



CGA G-5.5—2021 STANDARD FOR HYDROGEN VENT SYSTEMS

FOURTH EDITION

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NOTE—Technical changes from the previous edition are underlined.

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1 Introduction

This publication provides information for personnel who design, install, and maintain hydrogen vent systems.

2 Scope

This publication provides design guidelines for hydrogen vent systems used in gaseous and liquid hydrogen systems at user sites and provides recommendations for safe operation of these vents. It begins at the discharge port of safety devices and other components that control the release of hydrogen and ends at the point where hydrogen concentration in the atmosphere is below the lower flammable limits.

It also provides information on the production, transportation, handling, and storage of compressed hydrogen, cryogenic liquid hydrogen, and related products. Additional information on hydrogen can be found in CGA G-5, *Hydrogen*, CGA G-5.4, *Standard for Hydrogen Piping Systems at User Locations*, CGA *Handbook of Compressed Gases*, and NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, and NFPA 2, *Hydrogen Technologies Code* [1, 2, 3, 4, 5].¹

Pressure relief devices (PRDs) for cylinders and tube trailers required by U.S. Department of Transportation (DOT) in Title 49 of the *U.S. Code of Federal Regulations* (49 CFR) are not covered in the scope of this publication [6].

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 ASME piping code

American Society of Mechanical Engineers (ASME) B31.12, *Hydrogen Piping and Pipelines* [7]. The process piping code in North America for hydrogen piping and pipelines.

3.2.2 Cylinder

Pressure vessel designed for pressures higher than 40 psi (276 kPa) and having a circular cross section with an internal water volume not exceeding 16 ft³ (450 L) or a water capacity of 1000 lb (454 kg) constructed in accordance with DOT specifications for cylinders [6].² In Canada, *Transportation of Dangerous Goods* (TDG) regulations apply to cylinders [9].

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

² kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [8].

3.2.3 Deflagration

Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium [10].

3.2.4 Detonation

Propagation of a combustion zone at a velocity that is greater than the speed of sound in the unreacted medium [10].

3.2.5 Gaseous hydrogen storage system

System in which hydrogen is delivered, stored, and discharged in gaseous form to the user's piping.

NOTE—A gaseous hydrogen storage system includes stationary containers or transport containers used as stationary storage for temporary supply, pressure regulators, PRDs, manifolds, interconnecting piping, and controls. The system terminates where hydrogen at service pressure first enters the user supply line.

3.2.6 Liquid hydrogen storage system

System in which hydrogen is delivered and stored as a liquid and from which it is discharged in liquid or gaseous form to the user's piping.

NOTE—A liquid hydrogen storage system can include stationary or portable containers, pressure regulators, PRDs, manifolds, interconnecting piping, and controls as required. The system originates at the storage container fill connection and terminates where hydrogen at service pressure first enters the user supply line.

3.2.7 Recognized and generally accepted good engineering practice (RAGAGEP)

Term used in Occupational Safety and Health Administration (OSHA) Title 29 of the U.S. *Code of Federal Regulations* (29 CFR) 1910.119 (D)(3)(ii) for design and practices that should be used in the absence of any regulations or industry accepted standard [11].

3.2.8 Tube

Any seamless pressure vessel having an internal water volume greater than or equal to 16 ft³ (450 L) in accordance with DOT regulations or any pressure vessel designed in accordance with ASME codes [6, 7, 12].

4 Properties of hydrogen

Hydrogen is a flammable gas. It is colorless, odorless, tasteless, and nontoxic. It is the lightest gas known, having a specific gravity of 0.0696 (air = 1.0). Gaseous hydrogen is buoyant in air at normal temperatures. Hydrogen diffuses rapidly in air and through porous materials. Hydrogen burning in air has a pale blue flame that is nearly invisible.

4.1 Flammability

At atmospheric pressure, the ignition temperature of hydrogen-air mixtures has been reported to be as low as 932 °F (500 °C). The flammable limits of hydrogen-air mixtures depend on pressure, temperature, and water vapor content. At atmospheric pressure, the flammable range is approximately 4% to 75% by volume of hydrogen in air [13]. Hydrogen-air mixtures are extremely easy to ignite only requiring 0.02 millijoules (mJ) ignition energy compared to 0.25 mJ for hydrocarbons.

