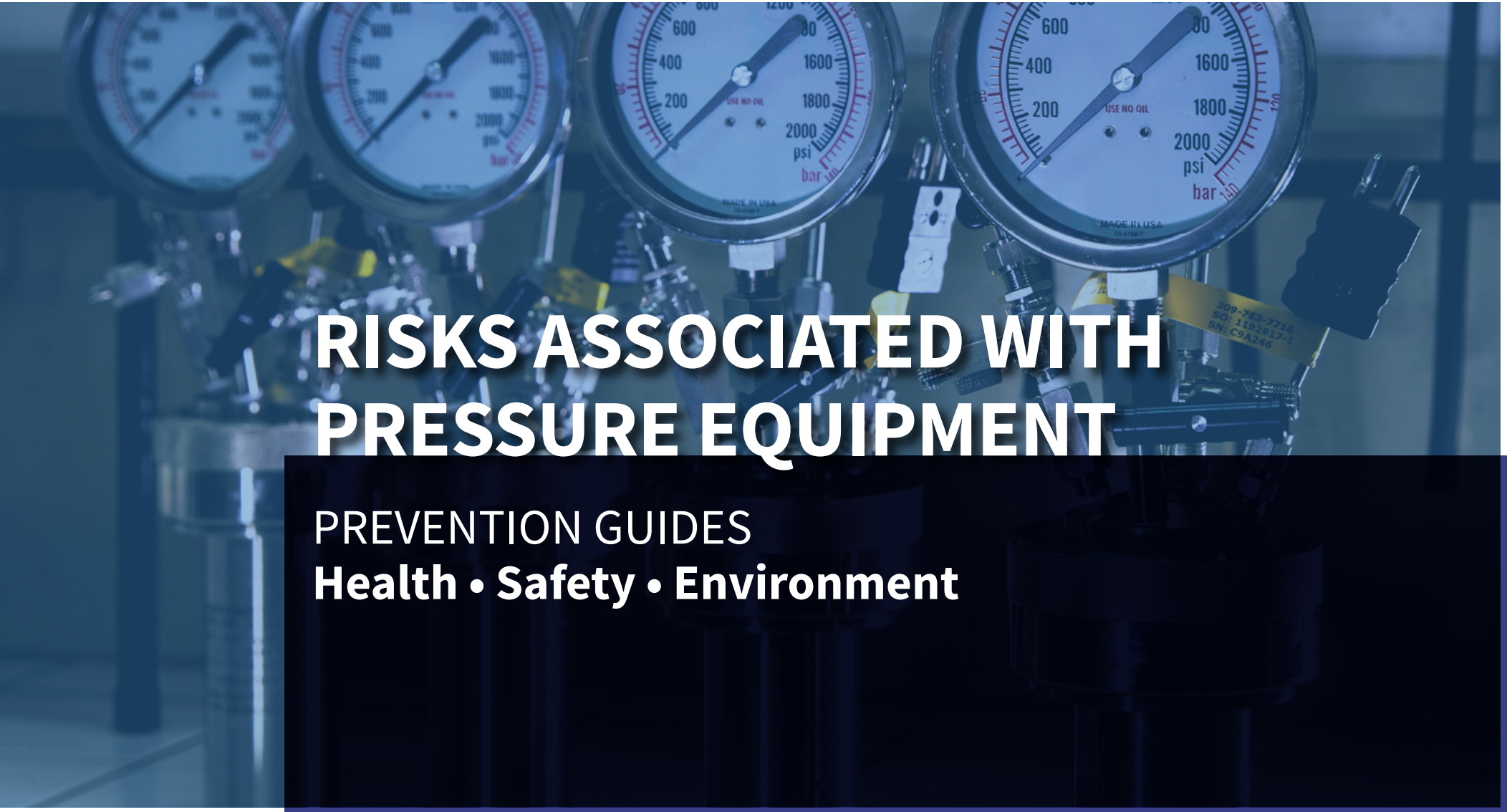

RISKS ASSOCIATED WITH PRESSURE EQUIPMENT

PREVENTION GUIDES

Health • Safety • Environment

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This document was prepared by:

Céline BATAILLON
Health and Safety Engineer,
CNRS National Health and Safety Centre

Aurélien CADET
Adviser,
CNRS National Transport Safety of Dangerous Goods

Azziz HOCINI
Laboratory Engineer,
Science of Processes and Materials (LSPM – UPR 3407)

Head of the “High Pressure and Mechanical Testing” department

Member of the CNRS High Pressure Network Steering Committee

Christine LUCAS
Laboratory Engineer, Chemistry, Catalysis,
Polymers and Processes (LC2P2 – UPR 5265)

Staff Representative on the CNRS Occupational Health, Safety,
and Working Conditions Central Committee

Pascal OLIVIER
Regional Health and Safety Engineer,
CNRS Nord-Pas-de-Calais and Picardie Region (2011-2019)

Deputy Director,
Risk Prevention Department at Université de Lille

Janine WYBIER
Deputy National Coordinator,
CNRS National Health and Safety Centre

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1 • INTRODUCTION

Pressure equipment (PE) is commonly found in research units because, in the course of their work, staff need to use autoclaves, high and low pressure equipment, gas cylinders and so on. Some of the facilities in buildings also involve PE such as boilers and compressors.

Being aware of the risks associated with pressure is very important. A fault in design, handling or maintenance can lead to serious accidents such as an explosion, an implosion or the failure of fragile components (joints, sight glasses, regulators, etc.) Their impact can include flying particles, the propagation of shock waves and the leakage of liquid or gas.

Such accidents generally cause serious injury to any users close by, including severe trauma, cuts and burns.

In addition to the risks associated with pressure, some equipment items containing fluids may present risks associated with the nature of the leaked substance. They include asphyxia, burns, poisoning, inflammation and explosion.

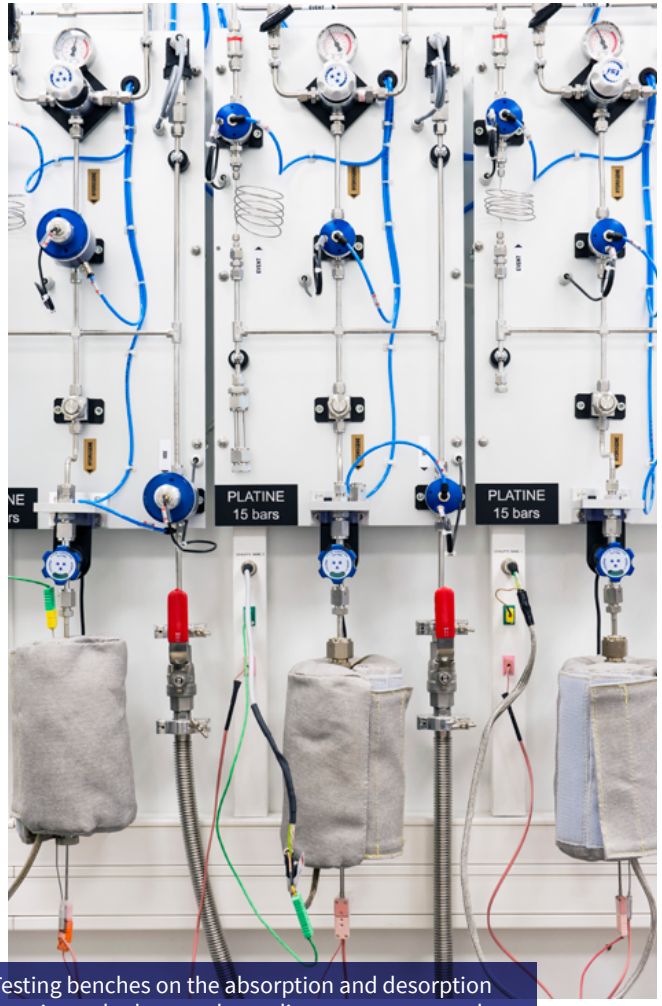
This guide will help you identify the hazards associated with facilities and equipment, to assess risks and to implement an appropriate three-fold prevention plan addressing putting into use, handling/experiments and maintenance/checks.

This guide is for any person who is likely to use pressure or vacuum equipment: junior and senior investigators, and maintenance staff.

