Codes and Standards Gap Analysis for Delayed Ignition

DRAFT

9/5/2024

D. Murphy

CGA G5.5 (2021)

- Vent exit elevations do not account for maximum flow rate of hydrogen expected (no bounds are provided on when the distances are applicable and when risk analysis should be used instead)

> **6.2.4 Discharge of warm gas**
>
> High exit velocities in a vertically released vent and the low density of warm, gaseous hydrogen in relation to air will aid in its dispersion and dilution in the atmosphere. The vent exit elevation should be the greater of the elevation determined in 6.2.3 or 10 ft (3 m) above grade; or 2 ft (0.61 m) above adjacent equipment; or 5 ft (1.5 m) above rooftops.

- No considerations for dispersion and extent of the flammable gas cloud at the vent outlet
- Little guidance provided for establishing thermal heat flux from an ignited jet and establishing adequate setback distances

> **6.2.3 Thermal radiation and impingement**
>
> Vent stacks shall be located to prevent impingement exposure and lessen the effects of high temperature or thermal radiation exposure from the escaping plume to the supply system, personnel, and adjacent structures. The vent system for cold vapors or large flows of warm gas shall be designed to discharge vertically upwards at a sufficient height from grade and with proper configuration and velocity to facilitate flow dispersion. Discharge of small warm gas flows can be directed laterally, if necessary. Vent exits shall be elevated sufficiently to reduce thermal radiation doses to levels recommended in ANSI/API RP 521 or other reliable sources [15].

- Vent locations are required to be “away from personnel areas, ignition sources, air intakes, building openings, and overhangs”, but no clear guidance on what “away” means is provided
- No clear guidance on when multiple vent stacks should be used instead of just a single large stack based on maximum flow rate expected
- No significant guidance provided for establishing thrust forces and how to secure the vent stack
- No guidance for establishing pressure decay in the vent and necessary vent tubing strength
- Use of flame arrestors is not explicitly discussed
- Use of siphons is not explicitly discussed
- Outlet shapes that entrain air into the hydrogen flow are not forbidden
- Section 6.5 Operation states, “The operator should watch the vent plume at all times and adjust the vent rate so the plume does not pose a hazard to adjacent equipment or to third parties.” I am not sure how the operator is supposed to “watch the vent plume” unless he is looking at the condensate cloud from a cold gas release off a cryogenic system. This section is not specific to LH2 venting, nor would that be an accurate assessment of the location of the flammable gas cloud.

Separation distances exist in codes such as NFPA 2 (2023) and CGA G5.5 (2021), but the guidance may not be conservative for every situation including planned events such as process and emergency venting. In NFPA 2, Table E.7, for example, separation distances for Groups 1, 2, and 3 are all less than 15 m (50 ft) even for pressures up to 104 MPa (15000 psi). NFPA’s separation distances are based on heat flux and concentration, but do not consider deflagration overpressure. CGA G5.5(2021) specifies vent outlets at a minimum of 1.5 m (5 ft) above a roof, but thermal radiation from large releases can damage the roof structure or injure personnel on rooftop catwalks at that distance. OSHA specifies distances based on storage volume and it is 15 m (50 ft) or less for personnel, buildings, flammable gases, solids, and liquids, and oxygen storage.

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Table E.7 Updated Values to 2016 NFPA 2 and NFPA 55 Tables with 1.5 Safety Factor

Exposures		Separation Distance >0.10 to 1.7 MPa (>15 to 250 psig)	>1.7 to 20.7 MPa (>250 to 3000 psig)	>20.7 to 51.7 MPa (>3000 to 7500 psig)	51.7 to 103.4 MPa (7500 to 15000 psig)
Group 1	2010 edition	12 m (40 ft)	14 m (46 ft)	9 m (29 ft)	10 m (34 ft)
	2019 edition	5 m (16 ft)	6 m (20 ft)	4 m (13 ft)	5 m (16 ft)
Group 2	2010 edition	6 m (20 ft)	7 m (24 ft)	4 m (13 ft)	5 m (16 ft)
	2019 edition	5 m (16 ft)	6 m (20 ft)	3 m (10 ft)	4 m (13 ft)
Group 3	2010 edition	5 m (17 ft)	6 m (19 ft)	4 m (12 ft)	4 m (14 ft)
	2019 edition	4 m (13 ft)	5 m (16 ft)	3 m (10 ft)	4 m (13 ft)

