2006) Design and manufacture of site built, vertical, cylindrical, flat-bottomed, steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and -165 °C PARTS 1 – 5.

CEB Bulletin 187 (1988) Concrete Structures under Impact and Impulsive Loading.

2. *Add new 3.3.4.3.3* and Annex to read as follows (renumber current 3.3.4.3.3 as 3.3.4.3.4):*

3.3.4.3.3* Membrane Containment Tank System. A tank system consisting of a thin metal liquid barrier and load-bearing thermal insulation supported by a self-standing outer concrete container jointly forming an integrated composite tank structure designed to contain liquid and vapor during tank operation as well as LNG in the event of leakage from the liquid barrier, and where the vapor-containing roof of the outer container is either steel or concrete configured such that the excess vapor caused by a spill of LNG from the liquid barrier will discharge through the relief valves.

A.3.3.4.3.3 A membrane containment tank system consists of a thin metal liquid- and vapor-tight barrier resting against load-bearing thermal insulation and supported by a free-standing outer pre-stressed concrete container.

In normal conditions, primary liquid and vapor containment is provided by a thin metallic barrier which is structurally supported via load-bearing insulation on an outer pre-stressed concrete container. Under these conditions primary vapor containment is provided by a thin metallic barrier which is connected to the metallic roof liner.

In emergency conditions, the secondary liquid and vapor containment is provided by an outer pre-stressed concrete container and metallic roof liner. The outer container must be capable of both containing the liquid product and controlling the vapor resulting from evaporation. In this instance the vapor generated from the leakage is discharged through pressure relief valves located in the roof. Vapor losses due to permeability through the outer pre-stressed concrete are acceptable while the wall is containing liquid in the event of leakage from the thin metal barrier and insulation system.

The roof of the outer pre-stressed concrete container may be concrete or steel. Significant design issues arise at the monolithic base-to-wall connection due to the mechanical restraint offered by the base. To mitigate these issues, a secondary liquid containment barrier inside the insulation system across the entire bottom and part of the wall in the vicinity of the base-to-wall joint is to be provided to protect and thermally isolate this area from the cold liquid and provide liquid-tightness. Other alternatives of the monolithic base-to-wall are described in ACI376.

3.3.4.3.4* Single Containment Tank System.

A single wall container or a double wall tank system in which only the self-supporting primary or inner container is designed to contain LNG.

3. Revise 5.3.1.1(4) to read as follows:

5.3.1.1 Provisions shall be made to minimize the potential of accidental discharge of LNG at containers, pipelines containing LNG, and other equipment such that a discharge from any of these does not endanger adjoining property or important process equipment and structures or reach waterways. LNG containers shall be provided with one of the following methods to contain any release:

- (1) An impounding area surrounding the container(s) that is formed by a natural barrier, dike, impounding wall, or combination thereof complying with 5.3.2 and 5.3.3
- (2) An impounding area formed by a natural barrier, dike, excavation, impounding wall, or combination thereof complying with 5.3.2 and 5.3.3, plus a natural or man-made drainage system surrounding the container(s) that complies with 5.3.2 and 5.3.3
- (3) Where the container is constructed below or partially below the surrounding grade, an impounding area formed by excavation complying with 5.3.2 and 5.3.3
- (4) Secondary containment as required for double, ~~or~~ full, or membrane containment tank systems complying with 5.3.2 and 5.3.3.

4. Revise 5.3.2.5 and Annex to read as follows:*

5.3.2.5* Dikes and impounding walls shall meet the following requirements:

- (1) Dikes, impounding walls, drainage systems, and any penetrations thereof shall be designed to withstand the full hydrostatic head of impounded LNG or flammable refrigerant, the effect of rapid cooling to the temperature of the liquid to be confined, any anticipated fire exposure, and natural forces, such as earthquakes, wind, and rain.
- (2) Where the outer shell of a tank system-complies with the requirements of 5.3.1.1, the dike shall be either the outer shell or as specified in 5.3.1.1.