This guide does not cover the following:
- the design and manufacture of equipment, which are the exclusive remit of specialists;
- risks associated with using extinguishers;
- refrigeration units.

This prevention guide is in three parts:
- the body of the document covers the different types of equipment, legislation, the various hazards and how to prevent them,
- appendices listing all the legal instruments and definitions relating to PE and a glossary,
- factsheets on certain specific items (autoclaves, gas cylinders, experimental setups under pressure, etc.) and on certain mandatory rules.

This guide is the work of a group comprising investigators, health and safety engineers and a member of the Occupational Health, Safety and Working Conditions Central Committee.



Testing benches on the absorption and desorption reaction to hydrogen, depending on pressure and temperature.

2 • AN OVERVIEW OF THEORY

2.1. DEFINITIONS

Pressure is defined as the force divided by the area:

P (pressure) = F (force) / A (area)

The legal unit is the pascal (Pa). One pascal is equivalent to the force of one newton exerted over an area of one square metre (1 Pa = 1 N / 1 m²).

Pressure can also be expressed in bar (1 bar = 105 Pa), in pounds per square inch (1 PSI = 6 894 Pa), in millimetres of mercury (1 mm Hg = 133.32 Pa) and in atmospheres (1 atm = 101,325 Pa).

To express pressure in "MPa" from a value in bar, the value must be multiplied by 0.1.

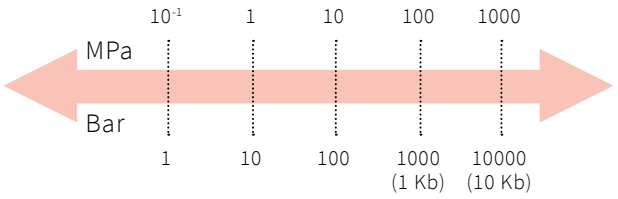


Figure 1 *Pa/Bar scale pressure*

Absolute pressure
Pressure measured above absolute zero.

Atmospheric pressure
Pressure exerted by the atmosphere on the Earth's surface.

Service pressure
A device's operating pressure.

Relative pressure
Pressure measured against atmospheric pressure.

Differential pressure
Difference between two pressures, one being the reference.

Vacuum
Absolute zero pressure.

Normal conditions
0 °C, 1 atmosphere, in accordance with the ISO 10 780 standard.

Examples of different pressure levels are given in **Factsheet 1**.

2.2. IDEAL GAS LAW

A real gas at sufficiently low pressure may be considered as an ideal gas. In this case, for n moles, state variables P, V and T are linked by the "general gas equation":

$P . V = n . R . T$

with P: pressure, in pascal (Pa)
V: volume, in m^3
T: temperature, in kelvin (K)
n: number of moles (mol)
R: molar gas constant ($R = 8,31\ J .K^{-1}.mol^{-1}$)

In an isochoric transformation (constant volume), Gay-Lussac's law shows that pressure P is proportional to temperature T, thus P / T = constant.

In an isothermal transformation (constant temperature), Boyle-Mariotte's law shows that volume V is inversely proportional to pressure P, thus P . V = constant.

In an isobaric transformation (constant pressure), Charles's law shows that volume V is proportional to temperature T, thus V / T = constant.

APPLICATION OF IDEAL GAS LAW TO A PRESSURE COOKER

When water heats up in a cooker pressure, steam – considered an ideal gas – is produced and cannot escape from the receptacle. The volume V and the quantity of matter n remain unchanged. The increased heat in the vessel, hermetically sealed, leads to increased pressure, which balances out the ideal gas equation.

WARNING
Applying the ideal gas law to gas cylinders under pressure can only provide an approximate result.

This table shows examples of mistakes made on the volume occupied by the gas when only using the ideal gas law (source: Gas Encyclopedia, Air liquide).

Substance	1bar	150bar
C_2H_2	+ 0.7 %	Liquid
NH_3	+ 1.2 %	Liquid
CO_2	+ 0.6 %	Liquid
SO_2	+ 0.2 %	Liquid
Ar	+ 0.07 %	+ 8 %
N_2	+ 0.03 %	- 2 %
C_2H_4	+ 0.6 %	+ 150 %
He	- 0.04 %	- 7 %

3 • LABORATORY PRESSURE EQUIPMENT (PE)

Gas pressure equipment

• compressors,
• cylinders, tanks, piping and accessories,
• autoclave reactors.

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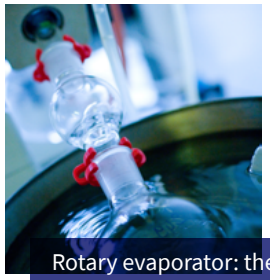

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Rotary evaporator: the solvent is removed by vacuum evaporation

Negative pressure equipment

• evaporators, dessicators,
• laboratory glassware (e.g. vacuum pump),
• pressure vessel (deposits, growth, plasma, etc.)

Steam pressure equipment

• boilers,
• sterilisation autoclaves.

Laboratory sterilisation autoclave.

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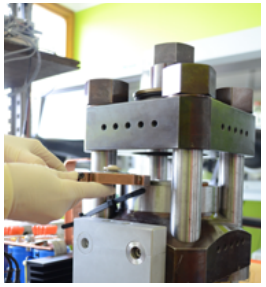
HYCOMAT platform for a range of mechanical tests (traction, compression, creep, fatigue, fissure, explosive decompression) under pressure of hydrogen, carbon dioxide and nitrogen gas. This pressure can reach 400 bar between ambient temperature and 150°C.

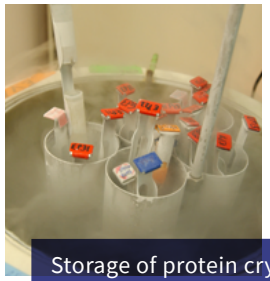
Experimental setups

• equipment containing a liquid which can be over- or under-pressurised in operating conditions or accidentally.

Liquid pressure equipment

• hydraulic equipment.





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Storage of protein crystals before analysis by synchrotron radiation.

Cryogenic vessels

• equipment which can become over-pressurised because of a fault or improper use: Dewar flask, cryogenic liquid and dry ice containers, etc.

4 • LEGISLATION

Successive legal instruments have made it mandatory for pressure equipment to be subject to rules and checks at the manufacturing stage and also during initial testing. This needs to be carried out before being put into service by the DREAL[1]/ DRIEE[2], which issues a test certificate.

Periodic inspections and recertification – the cost of which is met by the pressure equipment owner – need to be undertaken.

Because legislation takes into account several factors, including vessel volume, some of the equipment used at very high pressure may not be covered by legislation in the case of small volumes.

Legislation derived from the **European Pressure Equipment Directive** 97/23/CE (PED), published on 29 May 1997, has been transcribed into French law by the decree of 13 December 1999. This decree replaced previous French legislation on the design and purchase of new equipment and its application became mandatory in May 2002

In 2014, two European directives replaced the 1997 directive, to ensure greater safety when putting pressure equipment into service.

They were transcribed into French law by the **decree of 1 July 2015 on hazardous products and substances** and by the **decree of 28 December 2016** and the **decree of 20 November 2018 on the monitoring of operating pressure equipment and simple pressure vessels,** in force since 1 January 2018.

Most of the legislation on PE can be found in **chapter 7, title 5, book 5 of the regulatory section of the French Environmental Code.**

Details of the legal instruments in force at the date of this guide's publication are provided in appendix 1.

4.1. LEGISLATION PRIOR TO MAY 2002

Up until 31 December 2019, this legislation still applied to equipment put into service prior to May 2002.

The following four principles were taken into consideration:

- the equipment's mechanical resistance was calculated and tested in conditions such that the risk of explosion was unlikely if it had been used properly;
- protection from danger was effected in such a way that staff were sheltered in the event of an accident;
- this equipment was only used by trained people who were aware of the risks it posed and of the measures to be taken to prevent these risks;
- in the event of a fault, safety devices limited its potentially dangerous effects: valves, rupture disks and sensors reacting to a range of parameters (pressure, temperature and concentration) controlled prevention systems (supply cut off and ventilation activated) should set values be exceeded.

