TECHNICAL BULLETIN

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Cylinders and Valves - Pressure Definitions

1. Introduction

Pressure retaining parts of a gas cylinder package can be exposed to various levels of pressure, depending upon the conditions that the gas cylinder package is exposed to, whether during service or in testing. Cylinder and valve standards that are used for the design and testing of gas cylinder package items reference different pressures that correspond to those service and testing conditions.

The objective of this Technical Bulletin is to summarise pressure terminology, and pressure definitions, as referenced in the applicable standards and regulations.

2. Scope

The scope of the pressure terminology and definitions for this Technical Bulletin are those contained within regulations and standards that are relevant to Europe.

The first reference point is the *European Agreement on the Carriage of Dangerous Goods by R*oad[1], (ADR) [1], has been used for this document.

The second reference is ISO Technical Committee 58, Gas Cylinders, and this includes three sub committees:

- ISO/TC58/SC2 Cylinder fittings;
- ISO/TC58/SC3 Cylinder design and;
- ISO/TC58/SC4 Operational requirements for gas cylinders.

The definitions that are stated ISO 10286: *Gas cylinders – Terminology* [2] shall be used as a common point of reference for each pressure term.

3. Pressure definitions

3.1 Working pressure

Working pressure is a common term used across cylinder packages and associated components within the scope of ISO/TC58. However, it differs between compressed and dissolved gases.

ISO 10286 [2] defines working pressure of a compressed gas as:

“settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas”

ISO 10286 [2] defines working pressure of a dissolved gas as:

“settled pressure at a uniform reference temperature of 15 °C in an acetylene cylinder containing the specified solvent content and the maximum acetylene content”.

These definitions are used across multiple standards within the scope of ISO/TC58 SC2, SC3 and SC4 and are used to describe the baseline pressure to which an item of equipment can be designed or tested.
Working pressure is often abbreviated using the symbol p_w, and common European working pressures for

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

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compressed gases are 200 bar and 300 bar.

3.2 Test pressure

Test pressure is a common term used across many standards within the scope of ISO TC58. In its simplest form, it can be defined as in ISO 10286 [1]:

"required pressure applied during a pressure test".

However, the value of test pressure differs, depending upon the type of package equipment it is being applied to.

Test pressure is only applied to an item of a cylinder package equipment during testing; either during type approval, manufacture or retest.

3.2.1 Test pressure of a cylinder

For a cylinder, test pressure is often abbreviated using the symbol p_h.

It is generally assumed that, for a compressed gas, $p_h = 1.5 \times p_w$, for cylinders designed and manufactured to conform with ISO 9809-1, *Gas cylinders -- Refillable seamless steel gas cylinders -- Design, construction and testing -- Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa* [3]. For example, for a cylinder with a working pressure of 200 bar, its respective test pressure would be 300 bar.

For liquefied gases, such as carbon dioxide, test pressure is defined by Packing Instruction P200 of ADR [1], and is based upon elevated pressure of the respective liquefied gas at 65°C.

For dissolved gases, such as acetylene, test pressure is defined by Packing Instruction P200 of ADR [1], and is based upon elevated pressure of the respective dissolved gas at 65°C.

Cylinder test pressure is normally a hydraulic pressure that is required to be applied to a cylinder during various tests as part of the type approval and manufacturing checks, to be able to assess its ability to achieve different requirements, for example, maximum volumetric expansion.

Bundles of cylinders and manifolds also follow the same philosophy as cylinders with respect to definition of test pressure.

3.2.2 Test pressure of a valve

For a valve, test pressure is often abbreviated using the symbol p_{vt}.

For a compressed gas, $p_{vt} = 1.2 \times p_w$. For example, for a valve with a working pressure of 200 bar, its respective test pressure would be 240 bar.

For liquefied gases, such as carbon dioxide, test pressure is defined by Packing Instruction P200 of ADR, and is based upon developed pressure of the respective liquefied gas at 65°C.

For dissolved gases, such as acetylene, test pressure is defined by Packing Instruction P200 of ADR, and is based upon developed pressure of the respective dissolved gas at 65°C.

Valve test pressure is normally a gas pressure that is required to be applied to a valve during various tests as part of the type approval and manufacturing checks, to be able to assess its ability to achieve different requirements, for example, gas tightness.

