

CGA H-3 — 2024

4TH EDITION

STANDARD FOR CRYOGENIC HYDROGEN STORAGE

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NOTE—Technical changes from the previous edition are underlined.

NOTE—Appendices A and B (Informative) are for information only.

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1 Introduction

This publication contains the suggested minimum design and performance requirements for shop-fabricated, vacuum-insulated cryogenic tanks (vertical and horizontal) intended for above ground storage of liquid hydrogen.

2 Scope

This publication applies to liquid hydrogen storage tanks with maximum allowable working pressures (MAWP) up to and including 175 psi (1210 kPa).^{1,2} Tanks less than 1000 gal (3785 L) gross volume or greater than 25 000 gal (94 600 L) gross volume and all transportable containers are excluded. Tanks outside these pressure and volume constraints may also meet the requirements of this standard when agreed upon by the purchaser/manufacture and the authority having jurisdiction (AHJ). This standard does not include operation and installation requirements or emergency response information.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Ancillary equipment

Group of components used for operation of the tank including valves, gauges, fittings, telemetry systems, etc.

3.2.2 Annular space

Volumetric space between the inner vessel and outer jacket that contains insulation materials and is evacuated to lessen heat flux.

3.2.3 Annular space piping

Interconnected piping between the inner vessel and outer jacket.

3.2.4 Cold net volume

Net capacity of the inner vessel at -423°F (-253°C) in liters or gallons.

NOTE—This value is also referred to as the full trycock volume or the net liquid capacity of the inner vessel. It may be expressed as the cold gross volume minus the ullage (vapor space) of the inner vessel.

¹ psi, bar, and kPa shall indicate gauge pressure unless otherwise noted as (psia; bar, abs; and kPa, abs) for absolute pressure or (psid; bar, dif; and kPa, dif) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [1].

² References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.2.5 Cold spot

Surface temperature that is 10 °F (5 °C) or more below ambient in-the-shade air temperature.

3.2.6 Gross volume

Total internal volume of the inner vessel in liters or gallons.

3.2.6.1 Cold gross volume

Total internal volume at −423 °F (−253 °C).

NOTE—Cold gross volume is the warm gross volume adjusted for the thermal contraction of the inner vessel. It may be expressed as the cold net volume plus the ullage (vapor space) of the inner vessel.

3.2.6.2 Warm gross volume

Total internal volume at 68 °F (20 °C).

NOTE—Warm gross volume is frequently referred to as water volume.

3.2.7 Inner vessel

Internally pressurized envelope (including nozzle penetrations) that contains the liquid hydrogen.

3.2.8 Insulation

Material surrounding the inner vessel that reduces the flow of heat into the inner vessel.

NOTE—Typically, the insulation is perlite (expanded siliceous volcanic rock) or super insulation (alternating layers of reflective surfaces and nonconducting spacers).

3.2.9 Maximum allowable working pressure (MAWP)

Maximum vapor space gauge pressure permitted at the top of the inner vessel.

3.2.10 Outer jacket

External vessel that contains the inner vessel, annular space piping, and insulation. The outer jacket is externally pressurized by atmospheric pressure on the outside and low absolute pressure (high vacuum) on the inside.

3.2.11 Tank

Inner vessel, annular-space piping, insulation, outer jacket, and external control piping and instrumentation system.

3.2.12 Ullage

Minimum vapor volume in a cryogenic liquid storage tank that is the difference between the gross volume of the tank and the maximum fill point of the tank at operating conditions. This volume is required to accommodate liquid expansion.

4 Properties of hydrogen

For properties of hydrogen, see CGA G-5, *Hydrogen* [2].

5 General requirements**5.1 Certification and approvals**

The supplier and the supplier's facilities, personnel, equipment, and procedures shall be currently qualified (certified, approved, authorized) as required by any of the applicable ASME codes and/or by this standard. All welding and brazing performed on the tank or pipework shall be performed by qualified welders according to qualified shop procedures contained in the applicable ASME codes. Documentation of each welder's qualification test for range of line size shall be maintained.

5.2 Quality control

The purchaser and/or a designated inspector shall be permitted to inspect the tank fabrication and testing to ensure that this standard is being followed. The purchaser shall be permitted reasonable access for inspection



times as requested. Rejection of any welds or inner vessel sections shall be recorded in the tank quality control document. Rejected items shall be corrected or replaced. Fabrication inspection on the inner vessel shall be performed by a third-party, independent inspection organization.