[1] *DREAL : Regional agencies for the environment, planning and housing*
[2] *DRIEE : Regional interdepartmental agencies for the environment and energy*

Tests and recertification were required to be carried out under hydraulic pressure, which were:
- either 1.43 times the maximum allowable pressure,
- or the pressure equivalent to the maximum charge borne by the equipment in service, taking into consideration its maximum allowable pressure and temperature, multiplied by 1.25.

This legislation applied to:
- vessels: effective pressure > 4 bar plus the product of [pressure (bar) . volume (litre)] > 80;
- compressors: pressure > 10 bar plus the product [pressure (bar) . debit (m3 /m in)] > 50.

PLEASE NOTE

As of 1 January 2020, this equipment must comply with the new legislation in force and is termed "newly submitted".

4.2. LEGISLATION CURRENTLY IN FORCE

Current legislation* is mainly based on the **decree of 20 November 2017** and applies to any equipment under gas or steam pressure, the pressure of which is greater than 0.5 bar. It also applies to piping, accessories and safety devices.

Legislation classifies PE into various hazard categories, each one having to meet conformity criteria. In addition, PE is also subject to inspection when put into service and during in-service monitoring.

* This legislation does not cover devices already covered in other legal instruments (for example, extinguishers), those presenting no real danger (tyres, water supply and bottles of carbonated beverages) or those presenting particular problems (for example, military equipment). The design of the above must however be "state-of-the-art", even if it bears no CE mark.

4.2.1 PE classification

PE classification is based on three key criteria:
- the equipment type (vessels, piping and accessories),
- the physical nature of the fluid (gas, liquid, vapour or solid),
- the hazard level of the fluid contained:
  - group 1: explosive, highly flammable, easily flammable, flammable when the flash point is lower than the maximum operating temperature, toxic, oxidising;
  - group 2: all other fluids.

In order to establish a fluid group, please refer to section I of **article R557-9-3 of the French Environmental Code.**

NOTE

If the fluid is not known, it must be considered as belonging to group 1.

In addition, these three criteria are associated with two parameters:
- maximum service pressure
- volume (for tanks) or nominal size (for piping), which results in four PE categories (I, II, III et IV).

Manufacturers indicate which category the equipment belongs to, based on the equipment's characteristics, using classification diagrams.

4.2.2 Conformity assessment procedure

PE is subject to a conformity assessment procedure, to check that it meets regulatory requirements. The procedure applies to equipment design and manufacture. The laboratory (the operator) must hold a declaration of conformity, provided by the manufacturer.

4.2.3 CE marking

Marking must comprise:
- the "CE" mark,
- the identification number of the accredited organisation;
- the last two digits of the year the CE marking was affixed to the equipment
- the following technical characteristics: maximum service pressure (PS) expressed in bar, minimum operating temperature (T min) and maximum operating temperature (T max), expressed in °C and the receptacle's volume (V) expressed in litres,
- the name, the company name or registered trademark and the manufacturer's address,
- the type and identification of the series or batch,
- where applicable, any other mark indicating a hazard (e.g. equipment hazard category, fluid hazard category) and specific use.

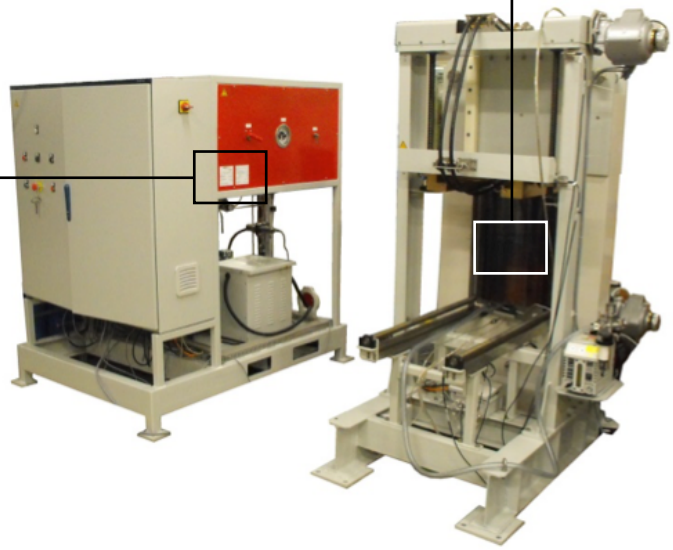
PS: 4,463 bar TS : +5 %+200 °C
PT: 6,382 bar on 16/06/2016
V: 85L
Fluid: inert gas (nitrogen, argon)
Group: 2
PED category IV

MP CIRCUIT
Maximum allowable pressure (PS): 210 bar
Valve: 200 bar +/- 5 %

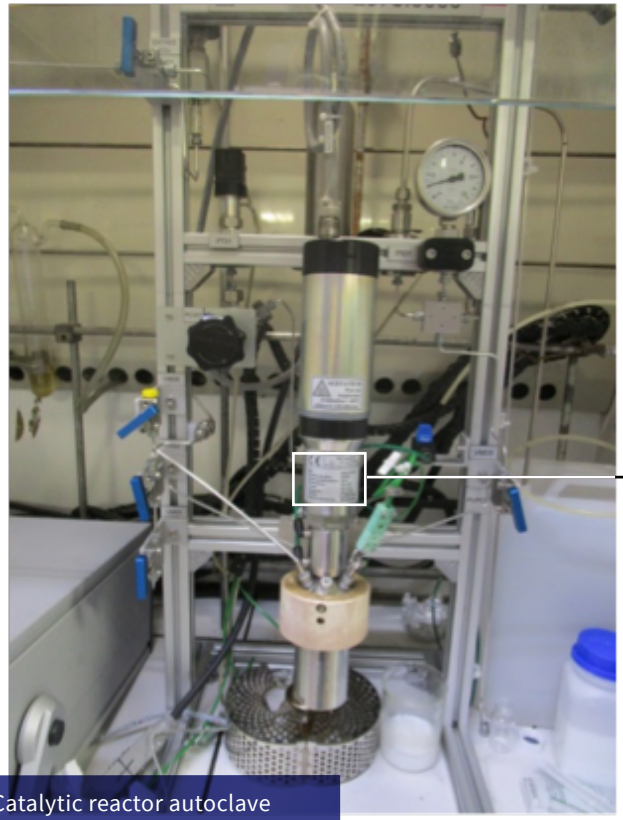
HP CIRCUIT
Vessel volume (V): ~ 8.5 L
Maximum use pressure (PU): 4,000 bar
Maximum allowable pressure (PS): 4,462 bar
Maximum allowable temperature
- Vessel (TS): + 5 °C/+200 °C
- Oven (TS): + 1,450 °C

Fluid: gas (nitrogen, argon) Group: 2
PED category: IV
Nominal diameter (do): 1.6 mm
Valve: 4,250 bar +/- 3 %

ELECTRICAL PANEL
Supply: 400 Vac + N + T - 50 Hz
Power: 15kW



Hot isostatic pressing (HIP) Examples of marking



Catalytic reactor autoclave
Example of CE marking

5 • PE INSPECTION

PE is subject to regulatory inspection throughout its lifespan, starting with the putting into service inspection, coupled with the declaration of conformity.

After that, the frequency of inspections depends on the equipment in question and on the way the operator has chosen to monitor it in service.

5.1. PUTTING INTO SERVICE

The following PE items are subject to the declaration of conformity and putting into service inspection:

1. Vessels under gas pressure, with maximum allowable pressure (PS) greater than 4 bar and where the product [PS . Volume] is greater than 10,000 bar. (**Factsheet 2- flowchart a**).

2. Pipes with maximum allowable pressure (PS) greater than 4 bar belonging to one of the following categories (**Factsheet 2- flowchart b**) :
- Group 1 gas piping where the nominal diameter (DN) is greater than 350 or where the product [PS . DN] is greater than 3,500 bar, except for piping where the DN is equal to or lower than 100.
- Group 2 gas piping where the DN is greater than 250, except for piping where the product [PS . DN] is equal to or lower than 5,000 bar.

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Leak test on a gas panel of epitaxial growth

3. Steam generators belonging to at least one of the following categories (**Factsheet 2- flowchart c**) :
- steam generators where the PS is greater than 32 bar,
- steam generators where the volume (V) is greater than 2,400 litres,
- steam generators where the product [PS .V] is greater than 6,000 bar . litres.