Notes:

(1) Group 1 Exposures include: lot lines, air intakes, operable openings in buildings and structures, and ignition sources. Group 1 separation distances are based on the higher value of radiation heat flux of 4.7 kW/m^2 or the unignited jet concentration decay distance of 8percent hydrogen volume fraction concentration. In this instance, the separation distance is higher for the concentration value than the heat flux value.

(2) Group 2 Exposures include parked cars, exposed persons other than those servicing the system. Group 2 separation distances are based on the higher value of the incident radiation heat flux of 4.7 kW/m^2 exposure to employees for a maximum of 3 minutes or the visible flame length.

(3) Group 3 Exposures include everything else (e.g., buildings of combustible construction, ordinary combustibles, openings in buildings and structures, etc.). Group 3 separation distances are based on the higher value of the radiant heat flux for noncombustible equipment of 25.2 kW/m^2 or the visible flame length.

N **Table I.7 Updated Values to 2016 NFPA 2 and NFPA 55 Tables with 1.5 Safety Factor**

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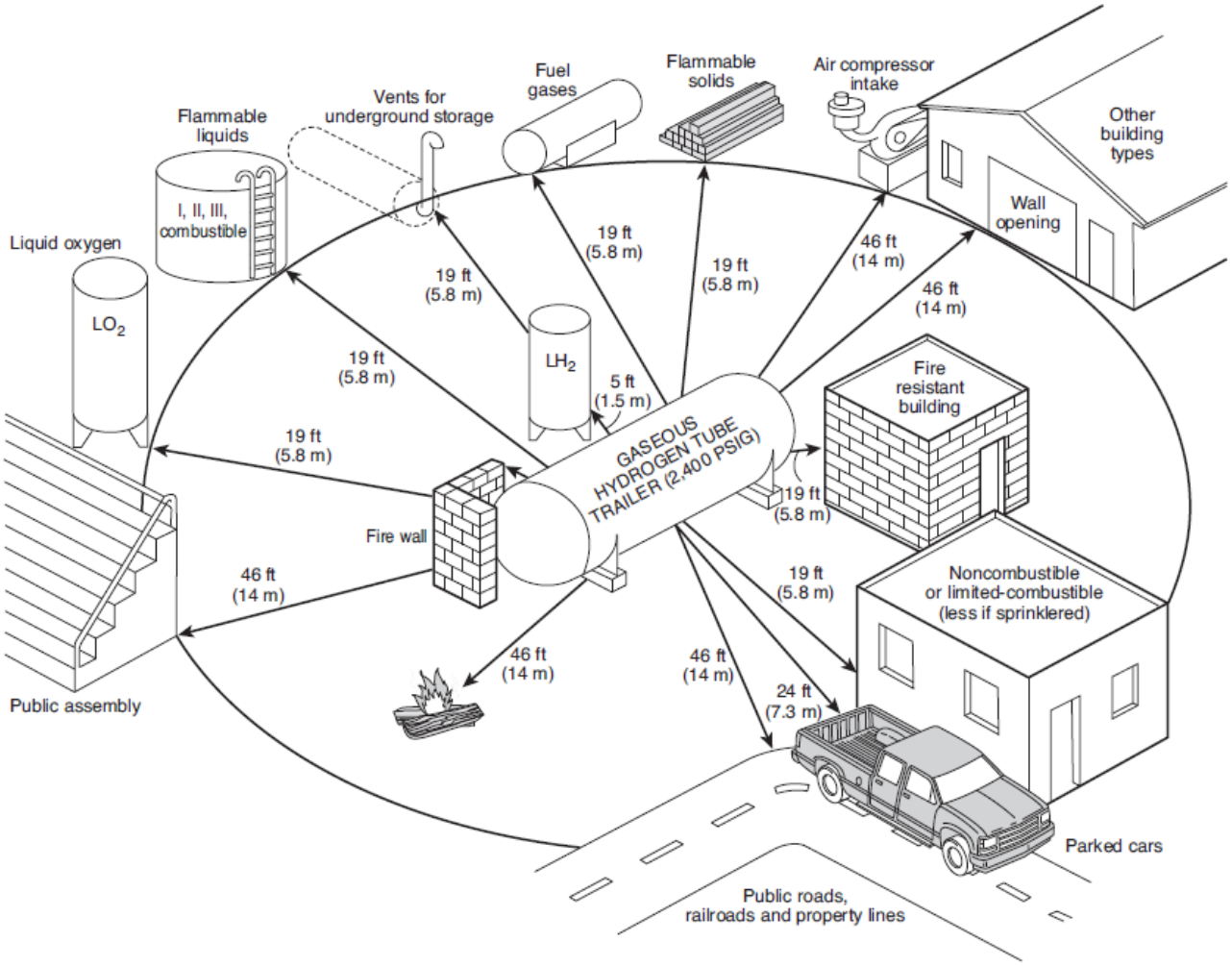