NOTE The test pressure of the valve does not limit the maximum pressure the valve could be exposed to during operation, for example, filling. It is used only for prototype and manufacturer tests.

3.3 Burst pressure

Burst pressure is a common term used across many standards within the scope of ISO/TC58.

ISO 10286 [2] defines burst pressure as:

"highest pressure reached in a cylinder during a burst test".

However, burst pressure is also applicable to valves, which do not follow this same definition. For a valve it can be defined as:

"minimum pressure applied to a valve during hydraulic burst pressure test".

Within these two definitions is the fundamental difference between burst pressure of a cylinder and valve. The differences can be summarised as:

- for a cylinder it is the maximum pressure applied before it ruptures; and
- for a valve it is the minimum pressure applied without rupture.

Burst pressure is only applied to a piece of cylinder package equipment during type approval testing.

3.2.3 Burst pressure of a cylinder

For a cylinder, burst pressure is often abbreviated using the symbol p_b, and it is the maximum hydraulic pressure that is applied to a cylinder before it ruptures.

Minimum burst pressure requirements can vary but, according to ISO 9809-1 [3], burst pressure shall be equal or greater than 1.6 times the test pressure, p_h. For example, a cylinder with a test pressure of 300 bar shall have a minimum burst pressure of 480 bar.

Manifolds of bundles of cylinders also follow the same philosophy as cylinders with respect to definition of burst pressure.

3.2.4 Burst pressure of a valve

For a valve, burst pressure is often abbreviated using the symbol p_{vbt}, and it is the minimum hydraulic pressure a valve shall withstand without permanent visible deformation.

Minimum burst pressure requirements for a valve are a defined value, calculated relative to test pressure, and defined as $p_{vbt} = 2.25 \times p_w$. For example, a valve with a working pressure of 200 bar shall have a minimum burst pressure of 450 bar.

3.4 Filling pressure

Filling pressure is a common term used across compressed gas cylinders, bundles and other packages within the scope of ISO/TC58.

ISO 10286 [2] defines filling pressure of a compressed gas as:

"pressure to which a cylinder is filled at the time of filling".

Nominal filling pressure is often the same value as working pressure.

NOTE Liquefied and dissolved gases are often filled by weight, and so not in scope for this definition.

3.5 Developed pressure

Developed pressure is a common term used across gas cylinders, bundles and other packages within the scope of ISO/TC58.

ISO 10286 [2] defines developed pressure as:

"pressure developed by the gas contents in a cylinder at a uniform temperature of T_{max}".

Pressure of a gas within a closed volume increases with temperature, and developed pressure is the respective pressure related to an increase of temperature above the reference temperature of 15°C used for working pressure.

This definition is applicable for compressed, liquefied and dissolved gases, with each gas having a different developed pressure for a given temperature.

The term is often used when gas packages are exposed to high temperatures during their life, for example, during a filling process.

3.6 Settled pressure

Settled pressure is a common term used across gas cylinders, bundles and other packages within the scope of ISO/TC58.

ISO 10286 [2] defines settled pressure as:

"pressure of the contents of a pressure receptacle in thermal and diffusive equilibrium".

This definition is applicable for compressed, liquefied and dissolved gases, with each gas having a different developed pressure for a given temperature.

The term is often used as an alternative to working pressure, because working pressure is specifically with respect to a temperature of 15°C. The term settled pressure is able to be related to other temperatures, for example, ambient temperature of a particular environment a gas package is exposed to.

3.7 Yield pressure

Yield pressure is a common term that is specifically related to the design and testing of gas cylinders within the scope of ISO/TC58.

ISO 10286 [2] defines yield pressure as:

"pressure at which the actual yield strength of a cylinder is reached".

The term is used when type approval testing gas cylinders, and is the observed pressure when cylinder starts yielding during a hydraulic burst test.

3.8 Design pressure

Design pressure is a common term that is specifically related to the design and testing of gas cylinders within the scope of ISO/TC58.

ISO 10286 [2] defines design pressure as:

"pressure based on which the minimum wall thickness is calculated".

The term is used when designing gas cylinders, and is a key parameter when calculating a cylinder's minimum wall thickness. ADR [1] defines this term as, calculation pressure.

3.9 Discharge pressure

Discharge pressure is a specific term that is specifically related to the use of gas cylinders, and referenced in ADR.