4. Autoclave (a sterilisation autoclave for example) (**Factsheet 2- flowchart d**).

5.1.1 Putting into service – Declaration

The operator logs on to the **LUNE platform** to make the declaration, which comprises:
- the main characteristics of the equipment,
- the name of the manufacturer and the country of manufacture,
- where applicable, the number of the notified body,
- the date of putting into service,
- the manufacturer's contact details,
- the equipment's location,
- a copy of the declaration of conformity issued by the equipment's manufacturer.

The operator receives a proof of submission of their declaration.

At the CNRS, the unit director, as operator, submits the declaration on the LUNE platform. The unit director must inform the supervisory organisation of this declaration.

5.1.2 Putting into service – Inspection

When putting equipment into service, inspection serves to certify that once installed, it complies with the general conditions of installation and use for safe operation. This must be carried out:

- before the equipment is first used;
- following conformity assessment and major work (see box: “Work on PE – Definitions”);
- before putting equipment into service following a removal.

Inspection relating to putting PE into service must be carried out by an accredited body for:

- steam generators
- autoclaves

For other equipment, such as piping and vessels, inspection may be carried out by a competent person (see box: “Competent person).

> WORK ON PE – DEFINITIONS

Major work
Work is considered to be major when it leads to changing the purpose, original type or performance of the equipment, such that it can no longer operate within the limits set by the manufacturer.

Notable work
Work is notable if it is not considered to be major but is liable to alter the equipment’s conformity as regards essential safety requirements.

Non-notable work
Work is non-notable if it is neither major nor notable. It must not alter the equipment’s conformity as regards essential safety requirements.

COMPETENT PERSON

This is a person appointed by the manufacturer, who is able to:

- check the continued conformity of equipment and related accessories as regards essential safety requirements, when PE is being installed;
- carry out work on PE;
- identify any equipment failures and evaluate their severity, in the course of periodic inspections and of any checks that may follow non-notable work;
- draw up the inspection programme under the responsibility of the operator;
- validate the proper implementation of the various measures set out in a **professional technical register**.

At the CNRS, the unit director is the operator.

During a putting into service inspection, the competent person or accredited body ensures that:
- the equipment has incurred no damage during transport
- the manufacturer has provided operational and appropriate safety accessories, if they have not been assessed together with the manufacturer's equipment;
- measures have been taken to protect staff in the event of dangerous emissions from safety accessories;
- there is a holding file;
- the instructions in the user guide are followed.

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Cell line samples placed in liquid nitrogen for conservation at -160°C.

5.2. IN-SERVICE MONITORING

There are two approaches to in-service monitoring:
- monitoring with an inspection programme,
- monitoring without an inspection programme.

The approach chosen can change over the PE's lifespan.

Monitoring with an inspection program is carried out with reference to one or several of the approved professional guides* listed in **Appendix 2 of the decree of 20 November 2017**. Monitoring is placed under the responsibility of the operator and approved by an accredited body.

The difference between the two approaches lies in the time interval between periodic inspections or recertification procedures and the inspection programme enables an extension of this interval. However in that case, inspections are carried out internally by a competent person (see box page 15: "Competent person"), which requires much work in terms of implementing monitoring activities (organisation, time, skills, etc.).

Whatever the option chosen (with or without an inspection programme), in-service monitoring consists in periodic inspection and recertification.

Periodic inspection focuses on pressure equipment and accessories, safety accessories and regulation and safety devices.

For devices with quick-closing movable lid (French acronym: ACAFR) and steam generators, this is carried out by an accredited body.
For other equipment, this comes under the responsibility of the operator and is carried out by a competent person.

Periodic inspection consists in:
- an external inspection (detailed visual inspection, with additional simple and non-destructive tests, where required);
- an inspection of the safety accessories;
- an inspection of accessories under pressure, with inspections similar to those conducted on the equipment they are attached to (generator, vessel and piping) or specific to a family of accessories;
- an internal inspection in the case of:
  - steam generators
  - vessels, unless the previous internal inspection was carried out less than two years ago;
- for ACAFR, an inspection of:
  - the state of repair and the proper functioning of safety devices,
  - the accreditation of staff who use them;

* by decision of the Minister of industrial security, following its publication in the Official Gazette of the French ministry in charge of industrial security.

• for steam generators, an inspection of:
- the state of repair and the proper functioning of regulation devices,
- the way monitoring is organised and implemented,
- the accreditation of staff who use them.

Periodic recertification is carried out by an accredited body. It consists in:
• an inspection of the use register,
• an external and external inspection (detailed visual inspection, with additional simple and non-destructive tests, where required),
• an inspection of the pressure accessories, safety accessories and regulation and safety devices,
• a hydraulic test, carried out with a pressure equal to at least 120% of the maximum allowable pressure.

Should recertification be successful, the accrediting body affixes the “horse’s head” mark and the date of recertification on the equipment.

Recertification is required for any new PE installation each time repair work or alterations have been carried out on PE and at each change of owner or operator.

PE types	Frequency of recertification
Diving bottles	2 years
Vessels and piping containing fluoride, boron fluoride, boron trichloride, hydrogen fluoride, hydrogen chloride, hydrogen bromide, nitrogen dioxide, carbonyl chloride, hydrogen sulfide	3 years
Vessels and piping containing a toxic or corrosive fluid, with respect to their walls	6 years
Other vessels, piping and steam generators	10 years

5.2.1 Monitoring without an inspection programme

The maximum time interval between periodic inspections is four years.
In addition, specific frequency intervals apply to certain equipment items:
• 2 years for steam generators and ACAFR;
• 1 year for diving bottles and non-metallic transportable receptacles.

The time interval between recertification procedures varies depending on equipment type (see table above).

5.2.2 Monitoring with an inspection programme

The inspection plan covers one equipment item or several with the same manufacturing characteristics and conditions of use. The plan sets out the minimum monitoring measures to be carried out and consists in:
• a periodic visual check of the safety accessories, pressure accessories and regulation and safety devices.
• periodic inspections and recertification procedures.

The maximum time interval between periodic inspections or after the internal that follows putting equipment into service is set by the operator but cannot be longer than six years.

For piping, this time interval is set by the operator as part of their operating procedures.
The maximum time interval between recertification procedures or after the internal that follows putting equipment into service cannot be more than twelve years. For piping, this is set out in an approved guide.

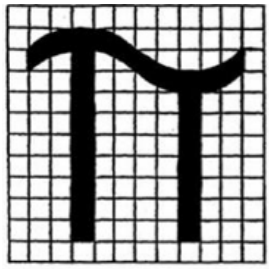
For PE installed in a facility containing a chemical catalyst, the time interval between inspections is extended to 7 and 14 years respectively. This longer time interval also applies to equipment upstream and downstream from the PE.

5.3. THE DIFFERENT TYPES OF MARKING

The "horse's head" mark
A hallmark certifying that the pressure equipment mentioned in the 1823 royal ordinances successfully completed a range of tests. Historically, the hallmark affixed to equipment by the Service des Mines (a ministerial industry department) showed the horse's head turned to the left, whereas it was turned to the right when the Service des Mines delegated this procedure to another organisation.

CE

The CE mark
A mark certifying that the pressure equipment complies with the essential safety requirements applicable in accordance with harmonised European Union legislation. This mark enables the free movement of the equipment throughout the European Union.



Pi mark
Mark showing that the pressure equipment complies with requirements applicable in terms of conformity assessment, as set out in the **decree of 29 May 2009 on the transport of dangerous goods by land** (known as the "arrêté TMD") and in the **decree of 28 June 2011 on transportable pressure equipment.**

6 • RISKS ASSOCIATED WITH USING PE

6.1. RISKS ASSOCIATED WITH PRESSURE

In the event of a containment failure (vessel, piping, bottle, etc.), a shock wave with a sudden and loud popping sound may occur. The blast may propel fragments at very high speed, transforming a flexible hose into a whip and a gas cylinder into a dangerous projectile.

In the event of a gas cylinder falling or colliding into something, the cap or valve can also be projected violently.

Handling a regulator under pressure can also present a risk.