N FIGURE A.7.3.2.3.1.1 Distances Between Bulk Hydrogen Systems and Exposures. [55:Figure A.10.4.2.2.1]

N Table G.2(a) OSHA Table: Minimum Distance from Gaseous Hydrogen Systems to Exposure

	Size of Hydrogen Systems					
	<3,000 scf (85 Nm^3)		3,000 to 15,000 scf (85 m^3 to 425 Nm^3)		>15,000 scf (425 Nm^3)	
Type of Outdoor Exposure	**ft**	**m**	**ft**	**m**	**ft**	**m**
1. Building or structure						
Wood frame construction[1]	10	3.1	25	7.6	50	15.2
Heavy timber, noncombustible, or ordinary construction[1]	0	0	10	3.1	25	7.6
Fire resistive construction[1]	0	0	0	0	0	0
2. Wall openings						
Not above any part of a system	10	3.1	10	3.1	10	3.1
Above any part of a system	25	7.6	25	7.6	25	7.6
3. Flammable liquids above ground						
0–1000 gal (3785 L)	10	3.1	25	7.6	25	7.6
In excess of 1000 gal (3785 L)	25	7.6	50	15.2	50	15.2
4. Flammable liquids below ground — 0–1000 gal (3785 L)						
Tank	10	3.1	10	3.1	10	3.1
Vent of fill opening of tank	25	7.6	25	7.6	25	7.6
5. Flammable liquids below ground, in excess of 1000 gal (3785 L)						
Tank	20	6.1	20	6.1	20	6.1
Vent of fill opening of tank	25	7.6	25	7.6	25	7.6
6. Flammable gas storage, either high pressure or low pressure						
0–15,000 scf (425 Nm^3) capacity	10	3.1	25	7.6	25	7.6
In excess of 15,000 scf (425 Nm^3) capacity	25	7.6	50	15.2	50	15.2
7. Oxygen storage						
12,000 scf (340 Nm^3) or less[4]				—		
More than 12,000 scf (340 Nm^3)[5]				—		
8. Fast-burning solids such as ordinary lumber, excelsior, paper	50	15.2	50	15.2	50	15.2
9. Slow-burning solids such as heavy timber, coal	25	7.6	25	7.6	25	7.6
10. Open flames and welding	25	7.6	25	7.6	252	7.62
11. Air compressor intakes or inlets to ventilating or air-conditioning equipment	50	15.2	50	15.2	50	15.2
12. Concentration of people[3]	25	7.6	50	15.2	50	15.2

[1]Refer to NFPA 220 for definitions of various types of construction (1969).
[2]But not less than one-half the height of adjacent side wall of the structure.
[3]In congested areas such as offices, lunchrooms, locker rooms, time-clock areas.
[4]Refer to NFPA 51 (1969).
[5]Refer to NFPA 566 (1969).