4.2 Temperature impact

Hydrogen has properties unlike most other compressed gases such as oxygen, nitrogen, and carbon dioxide when expanded from a higher to lower pressure. Hydrogen gas will increase in temperature approximately 10 °F (5.6 °C) when throttled from 2000 psi (13 790 kPa) to atmospheric pressure. The temperature increase resulting from throttled expansion is a function of the starting temperature as well as initial and final pressures.

4.3 Diffusion and leakage

Hydrogen, due to its small molecular size, rapidly diffuses through porous materials, which can also lead to leakage. It also dissolves in and diffuses through metals slowly at ambient temperatures and more rapidly at elevated temperatures. It can leak out of a system that is gas-tight for air or other common gases at equivalent pressure. Closed manual valves, relief valve seats, or other control devices can leak hydrogen at a low rate that can result in a flammable atmosphere within the vent stack.

4.4 Asphyxiant

Hydrogen is nontoxic but can act as an asphyxiant by displacing the oxygen in air. Unconsciousness from breathing air in which hydrogen has displaced oxygen can occur without warning symptoms because hydrogen is colorless, odorless, and tasteless. Hydrogen is a flammability hazard at much lower concentrations than those at which it causes asphyxiation.

4.5 Liquid hydrogen

At atmospheric pressure and a temperature of -423°F (-253°C), hydrogen becomes a transparent liquid with a density only one-fourteenth that of water. All other gases, except helium, will condense and freeze at liquid hydrogen and cold gaseous hydrogen temperatures. Liquid hydrogen has a relatively high thermal coefficient of expansion and high compressibility compared with other cryogenic liquids.

Upon contact with the skin and other tissues, liquid hydrogen and the cold gas evolving from the liquid can produce severe frost burns that are similar to thermal burns. Eyes can be injured by exposure to the cold gas or by a brief splash of liquid. Contact between unprotected parts of the body and uninsulated piping or vessels containing liquid hydrogen can cause flesh to stick and tear when an attempt is made to remove it from the piping or vessel.

Liquid hydrogen and cold gaseous hydrogen flowing through uninsulated piping can cause the liquefaction of air on the outer surfaces. This condensed liquid air can boil off the nitrogen first and can form an oxygen-rich liquid air.

Condensed liquid air dripping from piping will chill vent stack piping and mounting brackets. The system shall be designed to prevent liquid air and low temperatures from migrating to segments of the system that cannot withstand these cold temperatures, see Figure 1.

Cold hydrogen vapors are much denser than warm gas and can achieve densities close to air. In temperature inversion weather conditions, it is possible for cold hydrogen not to rise as rapidly as under normal conditions.

The density of hydrogen vapor at atmospheric pressure and -423°F (-253°C) is 0.0832 lbm/ft^3 . The density of air at 100°F (37.8°C) and atmospheric pressure is 0.0708 lbm/ft^3 and therefore the hydrogen is heavier than air at that cold temperature condition. The condition where the density of -423°F (-253°C) hydrogen is equal to the density of air at 17°F (-8.3°C). Hydrogen has an extremely high rate of thermal heat transfer, so it will warm rapidly in the vent piping and in contact with the atmosphere, but the designer shall understand that it is possible to have cold hydrogen vapors at the same or lower density of air at temperatures greater than 17°F (-8.3°C) and higher altitudes where the air is naturally less dense.

4.6 Embrittlement

Hydrogen is noncorrosive and nonreactive, but hydrogen service will generally reduce the mechanical properties of certain metals both by embrittlement of metals due to the extreme cold temperature of liquid hydrogen and cold gas as well as the process of chemical embrittlement caused by the formation of methane molecules inside the pores of the metal leading to work hardening and the formation of crack(s) caused by hydrogen embrittlement. For additional information, see CGA G-5.4 and CGA G-5.6, *Hydrogen Pipeline Systems* [2, 14].