5.3 Ancillary equipment

In addition to austenitic stainless steels, nonmetals such as polyamide, polytetrafluoroethylene, polychlorotrifluoroethylene, Dacron®, and fiberglass may be used as the wetted materials in system components (valves, gauges, etc.).

Because hydrogen is a small molecule that readily escapes through many materials and components, all system components shall have minimal leak rates (equivalent to 10^{-5} units on a mass spectrometer scale).

Due to permeation, only pressure gauges with bourdon tubes shall be used for hydrogen service. Diaphragm pressure gauges are not permitted.

6 Tank design and manufacturing criteria

6.1 Minimum ullage volumes

This value is given as a percentage of the cold gross volume. The cold net volume plus the ullage of the inner vessel is equal to the cold gross volume of the inner vessel. Lists of minimum required ullages are indicated in Tables A-1 and A-2 in Appendix A. The difference is typically 7%, meaning that the tank is filled to 93% of gross capacity. The ullage space accommodates liquid expansion as the cryogenic liquid becomes warmer.

6.2 Wind and seismic design

Anchor bolt holes shall be provided on all tank legs or skirts. The type and number of bolts shall be determined by the tank supplier based on the seismic, wind, and other loads specified by the purchaser or AHJ and/or by the applicable codes for the tank installation.

6.3 Shipping design

External piping, controls, and instrumentation shall be adequately supported to withstand the stresses of operation, handling, and shipping. The inner vessel support system and piping supports shall be designed to withstand the minimum forces (g) shown in Table 1 during shipment of the empty tank.

Table 1—Shipping forces

	Shipment by road (g) ¹⁾	Shipment by rail (g) ¹⁾	Shipment by water (g) ¹⁾
Longitudinal force	1.5	4.0	1.5
Lateral force	1.5	1.5	1.5
Vertical force	2.0	2.0	2.0
¹⁾ g is a load factor, normal weight at sea level.			

For shipment by water, the lateral and vertical loads shall be considered to act simultaneously. The purchaser shall specify mode(s) of transportation. When the tank is transported by more than one mode (e.g., road and rail) the tank shall be designed for the most severe transportation mode.

The tank and attached lifting lugs shall be designed to withstand the stress imposed by loading the empty tank onto the transport vehicle for shipment and the stress imposed by unloading, rigging, and installation at the use location. The minimum dynamic factor for lifting design including the lugs shall be 1.5.

The tank shall include lashing and tie-down points designed to transmit the loadings imposed by the shipping method.

6.4 Supports

Tanks shall be provided with engineered supports (legs or saddles) of noncombustible material. Steel legs or saddles in excess of 18 in (457 mm) in height (from the top of the base plate to the closest attachment point to the tank measured vertically) shall have a minimum 2 hour fire-resistance rating according to ASTM E1529, *Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies* [3]. See Figure 1. The fireproofing material shall satisfy the requirements of *NFPA 2, Hydrogen Technologies Code* [4]. When specified by the purchaser, the fireproofing materials shall be installed by the supplier to withstand the rigors of shipping, installation, and weather without loss of integrity.

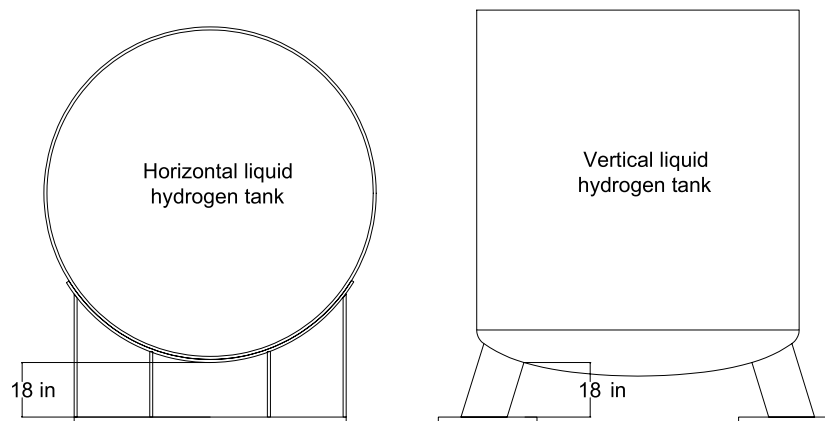


Figure 1—Measurement of support length requiring insulation

6.4.1 Vertical tank requirements

The tank shall have three or four carbon or stainless steel legs or a skirt to support the tank assembly on a suitable foundation or pad. Lifting lugs (including applicable tailing lugs) or trunnions shall be provided to enable lifting to and from the transport vehicle and for rotating to the operating position.