ADR [1] defines discharge pressure as:

"the maximum pressure actually built up in the tank when it is being discharged under pressure".

The term is used when designing and using gas cylinders.

4. References

Unless otherwise specified, the latest edition shall apply.

[1] ADR, *European Agreement on the Carriage of Dangerous Goods by Road*, www.unece.org

[2] ISO 10286, *Gas cylinders – Terminology* www.iso.org

[3] ISO 9809-1, *Gas cylinders -- Refillable seamless steel gas cylinders -- Design, construction and testing -- Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa* www.iso.org

[4] ISO 10297, *Gas cylinders -- Cylinder valves -- Specification and type testing* www.iso.org

[5] ISO 12209, *Gas cylinders -- Outlet connections for gas cylinder valves for compressed breathable air* www.iso.org

[6] ISO 14246, *Gas cylinders -- Cylinder valves -- Manufacturing tests and examinations* www.iso.org

[7] ISO 15996, *Gas cylinders -- Residual pressure valves -- Specification and type testing of cylinder valves incorporating residual pressure devices* www.iso.org

[8] ISO 17879, *Gas cylinders -- Self-closing cylinder valves -- Specification and type testing* www.iso.org

[9] ISO 22435, *Gas cylinders -- Cylinder valves with integrated pressure regulators -- Specification and type testing* www.iso.org

[10] ISO 11118, *Gas cylinders -- Non-refillable metallic gas cylinders -- Specification and test methods* www.iso.org

[11] ISO 11119, *Gas cylinders -- Refillable composite gas cylinders and tubes -- Design, construction and testing -- Part 1: Hoop wrapped fibre reinforced composite gas cylinders and tubes up to 450 l* www.iso.org

[12] ISO 11120, *Gas cylinders -- Refillable seamless steel tubes of water capacity between 150 l and 3000 l -- Design, construction and testing* www.iso.org

[13] ISO 11439, Gas cylinders -- High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles www.iso.org

[14] ISO 10462, *Gas cylinders -- Acetylene cylinders -- Periodic inspection and maintenance* www.iso.org

[15] ISO 10961, *Gas cylinders -- Cylinder bundles -- Design, manufacture, testing and inspection* www.iso.org

[16] ISO11372, *Gas cylinders -- Cylinder bundles -- Design, manufacture, testing and inspection* www.iso.org

[17] ISO13088, *Gas cylinders -- Acetylene cylinder bundles -- Filling conditions and filling inspection* www.iso.org

[18] ISO16148, *Gas cylinders -- Refillable seamless steel gas cylinders and tubes -- Acoustic emission examination (AT) and follow-up ultrasonic examination (UT) for periodic inspection and testing* www.iso.org

[19] ISO 19078, *Gas cylinders -- Inspection of the cylinder installation, and requalification of high pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles* www.iso.org

[20] ISO 14245, *Gas cylinders -- Specifications and testing of LPG cylinder valves -- Self-closing* www.iso.org

[21] ISO 15995, *Gas cylinders -- Specifications and testing of LPG cylinder valves -- Manually operated* www.iso.org

[22] ISO 21172, *Gas cylinders -- Welded steel pressure drums up to 3 000 litres capacity for the transport of gases -- Design and construction -- Part 1: Capacities up to 1 000 litres* www.iso.org

[23] ISO 16964, *Gas cylinders -- Flexible hoses assemblies -- Specification and testing* www.iso.org

[24] ISO 11515, *Gas cylinders -- Refillable composite reinforced tubes of water capacity between 450 L and 3000 L -- Design, construction and testing* www.iso.org

