Training Package

TP 26/20

Filling Liquified Gases in Cylinders - Hazards & Safeguards

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Filling Liquified gases in Cylinders- Hazards & Safeguards

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Introduction

Safety incidents arising out of overfilling, rapid pressurization, etc., have been observed in the gas industry during filling of liquified gases into cylinders/ containers by untrained staff or due to lack of awareness about the properties of liquefied gases, cylinder fill ratios, or due to gaps in operational discipline.

This Training Package has been developed to create safety awareness among Supervisors, Operators and Technicians involved in filling and handling of Liquified Gas Cylinders/Containers.

Content

- Liquefied gas – definition & examples
- Key Hazards
- Fill Ratios
- Safeguards
- References

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What is Liquified Gas

- A liquefied gas is a gas that can be liquefied by pressure at or above -50°C (-58°F). Therefore, liquefied gas is liquid in the container at normal ambient temperature and can be filled by weight, volume or mass flow measurement, but not by pressure.
  - Liquefied gases are either **high pressure liquefied or low pressure liquefied gas**. Pressures range from carbon dioxide (50 bar (725.2psi) at 15°C (59°F)) to butane (1.1bar (15.9psi) at 15°C (59°F)).
  - **Pressure must not be used to indicate the correct filling level when filling liquefied gases.**

Examples of Liquified Gases

High Pressure	Low Pressure
Carbon Dioxide	Ammonia
Nitrous Oxide	Ethylene Oxide
Ethane	Liquefied Petroleum Gases - (Butane/Propane)
Ethylene	Sulphur Dioxide
	Chlorine
	Refrigerant Gases.

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Key Hazards

- Over-filling: Cylinder is hydraulically full
- Weight: Cylinders with liquified gas are heavier than other compressed gases like Oxygen, Argon, etc.,
- Pressure: Unlike Permanent (compressed) gases, the pressure in a liquefied container is not directly proportional to the contents.
- Gas release
  - Properties of released gas: Flammability, Toxicity, Asphyxiation.
  - Release in confined space
- Noise while releasing gas

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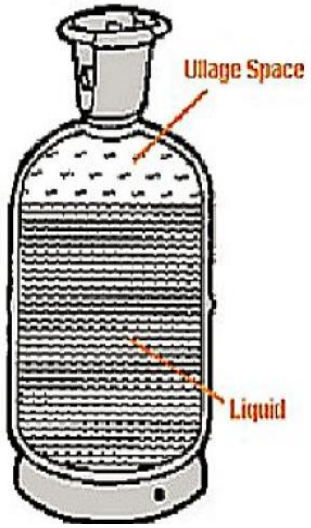
Overfilling

- The main danger with filling liquefied gas containers is overfilling the container to the extent that it becomes hydraulically full.



Overfilled Cylinders

- Become “over pressurized” when the temperature increases
- Become completely liquid filled and develop very high pressures
- Potentially burst if exposed to high ambient temperatures when there is no Pressure Relief Device (PRD) fitted on the package or is tampered.
- Ullage space should be large enough to allow for liquid expansion due to temperature rise.

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Fill Ratios

- Filling ratio is used to determine the maximum filling weight for each gas.
- The filling ratio is the weight of liquefied gas divided by the water capacity of the container – expressed as fraction or in % (e.g., 0.68 or 68%)
- The developed pressure at the **reference temperature shall** never exceed the maximum permissible pressure of cylinder and valve.
- Also governed by local regulations.

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Example of Fill Ratio Table
(Refer to local regulations)