A.5.3.2.5 Section 7.2.1.1 requires compliance with API 625. API 625 paragraph 5.6 requires the selection of storage concept to be based on a risk assessment. API 625 Annex C discusses implications of a release of liquid from the primary liquid container and provides specific discussion related to each containment type. API 625 Annex D provides guidance for selection of storage concepts as part of the risk assessment including external and internal events and hazards to be evaluated. Paragraph D.3.2.2 discusses the possibility of sudden failure of the inner tank and advises “if extra protection from brittle fracture” (or unabated ductile crack propagation) “is desired, the general practice is to increase the” primary container toughness. Available materials meeting the required specifications of API 620 Appendix Q (and this standard) for LNG service are considered to have crack-arrest properties at LNG service temperature and stress levels. Therefore, rapid failure of a steel primary container meeting this standard is not considered credible. In membrane containment tank systems, brittle fracture of membrane material is typically not a pertinent hazard for membrane tanks. However, other hazards based on a risk assessment should be considered.

5. Revise 5.3.2.7 to read as follows:

5.3.2.7 Double, full, and membrane containment tank systems shall be designed and constructed such that in the case of a fire in an adjacent tank, the secondary container shall retain sufficient structural integrity to prevent collapse, which can cause damage to and leakage from the primary container.

6. Revise 5.3.2.8 to read as follows:

5.3.2.8 Double, full, and membrane containment tank systems shall have no pipe penetrations below the liquid level.

7. Revise 5.3.4.2 and add new 5.3.4.2.1 to read as follows:

5.3.4.2 Double, full, and-membrane containment tank systems of greater than 70,000 gal (265 m³) water capacity shall be separated from adjacent LNG storage containers such that a fire in an adjacent single or double containment impoundment or from a design spill will not cause loss of containment from adjacent containers. This shall be accomplished by ensuring that no part of the adjacent storage container roof, walls, or its impoundment structure reaches a temperature at which the strength of the material of the container roof, wall, or its impoundment is reduced to a level where the LNG tank, roof, or impoundment loses its structural integrity....

5.3.4.2.1 The outer concrete container shall be designed for the external fire in accordance with ACI 376 unless fire protection measures are provided. The outer tank thermal analysis shall be performed to determine temperature distribution for the heat flux and duration of exposure as specified in the fire risk assessment within API 625.

- (1) The applicable load components and the ultimate state load factors for the fire load combinations shall be in accordance with ACI 376 Table 7.3. For membrane tanks, an additional liquid pressure load in accordance with ACI 376 Table 7.2 shall be included.
- (2) The design of the outer concrete container shall take into account the following factors:
 - (a) Reduction in the wall post-tensioning due to the difference in the coefficient thermal expansion of post-tensioning steel and wall concrete at the temperature to which the post-tensioning steel is exposed. The effects of the concrete aggregate type on the concrete coefficient thermal expansion shall be considered;
 - (b) Reduction in strength and modulus of elasticity of the outer tank concrete, reinforcing and post-tensioning steel due to elevated temperature;
 - (c) Reduction in the wall post-tensioning due to pre-stressing steel softening and relaxation at elevated temperature;
- (3) The concrete wall, including the wall concrete mix, shall be designed to avoid explosive spalling.

8. *Revise 7.2.1.1 to read as follows:*

7.2.1.1 Storage tank systems shall comply with the requirements of API 625, *Tank Systems for Refrigerated Liquefied Gas Storage, including membrane containment tank systems*, and the additional provisions of this chapter. The API 625 risk assessment shall be approved by the AHJ.

9. *Add new 7.2.1.4 and 7.2.1.5 and renumber current 7.2.1.4 to read as follows:*

7.2.1.4 The metallic membrane, load-bearing insulation, and the outer container moisture barrier specific to the membrane tank system shall comply with EN 14620 parts 1-5 for material selection, design, installation, examination, and testing and further requirements of 7.4. All other components of the membrane tank system shall comply with API625, API620, ACI376 and additional requirements in Section 7.4.

7.2.1.5 All the membrane system components, including insulation, primary membrane, and the secondary barrier of the thermal protection system, shall be designed in such a way that they can withstand all possible static and dynamic actions throughout the tank lifetime.

7.2.1.46 Should any conflict exist between the above requirements, the most stringent requirement shall apply.

10. *Revise 7.3.1.2 (A) to read as follows:*

7.3.1.2 All piping that is a part of an LNG tank system shall comply with requirements in this chapter and requirements within API 625.