6.2. RISKS SPECIFIC TO EQUIPMENT

Gas pressure equipment
For this equipment, the danger lies in the projection of shards in the event of a vessel failure, a fault in a fragile part and gas leaks, which can lead to poisoning and explosions.

Steam pressure equipment
The main hazards are jets of steam or superheated water in the event of a leak and the projection of shards in the event of a sudden failure of the vessel and/or pipes. Factsheet 3 deals with sterilisation autoclaves in more detail.

Liquid pressure equipment
The main hazards are the jets of contained liquid in the event of a leak and the whiplash of flexible piping in the event of a failure.

Negative pressure (vacuum) equipment
The main hazards here, similar to the previous ones, are generally due to implosion following a collision or a spontaneous implosion because of faulty material (cracked glass for example).

Multi-anvil press

Experimental setups

In this field, the following needs consideration:

- setups usually operating at atmospheric pressure or a pressure at which, given the equipment's characteristics, the risk of explosion is limited, but which can accidentally become over- or under-pressurised,
- equipment used at very high or very low service pressure.

The consequences of an accident are identical for these two setups but specific prevention measures may be required (see **Factsheet 4**).

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Rotary evaporator

6.3. RISKS ASSOCIATED WITH PE

The main associated risks are linked to the use of cryogenic gas and liquids:

- The chemical nature of the product used in the PE first needs to be considered. **Factsheet 5** shows the hazard symbols associated with each of those products.
- In addition, the risks and precautions relating to the use of gas cylinders (transport, handling, putting into service, etc.) are covered in more detail in **Factsheets 6**.

6.3.1 Risks associated with the nature of the gas

- Oxidising gases such as air, oxygen, nitrous oxide, chloride, etc. enable and fuel combustion.
- Combustible gases burn or explode in the presence of an oxidiser: hydrogen, carbon monoxide, acetylene, etc.
- In the event of a leak, neutral or inert gases can lead to asphyxia because of a lack of oxygen (anoxia) (**Figure 2**).
- Toxic gases act as poisons from a certain level of concentration and depending on exposure time. They include sulfur dioxide, arsine, phosphine and hydrogen sulfide.
- Corrosive gases damage various substances such as skin, mucous membranes, clothing, metals. They include sulfur dioxide, hydrogen bromide, hydrogen chloride, hydrogen fluoride and hydrogen iodide.

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High-pressure hydrogenation reactor

Further information on chemical risk is available in a new guide (to be published).

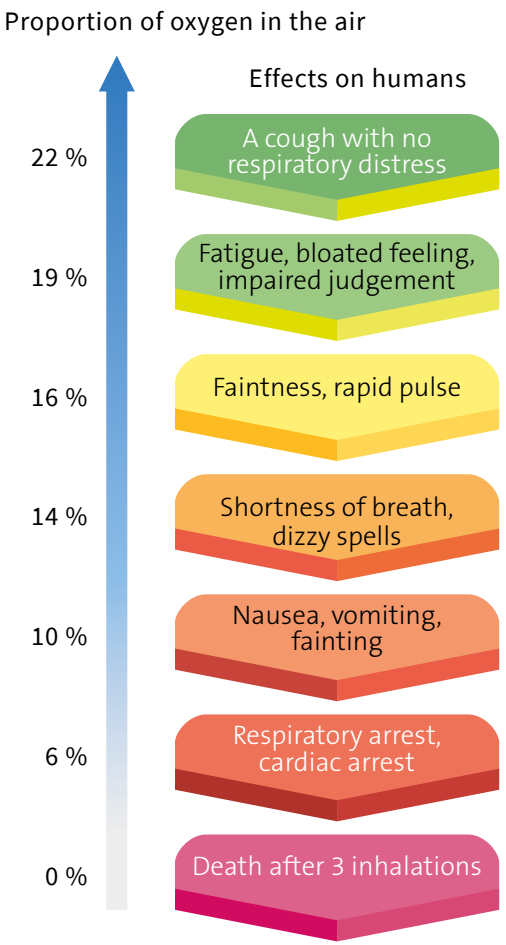


Figure 2 *Oxygen levels in the air and impact on humans*

6.3.2 Risks associated with handling

Gas cylinders are heavy and during transport and handling, they can cause back pain and injury (bruising or fracture) in the event of a fall.

6.3.3 Risks associated with the physical state of the substance (cryogenic liquid or dry ice)

- Skin burns and frost bite due to very low temperatures
- Burns in the upper respiratory tract following inhalation of a cold gas (helium gas at - 40 °C)
- Explosion: increase in pressure due to high liquid/gas expansion (dry ice in a refrigerator, fault in the security valve of a Dewar flask and so on),
- Asphyxia: a decrease in the oxygen level in the atmosphere following a sublimation episode (such as dry ice stored in a cold room) or a cryogenic liquid spill (as an example: a litre of liquid nitrogen generates 650 litres of gas at ambient temperature).
- Fire: higher levels of oxygen around containers of cryogenic liquid as the oxygen in the air condensates into liquid oxygen on the containers' surface.

Cell line samples in liquid nitrogen.

7 • PREVENTION

The preventive measures presented in this section apply to most PE. In addition, for certain setups (sterilisation autoclaves, experimental setups and gas cylinders) specific prevention measures are covered in **Factsheets 3, 4 et 6**.

7.1. INFORMATION AND TRAINING

Staff in charge of this equipment must be informed of the hazards present and of the preventive measures to be followed.

Once they have been trained, staff members recognised as having the required skills and competence level are accredited by the operator (the unit director).

7.2. SAFETY INSTRUCTIONS

PE instruction guides, procedures and instructions for use that incorporate risk prevention and the measures to be taken in case of accident are both mandatory and essential. These documents must be kept updated and known to the users.

7.3. EQUIPMENT PURCHASE

- Before purchasing PE, alternative solutions should be considered: a hydrogen generator instead of hydrogen bottles, membrane pumps instead of vacuum pumps, stainless steel instead of glassware and so on.

- Up until May 2002, the “horse’s head” hallmark or the CE mark both guaranteed the conformity of the device. Only the CE mark now guarantees conformity.

- The manufacturer must supply the purchaser with a declaration of conformity written in French, issued by a notified body from the European Union. The CE mark must be affixed to the equipment.

- Equipment choice must match needs, like the size of cylinders for instance.

- Only equipment guaranteed by the manufacturer must be used, as is the case for pressure gauges and connectors.

- Any modification must be carried out by the manufacturer and is subject to inspections by an accredited body.

7.4. INSTALLATION

This must take into account:
- the properties of the products used (flammability, corrosion, toxicity, etc.)
- the nature of the reaction (for example, exothermal)
- the conditions of use (volume, pressure and temperature).

If any gas is used, there must be appropriate ventilation.

In the case of gas cylinders, and where the layout of the premises permits, it is preferable to have a specific storage area outside the building. For gases that cannot withstand cold temperatures (which is the case for ethylene, with a critical point of 9 °C and 50 bar), a security cupboard needs to be installed in the laboratory.

7.5. USE

- PE must always be used in the conditions (temperature, pressure and nature of the fluid) set out during the design stage and detailed in the instructions provided for the operator.

- PE which has undergone substantial modification (equipment performance, purpose or original type) must always be subject to a renewed assessment of conformity.

- PE which has undergone non-notable repair or modification must always be subject to an inspection by an accredited body.

- Only qualified and trained people must use this type of equipment.