		UN Model Regulations(P200)			P.R. CHINA GB 14193		DOT 49 CFR 173.304a		TAIWAN CNS12242		India	
UN	Usual name	Formula	Minimum test Pressure (barg)	Filling ratio (kg/l)	Minimum Working Pressure MPag)	Filling ratio (kg/l)	Minimum test Pressure (psig)	Filling ratio (kg/l)	Minimum test Pressure (Kg/cm2)	Filling ratio (kg/l)	Minimum test Pressure (barg)	Filling ratio (kg/l)
1013	Carbon Dioxide	CO2	190	0.66	15	0.6	3000	0.68			190	0.667
			250	0.75	20	0.74	3333.3	0.703	250	0.75	250	0.75
							3775	0.732				
			300				4000	0.745				
1070	Nitrous Oxide	N2O	180	0.68	12.5	0.52	3000	0.68			180	0.667
			225	0.74	15	0.62	3333.3	0.703			225	0.74
			250	0.75			3775	0.732	250	0.75	250	0.75
							4000	0.745				
1035	Ethane	C2H6	95	0.25	12.5	0.31	3000	0.358			150	0.32
			120	0.3	15	0.34	3333.3	0.368				
			300	0.4	20	0.37			200	0.36	300	0.39
1962	Ethylene	C2 H 4	225	0.34	12.5	0.24	3000	0.31			225	0.34
			300	0.38	15	0.28	3333.3	0.325			300	0.37
					20	0.37	4000	0.355				
1005	Ammonia,ANHYDROUS	NH3	29	0.54	3.0	0.53	Note 1	0.54	50	0.54	45	0.53
1040	Ethylene Oxide	C2H4O	15	0.78	1.0	0.79	Note 2	Note 3			18	0.78
1079	Sulphur Dioxide	SO2	12	1.23	2.0	1.23	Note 1	1.25			18	1.23
1017	Chlorine	CL2	22	1.25	2.0	1.25	Note 1	1.25	50	1.25	30	1.25

Note 1: Refer to DOT 49 CFR 173.304a for approved specification cylinders
Note 2: refer to 49 CFR 173.323 for specific requirements for Ethylene Oxide

Example of Fill Ratio Table (Ref:DOT 49 CFR 173.304a)

Kind of gas	Maximum permitted filling density (percent) (see Note 1)	Packaging marked as shown in this column or of the same type with higher service pressure must be used, except as provided in §§ 173.301(l), 173.301a(e), and 180.205(a) (see notes following table)
Anhydrous ammonia	54	DOT-3A480; DOT-3AA480; DOT-3A480X; DOT-4AA480; DOT-3; DOT-3E1800; DOT-3AL480.
Bromotrifluoromethane (R-13B1 or H-1301)	124	DOT-3A400; DOT-3AA400; DOT-3B400; DOT-4AA480; DOT-4B400; DOT-4BA400; DOT-4BW400; DOT-3E1800; DOT-39; DOT-3AL400.
Carbon dioxide (see Notes 4, 7, and 8)	68	DOT-3A1800; DOT-3AX1800; DOT-3AA1800; DOT-3AAX1800; DOT-3; DOT-3E1800; DOT-3T1800; DOT-3HT2000; DOT-39; DOT-3AL1800.
Carbon dioxide (see Notes 4, 7, and 8)	70.3	DOT-3A2000, DOT-3AA2000, DOT-3AX2000, DOT-3AAX2000, DOT-3T2000.
Carbon dioxide (see Notes 4, 7, and 8)	73.2	DOT-3A2265, DOT-3AA2265, DOT-3AX2265, DOT-3AAX2265, DOT-3T2265.
Carbon dioxide (see Notes 4, 7, and 8)	74.5	DOT-3A2400, DOT-3AA2400, DOT-3AX2400, DOT-3AAX2400, DOT-3T2400.
Carbon dioxide, refrigerated liquid (see paragraph (e) of this section)		DOT-4L.
Chlorine (see Note 2)	125	DOT-3A480; DOT-3AA480; DOT-3; DOT-3BN480; DOT-3E1800.

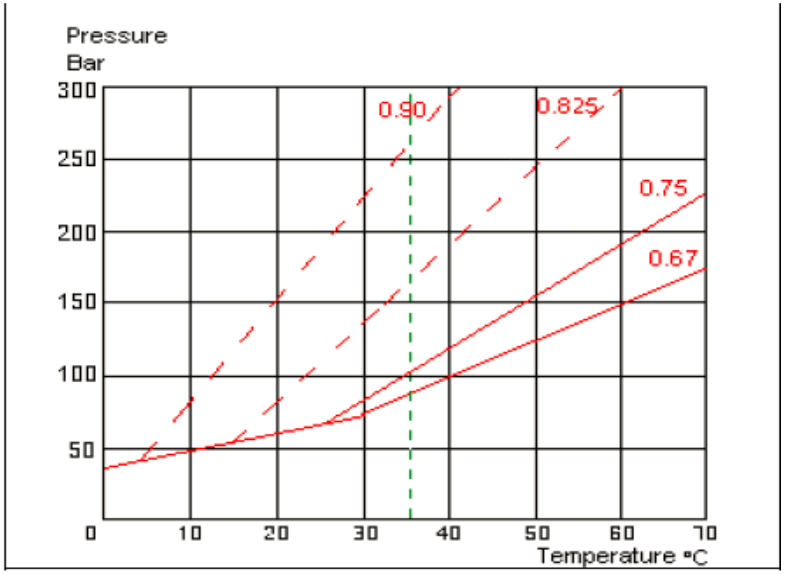
Note2: No aperture other than the one for the valve with PRD is allowed. Notes 4 and 7 refer to Mining devices and aircraft cylinders (3HT) and 8 refer to 173.301(a)(9)-Specification 2P, 2Q, 3E, 3HT, spherical 4BA, 4D, 4DA, 4DS, and 39: Refer to these sections for more details.