- (A) Tank system piping shall include all piping internal to the container, within insulation spaces and within void spaces, external piping attached or connected to the container up to the first circumferential external joint of the piping, and external piping serving only tank instrumentation (including tank pressure relief valves). All liquid piping with a source of external line pressure shall be designed for the external line relief valve setting but not less than 50 psi (345 kPa). Double, full, and membrane containment tank systems shall have no pipe penetrations below the liquid level...

11. *Revise 7.3.3.2, 7.3.3.2(A), and 7.3.3.2(C) and add new (D) to read as follows:*

7.3.3.2 The space between the inner container and the outer container shall contain insulation that is compatible with LNG and natural gas and that is noncombustible as installed for normal service and abnormal conditions.

- (A) A fire external to the outer tank shall not cause a reduction to the internal containment system performance due to damage to any component of the insulation systems.
- (B) The load-bearing bottom insulation shall be designed and installed so that cracking from thermal and mechanical stresses does not jeopardize the integrity of the container.
- (C) For tank systems other than membrane containment tank system, only materials used between the inner and outer tank bottoms (floors) shall not be required to meet the combustibility requirements, where the material and the design of the installation comply with all of the following:
- (1) The flame spread index of the material shall not exceed 25, and the material shall not support continued progressive combustion in air.
 - (2) The material shall be of such composition that surfaces that would be exposed by cutting through the material on any plane shall have a flame spread index not greater than 25 and shall not support continued progressive combustion.
 - (3) It shall be shown by test that the combustion properties of the material do not increase significantly as a result of long-term exposure to LNG or natural gas at the anticipated service pressure and temperature.
 - (4) The materials in the installed condition shall be demonstrated to be capable of being purged of natural gas.
 - (5) The natural gas remaining after purging shall not be significant and shall not increase the combustibility of the material.
- (D) For membrane containment tank systems, the insulation system block shall include a non-foam cover (underneath the primary membrane) and shall include a welding thermal protection system in order to withstand all heat from welding during installation and during maintenance, if any.

12. Add a new 7.4.2.3 to read as follows:

7.4.2.3 For membrane containment tank systems, weld procedure and production weld testing shall comply with EN14620 part 2 and the following requirements:

7.4.2.3.1 Qualification of Welders. All personnel associated with the welding fabrication of the membrane system shall be qualified by the manufacturer per an agreed upon schedule between the purchaser, the AHJ, and the fabricator. All records shall be available for review.

7.4.2.3.2 Inspection. 100% of all welding shall be visually examined for workmanship and conformance to the fabrication requirements. Bead placement and consistency shall be, at a minimum, documented by digital means for review by supervisory personnel.

The personnel performing this visual inspection shall be qualified to an accepted standard for this inspection work. Upon cooldown of the welds to room temperature, provisions shall be made to perform a penetrant inspection (PT) of at least 5% of each weld type each day. The selection factors include orientation, welding direction, and complexity of welding being performed.

a) All profiles and configurations of welds shall be subjected to this 5% requirement. The selection of this 5% sample shall be agreed upon by the fabricator, customer's representative, and the AHJ.

b) The acceptance standard for this inspection technique shall be agreed upon by all parties.

c) Any indication of a leak requires an additional 5% penetrant inspection of the total distance welded by each welder.

Inspection after completion of membrane represents the last step prior to the cooldown of the tank to service temperature.

After completion of the membrane, a leakage test shall be performed. Leakage shall be determined as agreed upon by the fabricator and customer.

Tracer gas for this leak test shall be in accordance with approved procedure. All areas where leakage exceeds limit shall be repaired and inspected per 7.4.2.3.2, and the manufacturer's approved procedure.

In parallel, mechanical stress testing of the welding joints shall be performed by applying 3 cycles from atmospheric pressure to +20 mbarg inside the insulation space, with the pressure maintained, for a minimum time of 30 minutes. Data shall be recorded.

7.4.2.3.3 Post-Repair Inspection. Additional tracer gas testing shall be performed if more than 4 leaks per 1,000 m² of membrane are identified.

All repaired areas shall be visually inspected (VT), vacuum box (VB) tested, and dye penetrant (PT) tested.