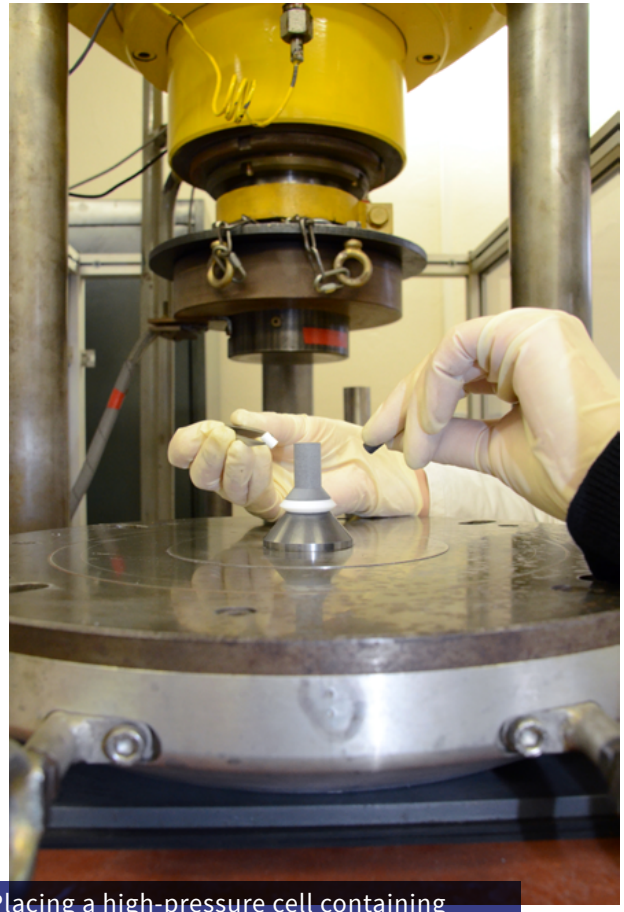
- People authorised to handle and use PE must be clearly identified in the unit. Their name must be posted close to the equipment.

- Before use, a visual inspection must be carried out systematically, to detect any corrosion, overheating or leak.

- When using PE, protective equipment needs to be implemented, depending on the nature of the risk:
- collective protective equipment (CPE): toxic gas detectors, ventilation, gas cylinders secured, cylinder trolley, choker cables, protection screen, metal mesh screens, etc.,
- personal protective equipment (PPE): mask or respirator, safety shoes and gloves (especially when transporting and handling gas cylinders), portable gas detector, safety glasses, etc.

- Inspection and repair dates and reports must be recorded in the safety register.

- If equipment has not been used for a long time and the operator has not taken the measures required to ensure its proper functioning, inspection – and possibly recertification – is required for putting the equipment back into service if the time interval between two periodic inspections has expired.



Placing a high-pressure cell containing a sample into a Paris-Edinburgh press.

8 • WHAT TO DO IN THE EVENT OF AN ACCIDENT

The hierarchy of actions to be taken in the event of an accident must be determined on a case-by-case basis, depending on the specific risks of the work situation and on whether there are any victims.

8.1. FAILURE OF A HIGH OR LOW PRESSURE VESSEL – PRESSURE VESSEL BLAST

This type of explosion can generate considerable damage due to the ensuing shockwave (blast effect) and to dangerous substances being released.

Victims can sustain a number of injuries (to ears, the digestive system and so on). You should call emergency services quickly (first aiders, firefighters, ambulance crew) and know what is to be done (**Factsheet 7**).

In addition, if the escaped substances are toxic:
- protect yourself before taking action (wear a self-contained breathing apparatus or mask, gloves, etc.),
- evacuate the area affected,
- call emergency services.

If necessary, have the premises decontaminated by a specialist company before they are used again.

8.2. GAS LEAK OR CRYOGENIC LIQUID SPILL

Use appropriate personal protective equipment (self-contained breathing apparatus, gloves, etc.) depending on whether the escaped substance is toxic (e.g. CO), corrosive, (e.g. NH3) or neutral (e.g. NH2).

If the gas is flammable (e.g.C2H2) or oxidising (e.g. O2), remove any risk of sparks, by cutting off electrical supply especially.

If a leak has occurred inside a building, open windows to renew air where possible (except for very toxic gases) and prevent access to the premises. If the risk is major, have the area evacuated and establish a security perimeter.

Stop the leak by closing the valve and wear appropriate PPE, such as a self-contained breathing apparatus. If that cannot be done and the situation is dangerous, call emergency services (firefighters) and the manufacturer to have the cylinder removed. **Never take any action while holding your breath.**

If there are any victims, quickly call emergency services (first aiders, firefighters, ambulance crew).

Placing a high-pressure cell containing a sample into a Paris-Edinburgh press.

APPENDIX 1

LEGISLATION/DOCUMENTATION

Legal instruments

- **Directive 2014/29/EU of the European Parliament and of the Council of 26 February 2014** on the harmonisation of the laws of the Member States on the making available on the market of simple pressure vessels.
- **Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014** on the harmonisation of the laws of the Member States on the making available on the market of pressure equipment.
- **Decree 2015-799 of 1 July 2015 on hazardous products and equipment.**
- **Decree N° 2016-1925 of 28 December 2016 on the in-service monitoring of pressure vessels.**
- **Order of 23 July 1943 on the legislation of equipment for the production, storage or use of gases** (in force up to 31 December 2019).
- **Order of 29 May 2009 on the transport of dangerous goods by land** (known as the "arrêté TMD").
- **Order of 25 June amending the decree of 3 May 2015 on the use of transportable pressure vessels.**
- **Order of 13 January 2015 creating an online service for the purpose of declaring the putting of pressure equipment into service,** the "Déclaration de mise en service".
- **Order of 20 November 2018 on the monitoring of pressure equipment and of simple pressure vessels.**
- **Decision BSERR 2019-056 of 24 May 2019 on the recognition of the professional guide** for the preparation of professional guides and technical notes for the preparation of in-service inspection programs for pressure equipment and simple pressure vessels.
- **Environmental Code: Book V – Title V – Chapter VII -** Articles L.557-1 to L.557-61.
- **NF-EN 1089 standard – Transportable gas cylinders Gas cylinder identification** (except GPL) – Part 3: colour code (mandatory application).

Documentation

- Brochure " **Les bouteilles de gaz - identification, prévention lors du stockage et de l'utilisation** " ("Gas cylinders – identification and prevention during storage and use", only available in French), ED 6369, INRS.
- Safety factsheet " **Codage couleur de tuyauteries rigides** " (Colour codes for rigid piping, only available in French), ED88, INRS.
- Gas Encyclopedia, Air liquide : **https://encyclopedia.airliquide.com/**

APPENDIX 2

PRESSURE EQUIPMENT DEFINITIONS ACCORDING TO LEGISLATION

Assembly
Several items of pressure equipment assembled by a manufacturer to constitute an integrated and functional whole.

Date of putting into service
Date of first use of the equipment or of the assembly by the user, certified by the operator, or by default the date of the final assessment.

Device with quick-closing movable lid
Any steam generator or vessel with at least one movable lid, bottom or door where closing and opening is centrally controlled, except in the case of an autoclave-type closing device.

Fixed vessel
A vessel that is not moved in normal use. However, vessels used in a place other than the place where they are filled are considered mobile.

Fluids
Gases, liquids and vapours in pure phase as well as mixtures of the latter; fluids may contain a suspension of solids.

Gas
Gas, liquefied gas, gas dissolved under pressure, vapour, including steam and superheated water, as well as any liquid whose vapour pressure, at the maximum allowable temperature, exceeds normal atmospheric pressure (1,013 bar) by more than 0.5 bar.

Inspection
An operation within the meaning of Article L557-28 of the Environmental Code or specific technique used to evaluate the state of an item of equipment.

Internal or external inspection
Detailed visual check, with potentially additional simple, non-destructive tests, such as thickness measurements, so that the areas impacted by visible damage are not likely to compromise the robustness of the equipment.

Maximum service pressure (PS)
Maximum pressure to be exerted in the normal operating conditions of the vessel.

Maximum/Minimum allowable temperature (TS_{min}, TS_{max})
The maximum/minimum temperatures for which the equipment is designed, as specified by the manufacturer.

Modification
Any change brought to the equipment or any change to their conditions of use when the latter do not fall within the limits set by the manufacturer.

Movable elements
Easily movable parts which incur no damage when dismantled.

Newly-submitted equipment
Pressure equipment manufactured before 29 May 2002, whose characteristics in terms of maximum allowable pressure (PS) volume or nominal dimension (DN) meant that they were not subject to current provisions on construction and in-service monitoring at the time.

APPENDIX 2 • PRESSURE EQUIPMENT DEFINITIONS ACCORDING TO LEGISLATION

Nominal dimension
A numerical designation of size, designated by DN, which is common to all components in a piping system other than components indicated by outside diameters or by thread size; it is a convenient round number for reference purposes and is only loosely related to manufacturing dimensions.