Fill Ratios

- **Ensure cylinder standard and pressure rating is in accordance with local regulations**
- **Typically CO2 & N2O content is 68% of cylinder water volume as per DOT**
  - **Ex. 43 Liter cylinder = 43 x 0.68 = 29.24 kg or 29 kg/cylinder**
- Note: Some Regulations allow higher Fill ratios for specific Test Pressures of Cylinders:

Kind of gas	Maximum permitted filling density (percent) (see Note 1)	Package
Carbon dioxide (see Notes 4, 7, and 8)	68	DOT-3A1800; DOT-3AX1800; DOT-3AA1800; DOT-3AAX1800; DOT-3; DOT-3E1800; DOT-3T1800; DOT-3HT2000; DOT-39; DOT-3AL1800.
Carbon dioxide (see Notes 4, 7, and 8)	70.3	DOT-3A2000, DOT-3AA2000, DOT-3AX2000, DOT-3AAX2000, DOT-3T2000.

Effect of Fill Ratios on developed pressures



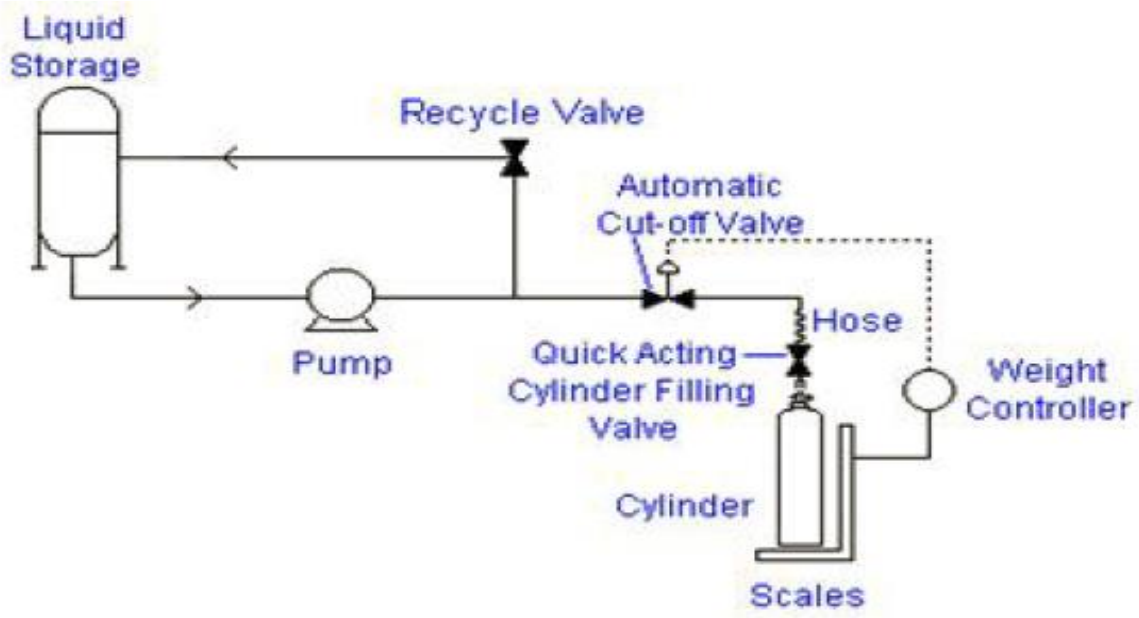
Pressure versus CO_2 Ratio

CO2 % of Water Volume	CO2 Pressure (PSIA) in cylinder @ 100 °F (37.7 °C)
68%	1,465
70%	1,530
75%	1,785
80%	2,185
85%	2,815
90%	3,800
95%	4,920

Example: at 37.7 C @ 95% fill ratio, cylinder can reach the burst pressure of a 150/225 bar WP/TP cylinder

Safeguards

- Fill by weight
- Install Auto-cut-off that stops filling when target weight is reached
- To be filled by trained & competent Operators



