



## Cylinder Maximum Fill Density

April 2022

To prevent a cylinder from rupturing due to overpressure, The transportation regulations limit the amount of gas that can be put into a cylinder.

49CFR173.301 General requirements for shipment of compressed [gases](#) and other [hazardous materials](#) in cylinders, [UN pressure receptacles](#) and spherical pressure vessels.

(a) *General qualifications for use of cylinders.* Unless otherwise stated, as used in this section, the term “cylinder” includes a [UN pressure receptacle](#). As used in this subpart, filled or charged means an introduction or presence of a [hazardous material](#) in a [cylinder](#). A [cylinder](#) filled with a [Class 2 hazardous material](#) (gas) and offered for transportation must meet the requirements in this section and [§§ 173.301a](#) through 173.305, as applicable.

Liquid expands with increasing temperatures as well as the vapor pressure. It could expand to completely fill the cylinder (liquid full).



Fig. 1: Overfilled Trifluoromethane Cylinder

A compressed gas above its critical temperature cannot exceed the pressure rating of the cylinder at 55°C.

In the US, the transportation regulations estimates the maximum fill amount as follows

49 CFR 173.300 Shippers-General Requirements for Shipments and Packages

- Pressure in the cylinder at 70°F (21°C) less than or equal to the rated pressure of the cylinder . Reference 173.301.
- The cylinder not to be liquid full at any temperature up to 131°F (55°C). Ref. 173.304(b) with some exceptions.
- The pressure in the cylinder at 131°F (55°C) is less than 5/4 the cylinder's rated pressure. Ref. 173.301 (a) 8

In the US, cylinders with a plus symbol next to the hydrotest date are authorized to be filled 10% above the service pressure for certain gases (49CFR173.302) and cylinders. This is common for nitrogen, helium, argon, etc.

Internationally the cylinder fill density is lower since a higher temperature reference is used.



ADR & United Nation ST/SG/AC.10/C.3/34

- 95% of the liquid density under its own vapor pressure at (50°C (122°F) Ref.: Packing Instructions P-200
- 100% of the liquid density under its own vapor pressure at 60°C (140°F) Ref.: Packing Instructions P-200
- The density such that the pressure at 65°C (149°F) is at the cylinder's test pressure. Ref.: Packing Instructions P-200

Some gases have reduced fill densities due to other factors

Overpressure that would occur from a decomposition reaction

Acetylene

Diborane (pure is shipped in dry ice) Mixtures are limited in pressure 49CFR173.302(d)

Germane

Nitric Oxide

Stibine

Reaction Pressure

Fluorine (limited to 400 psig) 49CFR173.302(e)

Fluorine Mixtures (limit partial pressure of F<sub>2</sub> to 400 psig)

Nitrogen Trifluoride (<1450 psig, Adiabatic Compression Heat)

Tetrafluorohydrazine (limited to 100 psig)

Stress Corrosion Cracking

Carbon monoxide pure and mixtures in carbon steel cylinders are limited in pressure to 1,800 psig unless they are very dry and sulfur free . 49CFR173.302(d). The Compressed Gas Association also has guidance on how to fill these cylinders safely, CGA P-57, Avoidance Of Failure Of Carbon Monoxide And Of Carbon Monoxide/Carbon Dioxide Mixtures Cylinders.

If 130°F is exceeded the cylinder while it is full. It could rupture. This condition can be reached if there is

1. Faulty heating blanket on the cylinder
2. The control thermocouple not being placed on the cylinder or in the wrong location
3. Flame impingement only on the side of the cylinder

An overfilled cylinder however could rupture before reaching this temperature

The following example is a typical consumer 20 lb propane cylinder at various temperatures and liquid expansion



Cylinder volume will vary between 47.1 - 47.8 lbs water capacity

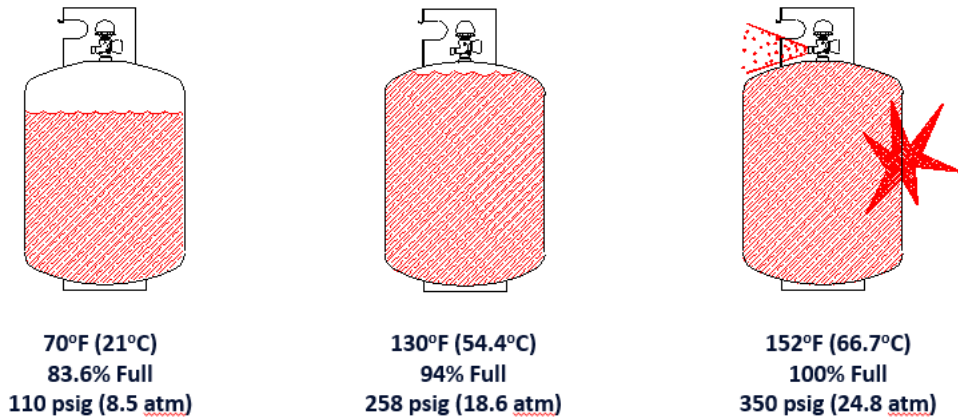


Fig. 1: 20 lb propane cylinder

Never trap liquid compressed gas between two valves without a spring loaded pressure relief valve to relieve pressure due to liquid expansion.