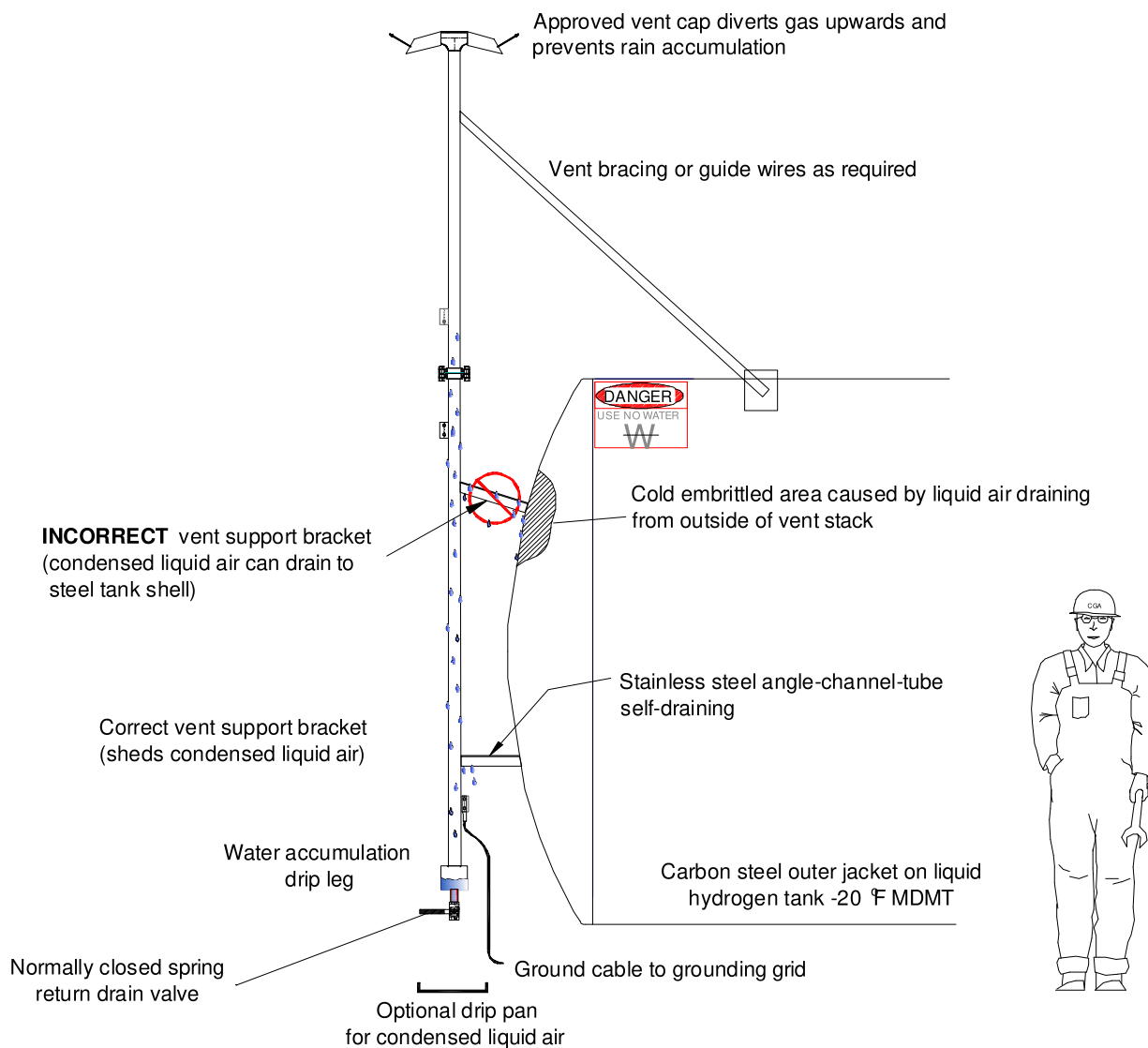


Figure 1—Example of a typical vent stack mounting and grounding

5 System considerations

5.1 Hydrogen discharges

Discharges of gaseous hydrogen shall be disposed of through an engineered vent system. The gaseous hydrogen is discharged into the air at the exit of the vent system. The discharge may be either manually controlled or by automatic control devices on the storage system. Typical system discharge devices include:

- purging of piping or components;
- manual vent valves;
- pressure control devices such as back pressure regulators or control valves; and
- PRD activation.