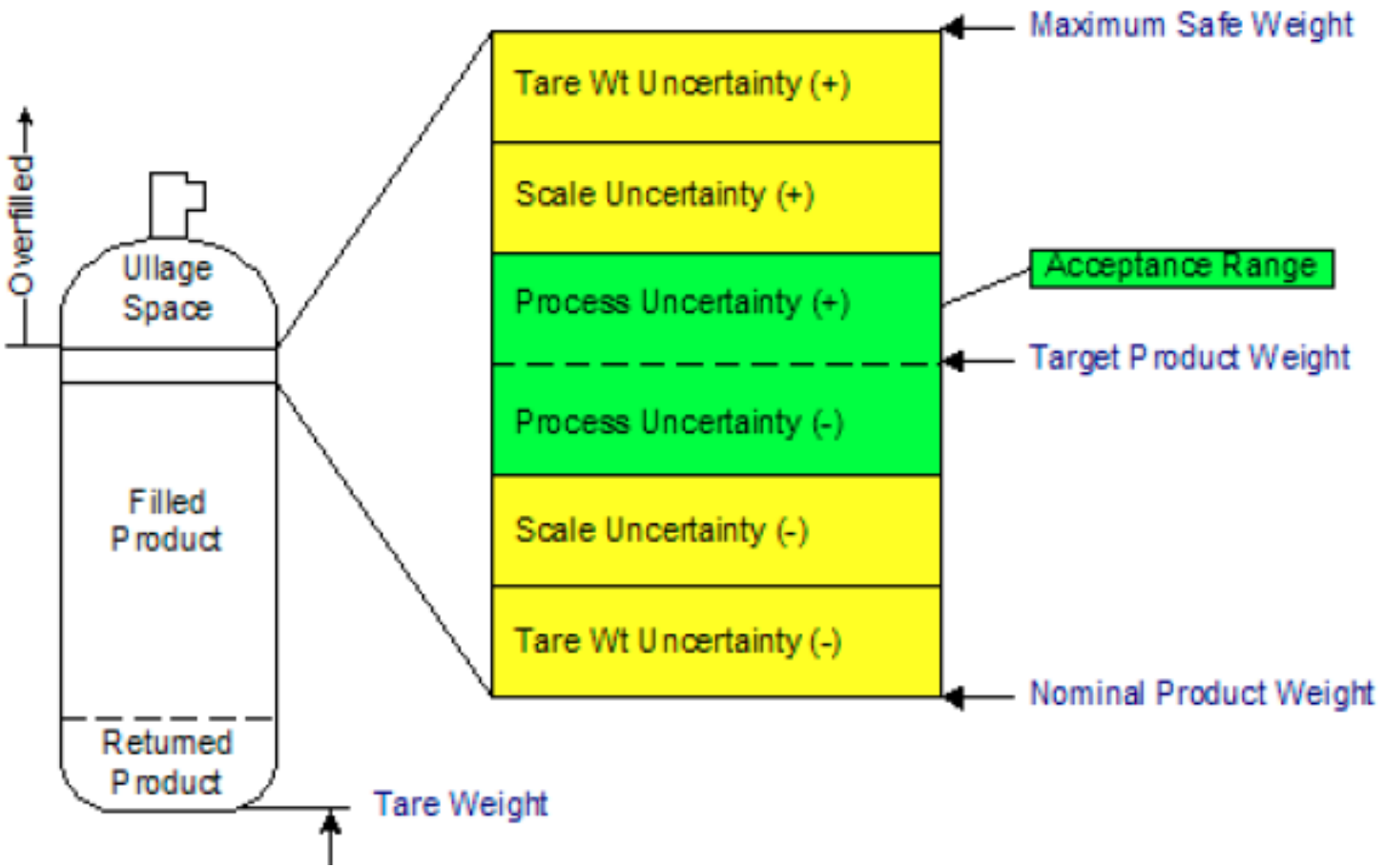
Safeguards

- Use calibrated Weigh Scale of suitable range for the type of cylinders filled.
- Establish maximum fill weight for each water capacity of cylinders with tolerances.
- Use Correct Tare Weight (empty cylinder, Valve/ Valve Guards, etc.) – Legible stamp marking on the shoulder / Tare weight metal ring below the valve above the test ring is preferred.
- Check weight after filling and disconnecting fill hose to ensure cylinder is not over-filled.
- Daily checks of weigh scale by calibrated dead weights.