#### Cylinder DOT Fill Densities @ 130°F

49 CFR 173.300 Shippers-General Requirements for Shipments and Packages

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2. The cylinder not to be liquid full at any temperature up to 131°F (55°C). Ref. 173.304(b) with some exceptions.
3. The pressure in the cylinder at 131°F (55°C) is less than 5/4 the cylinder's rated pressure. Ref. 173.301 (a) 8

Ratio is kg of gas/kg of water

Ratio	Gas/liquid	Remarks
0.41	acetylene	Requires special solid filled cylinder and solvent
0.58	ammonia	
	arsenic pentafluoride	(liquid filled in cylinders)
1.32	arsine	
1.31	boron trichloride	
0.78	boron trifluoride	
2.63	bromine trifluoride	(liquid filled in cylinders)
1.50	bromine chloride	
2.42	bromine pentafluoride	(liquid filled in cylinders)
1.62	bromotrifluoromethane (R13B1)	
0.61	1,3 butadiene	Stabilized with inhibitor
0.77	carbon dioxide	
	carbon monoxide	Stress corrosion cracking of steel, pressure 1,800 psig
0.77	carbonyl fluoride	



1.00	carbonyl sulphide	
1.37	chlorine	
1.77	chlorine pentafluoride	
1.71	chlorine trifluoride	
1.35	chloropentafluoroethane (R115)	
1.19	chlorodifluoromethane (R22)	
1.10	chlorotrifluoromethane (R13)	
0.85	cyanogen	Dermal toxicity
1.14	cyanogen chloride	Dermal toxicity
0.29	diborane	Pure must be shipped at dry ice temperature
1.33	dichlorodifluoromethane (R12)	
1.21	dichlorosilane	
0.90	1,1-difluoroethane (R152a)	
0.77	1,1-difluoroethylene	
0.96	difluoromethane (R32)	
0.38	ethane	
0.35	ethylene	
0.85	ethylene oxide	
0.88	ethyl chloride	
0.71	ethyl fluoride	
	fluorine	Pressure limited to 400 psig due to reactivity
0.06	germane	Can autodecompose
1.42	heptafluoropropane (R227ea)	
1.38	hexafluoroacetone	
1.19	hexafluoroethane (R116)	
1.33	hexafluoropropylene	
1.71	hydrogen bromide	
0.78	hydrogen chloride	
0.64	hydrogen cyanide	Stabilized with sulfuric or phosphoric acid
0.87	hydrogen fluoride	Slowly reacts with carbon steel to form H <sub>2</sub>
2.49	hydrogen iodide	slowly decomposes store at 34°F
1.71	hydrogen selenide	
0.76	hydrogen sulphide	
3.14	iodine pentafluoride	(liquid filled in cylinders)
1.63	methyl bromide	
0.61	methyl fluoride (R41)	
0.85	methyl mercaptan	
	nitric oxide	Fill limited to 500 psig, decomposition reaction
1.38	nitrogen dioxide	
0.69	nitrogen trifluoride	Fill pressure limited to 1450 psig to reduce adiabatic compression heat



Large diameter piping can allow decomposition to

- 0.76 Nitrous oxide
- propagate
- 1.24 nitrosyl chloride
- 1.51 octafluorobut-2-ene
- 1.52 octafluorocyclobutane (RC318)
- 1.41 octafluoropropane (R218)
- 1.25 pentafluoroethane (R125)
- 1.41 perchloryl fluoride
- 1.29 perfluoromethylvinylether
- 1.35 phosgene
- 0.52 phosphine
- 1.18 phosphorous pentafluoride
- 0.50 propane
- 0.52 propylene
- 1.09 R404A
- 1.25 R502
- 1.16 R407A
- 1.16 R500
- 1.15 R407C
- 2.09 selenium hexafluoride
- 0.34 silane
- 1.04 silicon tetrafluoride
- 2.10 stibine decomposes in a day
- 1.33 sulfur dioxide
- 1.49 sulphur hexafluoride
- 2.71 telurium hexafluoride
- 1.21 1,1,1,2-tetrafluoroethane (R134a)
- 1.10 tetrafluoroethylene stabilized d-limonene
- tetrafluorohydrazine maximum cylinder pressure of 100 psig
- 0.77 tetrafluoromethane (R14)
- 1.38 trifluoroacetylchloride
- 0.96 trifluoromethane (R23)
- 0.97 1,1,1-trifluoroethane (R143a)
- 1.28 trifluorochloroethylene
- 3.41 tungsten hexafluoride
- 0.65 vinyl fluoride

**Example:**

44 liter Air Liquide cylinder has internal volume of 44 liter. Ammonia has a ratio of 0.58 there the maximum fill would be 25.52 kgs (56 lbs)