6.4.2 Horizontal tank requirements

The tank shall have saddles to support the tank on a foundation or pad. The saddle at one end of the tank (typically the nonpiping end) shall be fitted with slotted holes.

6.5 Lifting lugs

Lifting lugs shall be provided to permit lifting of the tank assembly. Lifting lugs shall be compatible with U.S. Federal Specification RR-C-271D, *Chain and Attachments, Welded and Weldless*, for using green pin shackles [5].

6.6 Grounding/earthing

Horizontal tanks shall have a grounding/earthing connection to each saddle. Vertical tanks shall have at least one grounding/earthing connection to a support leg or ring. Any vent stacks permanently attached to the tank shall have an independent grounding/earthing connection.

Tank electrical grounding/earthing connectors shall be either welded or permanent crimp-type connectors using a minimum of 2/0 AWG (70 mm²) copper cable connected to a properly engineered grounding grid with a maximum resistance to earth of 25 Ohms.

6.7 Tank nameplates and markings

A stainless steel, inner-vessel nameplate shall be affixed to the inner vessel as required by *ASME Boiler and Pressure Vessel Code* (ASME Code) [6]. An additional stainless steel, inner-vessel nameplate (as required by

ASME Code) shall be welded to the outer jacket or riveted or welded to a stainless steel bracket that is permanently affixed to the outer jacket or its supports and shall be visible from grade. When required by ASME Code, the additional plate shall be stamped DUPLICATE [6].

NOTE—It is recommended that the inner-vessel nameplate be affixed under the outer jacket protection device (lift plate). This will help locate the original nameplate in the event that the duplicate plate on the outer jacket is lost.

The tank shall be permanently identified with a supplier model number and the service (hydrogen) for which the tank is designed. This can be done either by using a separate stainless steel nameplate or adding this information to the ASME nameplate.

The supplier shall permanently install a decal or label that depicts the piping schematic and includes identification and nomenclature for nozzles, valves, controls, and instruments. The decal or label shall be installed on the front of the tank near the fill connection, 5 ft to 6 ft (1.5 m to 1.8 m) above the bottom of the tank supports.

7 Inner vessel

7.1 Material

Material used either for construction of the inner vessel or to support the inner vessel shall be suitable for the purity requirements of the tank and for use at cryogenic temperatures. The minimum and maximum design temperatures of the inner vessel shall include the range from -423°F to 100°F (-253°C to 38°C).

Aluminum is not a preferred material for the inner vessel and 9% nickel shall not be used because of low ductility.

7.2 Inner vessel design

The inner vessel shall be fabricated and code stamped according to ASME Code [6]. The inner vessel shall provide the cold net volume plus the appropriate ullage volume indicated in Tables A-1 and A-2 in Appendix A.

The inner vessel design pressure shall equal the specified MAWP plus full vacuum in the annular space plus the relevant static head. Additionally, the inner vessel shall be designed to withstand the external forces resulting from the following concurrent conditions:

- zero psi internal pressure in the inner vessel;
- outer jacket at its pressure relief device (PRD) activating pressure; and
- perlite compaction pressure (horizontal tanks only).

The perlite compaction pressure shall be determined by the pseudo-hydrostatic head of the insulation but cannot be less than 1 psi (6.9 kPa). A safety factor of two shall be used for the design collapse pressure because of external buckling.

NOTE—The inner vessel is not typically designed to withstand an internal vacuum.

Horizontal inner vessels shall be designed for longitudinal beam bending assuming no support from the annular space insulation material. All of the following concurrent conditions shall be considered when checking longitudinal bending stresses:

- zero psi internal pressure in the inner vessel;
- inner vessel is full of liquid; and
- loss of vacuum in the annular space.

The liquid densities used to determine the inner vessel hydrogen cryogen weight shall be 4.42 lb/ft^3 (71 kg/m^3).

All inner vessel welds shall be butt weld type joints with full penetration. Circumferential weld seams on the inner vessel may be sealed with the aid of a nonremovable backing ring. Manual or machine welding may be used. When rolling steel plate for inner-vessel fabrication, care shall be taken to ensure contaminants and residue on