7.4.2.3.4 Final Global Test and Control During removal of construction equipment.

This testing shall be in agreement with the approved test procedure and witnessed by all relevant parties. This represents the final acceptance testing of the completed membrane structure following completion of its installation in the structural outer shell / container.

a) The overall tightness of the membrane shall be determined by establishing a pressure difference between the tank and the insulation space.

b) This pressurization allows gas flow through the membrane representative of potential leaks on the membrane.

c) The potential leak(s) shall be characterized by measuring the oxygen content increase in the primary insulated space as the tank is pressurized with dry air

d) The primary insulated space shall be regulated slightly above the atmospheric pressure.

e) All test data, all records, documentation, and witness records shall be submitted to all parties for their review and final acceptance.

Daily tightness check/monitoring shall be performed during removal of construction equipment by pulling vacuum inside insulated spaces. Any pressure rise is indicative of a leak and must be reported and corrective action taken.

13. Revise 7.4.4.6(C) as follows:

(C) The SSE design shall provide for no loss of containment capability of the primary container of single, double and full containment tank systems and of the metal liquid barrier of membrane tank system, and it shall be possible to isolate and maintain the LNG tank system during and after the SSE

14. Revise 7.4.4.7 and add new 7.4.4.8 as follows:

7.4.4.7 The secondary liquid container or impounding system for single, double or full containment tanks shall, as a minimum, be designed to withstand an SSE while empty and an ALE while holding a volume equivalent to the primary containment liquid at the maximum normal operating level as defined in API 625.

7.4.4.8 For the membrane tank system, all components of the product-containing structure, including liquid barrier, insulation system, thermal corner protection system (see 7.4.7.1), and the outer concrete tank, shall be designed to withstand without failure an SSE event with the tank filled to the maximum normal operating level. The outer concrete tank and the thermal corner protection shall be designed to withstand an ALE with a tank full to the maximum normal operating level assuming that the membrane is failed and the outer tank wall and thermal corner protection system are exposed to LNG.

15. Add a new 7.4.4.12 to read as follows:

7.4.4.12 The outer concrete tank analysis and design for the leak and leak plus ALE aftershock event shall take into account any damage that may have occurred to the outer concrete tank due to prior events including the SSE earthquake. The outer concrete tank shall be considered as undamaged during the prior SSE event if the following conditions are met:

- (1) Tensile stresses in the reinforcing steel do not exceed 90% of the reinforcing steel yield
- (2) Maximum concrete compressive stresses do not exceed 85% of the concrete design compressive strength.

Otherwise, the prior damage shall be taken into account in the spill analysis.

16. Add new 7.4.6.5 and Annex to read as follows:

7.4.6.5* Membrane containment tank systems shall be tested in accordance with EN 14620 Part 5 Table 1. The leakage test, as defined in the Note under EN 14620 Part 5 paragraph 4.1.1, shall be performed. Leakage through the membrane to the insulation space during service shall be controlled in order to maintain gas concentration level below 30% of the LEL by sweeping the insulated space with an inert gas. If the gas concentration cannot be maintained below 30% LEL, the tank shall be decommissioned and retested. For purposes of evaluating this level, the flow of purge gas within the annular space shall not be increased above the normal operating rate.

A.7.4.6.5 EN 14620 Part 5 Table 1 requires the outer concrete tank to be hydrostatically tested prior to installing insulation and the membrane. The membrane is leak tested after all welding is completed. A retest is required following repairs to close leaks. An insulation space monitoring system is required by EN 14620 Part 1 paragraph 7.2.1.8 which is intended to identify any leaks of LNG gas or vapor into the space between the membrane and the wall.

17. Add new 7.4.6.6 to read as follows:

7.4.6.6 Verification of all components of the membrane containment tank system design by experimental data from model tests shall be carried out.

18. Add a new Subsection 7.4.7 to read as follows:

7.4.7 Additional Requirements for Membrane Containment Tank Systems.

7.4.7.1 A thermal corner protection system functionally equivalent to the thermal corner protection system for concrete tanks (as defined in API625 Section 6 and if required by ACI 376) shall be provided for the outer concrete tank of the membrane tank system. The thermal corner protection shall protect the outer tank entire bottom and at least lower 16.5 feet (5m) of the wall from thermal shock and shall be liquid tight when it is in contact with LNG and vapor tight in all conditions. The thermal corner protection system shall be permitted to be either metallic or from nonmetallic materials compatible with LNG and shall maintain structural integrity and liquid/gas tightness under all applicable mechanical and thermal loads.