Operator
The owner of the equipment or their authorised representative.

Periodic inspection
An inspection operation intended to verify that the state of the equipment is such that it may be maintained in service with a level of safety compatible with foreseeable operating conditions and which comprises an external inspection, an internal inspection where applicable, an examination of the safety accessories and additional checks as required.

Periodic recertification
An inspection operation intended to show that a piece of equipment may be used safely, taking into account foreseeable deterioration until the next deadline for an inspection operation or until the next stoppage, provided that the equipment is used in accordance with the instructions for use or, by default, the operation file; in the event of in-service monitoring with an inspection plan, periodic recertification makes it possible to ensure that the inspection operations provided for in the inspection plan are implemented. It notably includes analysis of the results of all checks and inspections performed since the previous periodic recertification or, by default, since the inspections performed when the new equipment was put into service, or after any substantial modification.

Permanent joints
Joints which cannot be disconnected except by destructive methods.

Piping
Piping components intended for the transport of fluids, when connected together for integration into a pressure system; piping includes in particular a pipe or system of pipes, tubing, fittings, expansion joints, hoses, or other pressure-bearing components as appropriate; heat exchangers consisting of pipes for the purpose of cooling or heating is considered as piping.

Pressure
Pressure relative to atmospheric pressure, vacuum being designated by a negative value.

Pressure accessories
Devices with an operational function and having pressure-bearing housings.

Pressure equipment
Vessels, piping, safety accessories and pressure accessories (including, where applicable, elements attached to pressurised parts, such as flanges, couplings, connectors, frames and lifting lugs) whose maximum allowable pressure (PS) is greater than 0.5bar.

Putting into service
First use of pressure equipment or an assembly by its user.

APPENDIX 2 • PRESSURE EQUIPMENT DEFINITIONS ACCORDING TO LEGISLATION

Safety accessories
Devices designed to protect pressure equipment against the allowable limits being exceeded, including devices for direct pressure limitation, such as safety valves, bursting disc safety devices, buckling rods, controlled safety pressure release systems, and limiting devices, which either activate the means for correction, shutdown and lockout, such as pressure switches or temperature switches or fluid level switches and safety related measurement control and regulation devices.

Simple pressure vessels
Vessels with all the following characteristics:

1° the vessels are welded, intended to be subjected to an internal pressure greater than 0.5 bar and to contain air or nitrogen, and are not intended to be fired.
2° the parts and assemblies contributing to the strength of the vessel under pressure are made either of non-alloy quality steel or of non-alloy aluminium or non-age hardening aluminium alloys.
3° The vessels are made of either one of the following elements:
a) a cylindrical part of circular cross-section closed by outwardly dished or flat ends. These ends revolve around the same axis as the cylindrical part.
b) two dished ends revolving around the same axis.
4° The maximum service pressure of the vessel does not exceed 30 bar . L and the product of that pressure and the capacity of the vessel (PS × V) does not exceed 10,000 bar . L.
5° The minimum operating temperature is no lower than –50 °C and the maximum operating temperature is not higher than +300 °C for steel and +100 °C for aluminium or aluminium alloy vessels.

Steam generator
Any pressure equipment, assembly of pressure equipment or assembly in which a fluid receives thermal energy, where the energy is used externally and the fluid may also be used, and when the maximum allowable temperature is higher than 110 °C.
In the meaning of the present definition, the following are considered as fluids:
• steam
• hot water
• any heat transfer fluid with a boiling temperature of less than 40 °C under normal atmospheric pressure and whose effective pressure of the steam produced or liable to be produced can exceed one bar when its maximum allowable temperature exceeds 120 °C.
• any mixture of steam or overheated water with another fluid under pressure.
The following is also considered as a steam generator: any pressure equipment, assembly of pressure equipment or assembly containing one or several closed vessels, in which water is heated to a temperature higher than 110°C without the fluid being used externally. By exception, a pressure equipment item, an assembly of pressure equipment or a closed-vessel assembly is not considered as a steam generator if the energy it receives is directly or indirectly conveyed to it by a fluid that itself comes from a steam generator.

Stoppage
A period during which an equipment item or installation is not used but is stored in such a way as to maintain its proper operating function.

Stripping
Removal of thermal and acoustic insulation mechanisms that does not afford access to the walls of the equipment.

Technical specifications
A document that prescribes technical requirements to be fulfilled by pressure equipment or an assembly.

Vessel
A housing designed and built to contain fluids under pressure including its direct attachments up to the coupling point connecting it to other equipment; a vessel may be composed of more than one chamber.

Visual inspection
Visual inspection, with no dismantling or testing, with a view to detect visible damage or significant errors that might compromise safety.

Work
Any equipment repair or modification

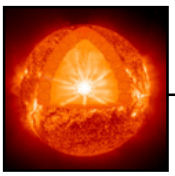
Volume (V)
Internal volume of each chamber, including the volume of couplings to the first connection and excluding the volume of permanent internal parts.

APPENDIX 3

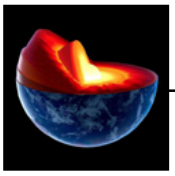
GLOSSARY

ACAFR	device with quick-closing movable lid
ADR	agreement concerning the international carriage of dangerous goods by road
ATEX	explosive atmosphere
DN	nominal size, a rounded number only loosely related to the manufacturing dimensions of piping (DN followed by a number)
DREAL	regional agencies for the environment planning and housing
DRIEE	regional interdepartmental agencies for the environment and energy
EC	European Community
PE	pressure equipment
PED	pressure equipment directive
PPE	personal protective equipment
PS	service pressure or maximum allowable pressure
SAMU	French ambulance service
SG	steam generator
TS_{min}/ TS_{max}	maximum/minimum allowable temperature
TDG	transport of dangerous goods
V	internal volume

FACTSHEET 1 • EXAMPLES OF PRESSURE LEVELS (SCALE)

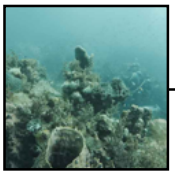


35 PPa ($3.5.10^{11}$ bars)
Solar core



380 GPa ($3.8.10^{6}$ bars)
Earth's core

10 GPa (10^{5} bars)
Diamond formation



100 MPa (1,000 bars)
Mariana Trench, 10 km from the surface

20 MPa (200 bars)
Gas cylinder

2 MPa (20 bars)
Steam engine boiler

800 kPa (8 bars)
Champagne bottle

250 kPa (2.5 bars)
Car tyre

101 325 Pa (1.01325 bar)
Atmospheric pressure

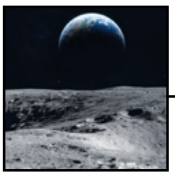
100 000 Pascal = 1 bar

31 430 Pa (0.3 bar)
Everest summit

10 Pa (10^{-4} bar)
Filament bulb

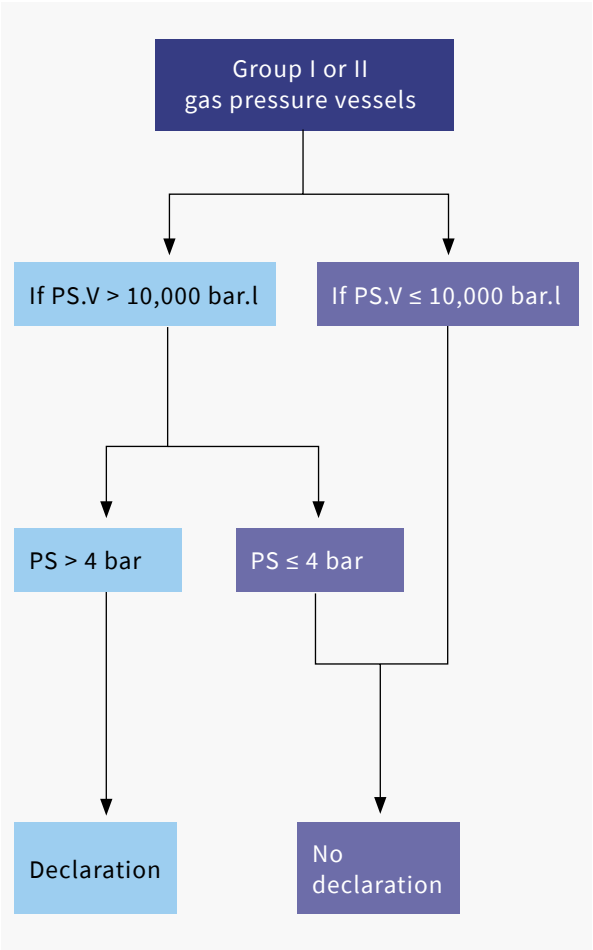
2 Pa (2.10^{-6} bar)
Atmospheric pressure on Pluto