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Appendix A: References

A.1 Working Pressure

Term	Symbol	Definition	Reference	Source
Working Pressure: Acetylene	-	settled pressure at a uniform reference temperature of 15 °C in an acetylene cylinder containing the specified solvent content and the maximum acetylene content	ISO 10286 [1]	TC58
Working Pressure: Compressed	-	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder	ISO 10286 [1]	TC58
Working Pressure	p_w	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder or cylinder bundle for which the valve is intended	ISO 10297 [4]	TC58/SC2
Working Pressure	-	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder	ISO 12209 [5]	TC58/SC2
Working Pressure	p_w	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder for which the valve is intended	ISO 14246 [6]	TC58/SC2
Working Pressure	p_w	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full pressure receptacle for which the RPV is intended	ISO 15996 [7]	TC58/SC2
Working Pressure	p_w	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder for which the valve is intended	ISO 17879 [8]	TC58/SC2
Working Pressure	p_w	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder or cylinder bundle for which the valve is intended.	ISO 22435 [9]	TC58/SC2
Working Pressure	-	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder	ISO 9809-1 [3]	TC58/SC3
Working Pressure	-	settled pressure of compressed gas at a uniform reference temperature of 15 °C (288 K) in a full gas cylinder	ISO 11118 [10]	TC58/SC3
Working Pressure	-	settled pressure of a compressed gas at a reference temperature of 15 °C in a full gas cylinder	ISO 11119 [11]	TC58/SC3
Working Pressure	-	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a	ISO 11120	TC58/SC3

Term	Symbol	Definition	Reference	Source
		full tube	[12]	
Working Pressure	-	settled pressure of a fully filled cylinder at a uniform temperature of 15 °C	ISO 11439 [13]	TC58/SC3
Working Pressure	-	settled pressure at a uniform reference temperature of 15 °C in an acetylene cylinder containing the specified solvent content and the maximum acetylene content	ISO 10462 [14]	TC58/SC4
Working Pressure	-	settled pressure for a compressed or dissolved gas at a uniform temperature of 288 K (15 °C) for a full bundle	ISO 10961 [15]	TC58/SC4
Working Pressure	-	settled pressure at a uniform reference temperature of 15 °C in a cylinder containing the specified solvent content and the maximum acetylene content	ISO 11372 [16]	TC58/SC4
Working Pressure	-	settled pressure at a uniform reference temperature of 15 °C in a cylinder containing the specified solvent content and the maximum acetylene content	ISO 13088 [17]	TC58/SC4
Working Pressure	-	settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder	ISO 16148 [18]	TC58/SC4
Working Pressure	-	settled pressure, at a uniform temperature of 15 °C	ISO 19078 [19]	TC58/SC4
Working Pressure	-	the settled pressure of a compressed gas at a reference temperature of 15°C in a full pressure receptacle	ADR [1]	ADR [1]
Maximum Working Pressure	-	the highest of the following three pressures that may occur at the top of the tank in the operating position: (a) The highest effective pressure allowed in the tank during filling (maximum filling pressure allowed); (b) The highest effective pressure allowed in the tank during discharge (maximum discharge pressure allowed); (c) The effective gauge pressure to which the tank is subjected by its contents (including such extraneous gases as it may contain) at the maximum working temperature.	ADR [1]	ADR [1]

A.2 Test Pressure

Term	Symbol	Definition	Reference	Source
Test Pressure	-	required pressure applied during a pressure test	ISO 10286 [2]	TC58
Test Pressure	p_{vt}	minimum pressure applied to a valve during testing. $p_{vt} = 1.2\ p_w$	ISO 10297 [4]	TC58/SC2
Test Pressure	-	pressure at which the valve or component is tested in bar gauge	ISO 14245 [20]	TC58/SC2
Test Pressure	p_{vt}	minimum pressure applied to a valve through a gas during testing	ISO 14246 [6]	TC58/SC2
Test Pressure	-	pressure at which the valve or component is tested in bar gauge	ISO 15995 [21]	TC58/SC2
Test Pressure	p_{vt}	minimum pressure applied to a RPV during testing pressure that is used specifically for testing, and which emulates the highest pressure a RPV is expected to see in service	ISO 15996 [7]	TC58/SC2
Test Pressure	p_{vt}	minimum pressure applied to a valve during testing	ISO 17879 [8]	TC58/SC2
Test Pressure	p_{vt}	minimum pressure applied to a valve during testing. $p_{vt} = 1.2\ p_w$	ISO 22435[9]	TC58/SC2
Test Pressure	p_h	required pressure applied during a pressure test	ISO 9809-1 [3]	TC58/SC3
Test Pressure	-	required pressure applied during the pressure test	ISO 11118 [10]	TC58/SC3
Test Pressure	p_h	required pressure applied during the pressure test of the composite cylinder	ISO 11119 [11]	TC58/SC3
Test Pressure	p_h	required pressure applied during a pressure test	ISO 11120[12]	TC58/SC3
Test Pressure	-	required pressure applied during a pressure test	ISO 11439 [13]	TC58/SC3
Test Pressure	-	pressure applied to the drum after completion of all fabrication	ISO 21172 [22]	TC58/SC3
Test Pressure	-	the required pressure applied during a pressure test for initial or periodic inspection	ADR [1]	ADR [1]
Proof Test Pressure	-	hydraulic pressure which demonstrates the structural integrity of the manifold	ISO 10961[15]	TC58/SC4