The membrane containment tank system supplier shall provide tests independently witnessed and verified by a third party agency clearly demonstrating the leak tightness of all the thermal corner system under spill conditions. Historical tests shall be acceptable provided that construction processes and materials of construction are the same as those proposed. Nondestructive examination (NDE) performed on the secondary barrier and NDE acceptance criteria shall ensure that provided tightness is equivalent to the tightness provided by the metallic thermal corner protection system of the full containment tank system.

7.4.7.2 The outer concrete container of the membrane containment tank system shall meet all requirements of ACI376 for the secondary concrete container including materials, design, construction, inspection, and testing and the additional requirements specified below:

7.4.7.2.1 The product liquid pressure shall be a design load for the outer concrete tank. Liquid product pressure ultimate limit state (ULS) load factors for operating and abnormal loading conditions shall be in accordance with Table 7.2 of ACI376.

7.4.7.2.2 The outer concrete container wall and slab-to-wall junction shall be checked for fatigue assuming four full load-unload cycles a week for the expected life of the tank. Performance criteria of ACI376 Appendix C shall apply.

7.4.7.2.3 The outer concrete container wall shall resist the specified impact load without perforation and scabbing.

- A) The concrete wall thickness shall be at least 40% greater than the scabbing depth calculated per CEB 187 Section 4.1.2.2
- B) The concrete wall thickness shall be at least 20% greater than the perforation thickness calculated per CEB 187 Section 4.1.1.1
- C) The concrete wall shall be designed so that either one of the following is satisfied;
 1. The distance between the outer face of the concrete container measured to the centroid of the pre-stressing tendons shall be greater than the penetration depth calculated as per CEB 187 Section 4.1.2.1 with the following allowances for uncertainty;
 - 20 % thicker than the penetration depth when $z > 0.75$
 - 50% thicker than the penetration depth when ≤ 0.75 .
 2. The concrete wall shall be designed to be able to resist normal operating loads with any one horizontal tendon completely ineffective.

D) For concrete walls post-tensioned with a wire wrapping system, the wall shall be designed to resist normal operating loads with the wires affected by a specified impact load considered completely ineffective. No unwrapping of the post-tensioning wires shall be allowed.

7.4.7.2.4 At a minimum, the outer concrete container for the membrane tank system shall meet the construction tolerances specified in ACI376. Where more stringent tolerances are required by the membrane and insulation systems, the more stringent tolerances shall be specified by the membrane tank engineer and met by the tank contractor.

7.4.7.2.5 The outer concrete container shall be hydrotested prior to membrane and insulation installation following primary container hydrotest requirements of API625 Section 10.

19. Revise the title of Figure 10.7.2(e) to read as follows:

FIGURE 10.7.2(e) Full and Membrane Containment Tank Systems.

20. Revise (3) to the Atmospheric Cryogenic Tanks section of Table 15.6.1 to read as follows:

Component	Annual Probability of Failure
Atmospheric Cryogenic Tanks	
(1) Instantaneous failure of primary container and outer shell, release of entire contents (single containment tank)	5E-07
(2) Instantaneous failure of primary container and outer shell, release of entire contents (double containment tank)	1.25E-08
(3) Instantaneous failure of primary and secondary container, release of entire contents (full and membrane containment tanks)	1E-08

21. Revise B.3.4 to read as follows:

B.3.4 The impounding system must, as a minimum, be designed to withstand the SSE level of loading while empty (and while full if a membrane containment tank system) and the ALE level of loading while holding the volume, *V*, as specified in 7.4.4.7. The rationale is that should the LNG container fail following an SSE, the impounding system must remain intact and be able to contain the contents of the LNG container when subjected to an aftershock.

Issue Date: December 8, 2015

Effective Date: December 28, 2015

(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/codelist)

Copyright © 2015 All Rights Reserve
NATIONAL FIRE PROTECTION ASSOCIATION