Safeguards

- Controlled rate of filling for small cylinders.
  - Higher capacity pumps used for filling large cylinders very often lead to overfilling when small cylinders are filled on the same system
- Carbon dioxide cylinders must be vented slowly because the temperature can drop to the point where solid carbon dioxide (dry ice) can form in the cylinder.
- Always account for residual gas content in the cylinder. There is a danger of over-filling if residual gas is not completely vented/ un-accounted for in the target weight calculations.
- Pay particular attention to smaller cylinders - could be over-filled quickly by adding smaller quantities.

Consider Weighing Uncertainties



Pressure Relief Devices (PRDs)

- Pressure Relief Devices (PRDs) when fitted (if the regulations allow) relieve excess pressure when the developed pressure increases to the set pressure of PRD (set less than the test pressure of the cylinder).
- Most common gases: CO2 and N2O
- PRDs on toxic gases are prohibited.

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Pressure Relief Devices (PRDs)

- Use appropriate type of PRD (refer to CGA S-1.1 or local standards). Example: Use Rupture disc on Pure CO2 & N2O and **NOT** Combination rupture disc and fusible plug so that the pressure is released in the event of over-pressure condition without rise in temperature also.

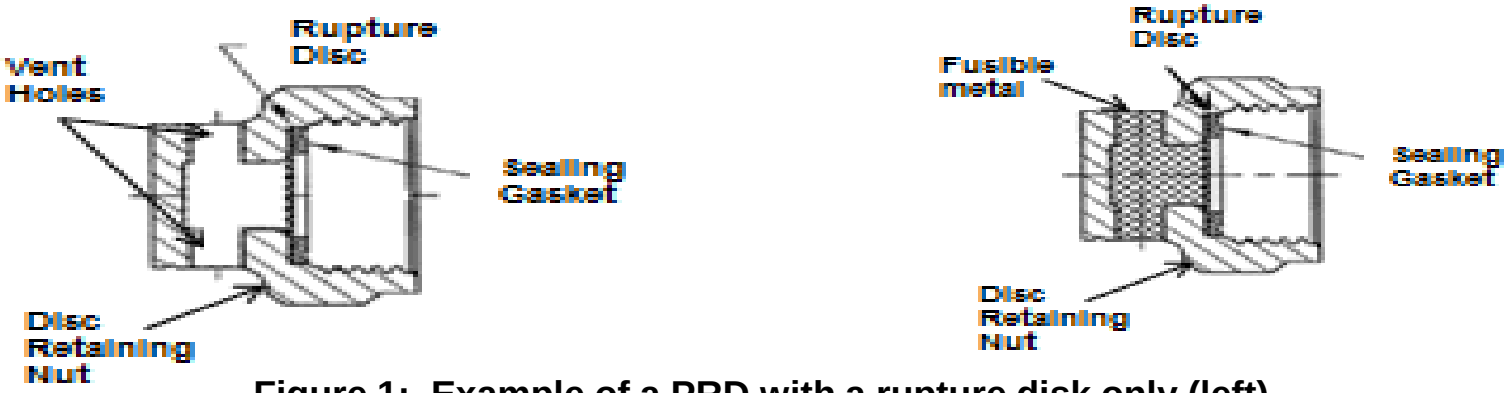

Figure 1: Example of a PRD with a rupture disk only (left) and a PRD with a combination type relief (right). The PRD on the right is not permitted on carbon dioxide and nitrous oxide cylinders.

Ensure that PRDs are in good condition and not tampered with.

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Residual Pressure valves in CO2

- RPV/NRV equipped cylinders: These cylinders shall be “prod checked” using a specially designed probe. If a positive pressure is given, the cylinder may be filled. If no residual pressure can be determined the cylinder shall be de-valved, the interior condition inspected and if satisfactory a new/refurbished valve fitted.

- For cylinders with Simple valves with no residual pressure may contain free water. Significant amount of water may be detected by weight check while smaller quantity depends on the accuracy of weigh scale. Inversion can detect even smaller quantity of water.

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References

- AIGA PP 066/18, Selection of PPEs
- DOT 49CFR
- UN Model Regulations (Part 4, Packing & Tank Provisions-P200)
- P.R. CHINA GB 14193 : Rules for filling of liquefied gas cylinders
- TAIWAN CNS12242 : Seamless Gas Cylinders
- IS 15795: Conditions for filling gas cylinders

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Stay Safe & Thank you!

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