Term	Symbol	Definition	Reference	Source
Bundle Test Pressure	-	test pressure of the cylinder and manifold assembled together	ISO 10961 [15]	TC58/SC4

A.3 Burst Pressure

Term	Symbol	Definition	Reference	Source
Burst Pressure	-	highest pressure reached in a cylinder during a burst test	ISO 10286 [2]	TC58
Burst Pressure	p_{vbt}	minimum pressure applied to a valve during hydraulic burst pressure test. $p_{vbt} = 2.25\ p_w$	ISO 10297 [4]	TC58/SC2
Burst Pressure	-	highest pressure reached in a flexible hose assembly during a burst test	ISO 16964 [23]	TC58/SC2
Burst Pressure	p_{vbt}	minimum pressure applied to a valve during hydraulic burst pressure test	ISO 17879 [8]	TC58/SC2
Burst Pressure	p_{vbt}	minimum pressure applied to a valve during hydraulic burst pressure test. $p_{vbt} = 2.25\ p_w$	ISO 22435 [9]	TC58/SC2
Burst Pressure	p_b	highest pressure reached in a cylinder during a burst test	ISO 9809-1 [3]	TC58/SC3
Burst Pressure	-	highest pressure reached in a cylinder during the burst test	ISO 11118 [10]	TC58/SC3
Burst Pressure	-	highest pressure reached in a cylinder, pb, or liner, pbl, during a burst test	ISO 11119 [11]	TC58/SC3
Burst Pressure	-	highest pressure reached in a cylinder during a burst test	ISO 11439 [13]	TC58/SC3
Burst Pressure	-	highest pressure reached in a tube or liner during a burst test	ISO 11515 [24]	TC58/SC3
Burst Pressure	-	highest pressure reached in a cylinder or the bundle manifold during a burst test	ISO 10961 [15]	TC58/SC4

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A.4 Filling Pressure

Term	Symbol	Definition	Reference	Committee
Filling Pressure	-	pressure to which a cylinder is filled at the time of filling	ISO 10286 [2]	TC58
Filling Pressure	-	pressure to which a bundle is filled at the time of filling	ISO 10961 [15]	TC58/SC4
Normal Filling Pressure	-	level to which a cylinder or tube is pressurized during filling	ISO 16148 [18]	TC58/SC4
Filling Pressure	-	the maximum pressure actually built up in the tank when it is being filled under pressure	ADR [1]	ADR [1]

A.5 Developed Pressure

Term	Symbol	Definition	Reference	Source
Developed Pressure	-	pressure developed by the gas contents in a cylinder at a uniform temperature of Tmax	ISO 10286 [2]	TC58

A.6 Settled Pressure

Term	Symbol	Definition	Reference	Source
Settled Pressure	-	pressure of the contents of a pressure receptacle in thermal and diffusive equilibrium	ISO 10286 [2]	TC58

A.7 Yield Pressure

Term	Symbol	Definition	Reference	Source
Yield Pressure	-	pressure at which the actual yield strength of a cylinder is reached	ISO 10286 [2]	TC58

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A.8 Design Pressure

Term	Symbol	Definition	Reference	Source
Design Pressure	-	pressure based on which the minimum wall thickness is calculated	ISO 10286 [2]	TC58
Calculation Pressure	-	a theoretical pressure at least equal to the test pressure which, according to the degree of danger exhibited by the substance being carried, may to a greater or lesser degree exceed the working pressure. It is used solely to determine the thickness of the walls of the shell, independently of any external or internal reinforcing device	ADR [1]	ADR [1]

A.9 Discharge Pressure

Term	Symbol	Definition	Reference	Source
Discharge Pressure	-	the maximum pressure actually built up in the tank when it is being discharged under pressure	ADR [1]	ADR [1]

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