20 µPa (2.10^{-10} bar)
Threshold of human hearing

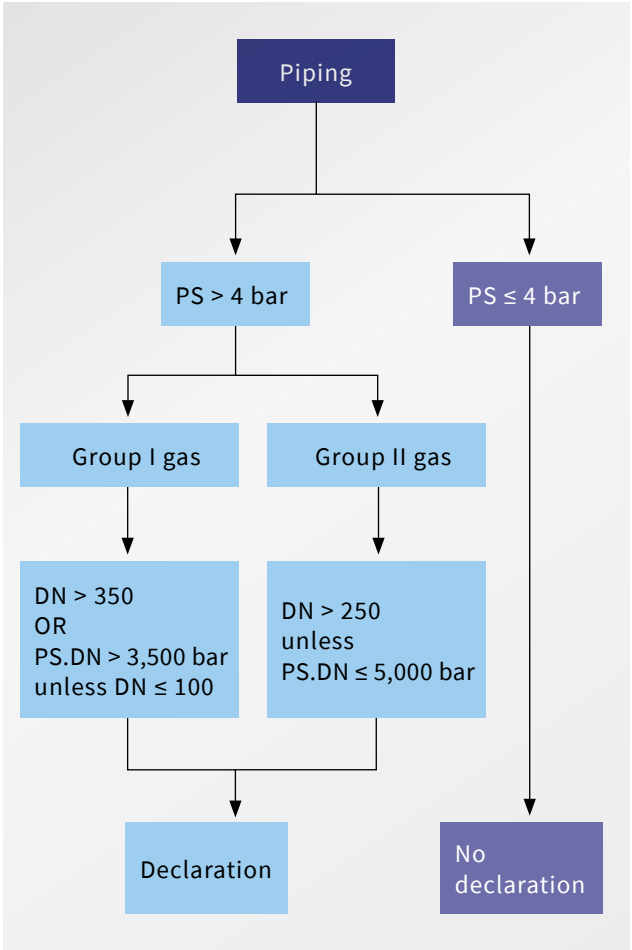


1 nPa (10^{-14} bar)
Atmospheric pressure on the moon

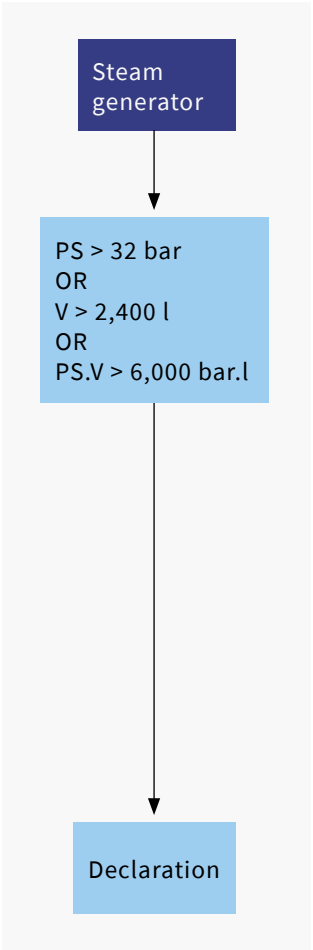
1 fPa (10^{-20} bar)
Pressure in interstellar space



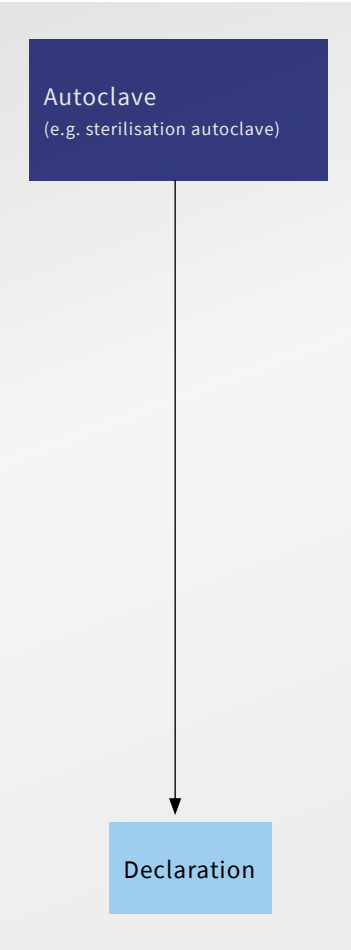
a. Gas pressure vessels



b. Piping



c. Steam generator



d. Autoclaves

FACTSHEET 3 • STERILISATION AUTOCLAVES

Hazards
The main hazards derive from steam or superheated water jets or from shard projection in the event of vessel or piping failure (especially if the lid was not shut completely or locked, or during opening at the end of an operating cycle when residual steam pressure was left in the device).
The energy stored in the vessel escapes suddenly and can lead to serious injury to any person close by, as well as damage to equipment.

Duties of the unit director
- when purchasing equipment, check conformity: CE mark and test certificate issued by the manufacturer, as well as the user guide,
- declare the purchase to the DREAL (outside the Île-de-France region)/DRIEE (Île-de-France region) via the LUNE application for the declaration of putting equipment into service.

> Click here for the LUNE application

- ensure that the unit has the following documents: user guide, declaration to the DREAL/DRIEE, safety register with reports of recertification and visits (for maintenance and inspection) describing incidents relating to the use of the equipment,
- ensure that staff are trained and provide them with the requisite authorisation,
- have the various regulatory inspections carried out, including the putting into service inspection,
- ensure all mechanical, electrical and pneumatic parts are cleaned meticulously.

Installation
Because autoclaves are a source of noise and heat, they should not be located close to a fixed workstation.
There must be effective manual or mechanical ventilation.


© Adobe stock

Risk prevention
- any person liable to use this equipment must be trained on how to operate an autoclave, after which the unit director can accredit them.
- a refresher course every three years is recommended,
- instructions for use (see next page) and the list of accredited persons are posted close to the equipment,
- heat-resistant gloves are available.

Periodic inspections

Periodic inspections are carried out by an accredited body.

• Inspection

A first inspection can take place at the same time as putting into service. It must take place at the latest one month after the equipment has been put into service and then:

- if there is no inspection programme, an inspection must take place every 2 years,
- if there is an inspection programme, inspections take place at the discretion of the operator (unit director) with a time interval not exceeding six years.

• Periodic recertification

- if there is no inspection programme: every 10 years*
- if there is an inspection programme: the maximum time interval between recertification procedures of putting equipment into service not exceeding 12 years.

General instructions for use **These instructions must be adapted to each equipment type, by referring to the manufacturer's guide.**

CLOSING THE DEVICE

In case of a device with manual operation

- check the state of the joint and shut the door; if necessary, check the water level,
- check that the door is properly secured,
- check that the vent valve is fully open,
- let the steam into the device; as soon as it flows into the vent valve, shut the latter,
- check that the device is under pressure (pressure gauge or recording pressure gauge).

In the case of a device with an automatic cycle

- check the state of the joint and shut the door. If necessary, check the water level.
- check that the door is properly secured,
- start the sterilisation program, following the manufacturer's instructions
- check that the device is under pressure (pressure gauge or recording pressure gauge).

OPENING THE DEVICE

In case of a device with manual operation

- close the steam supply,
- open the outlet valve (decompression)
- check the absence of pressure on the gauge pressure dial,
- open the aperture indicator valve: ensure that no pressure remains in the device and that no steam is escaping via the outlet,
- unlock and open the door.

In the case of a device with automatic operation

- refer to the manufacturer's guide.

RECOMMENDATIONS

- if liquids have been sterilised, wait at least half an hour before opening,
- if superheating occurs because of a lack of water, the safety thermostat stops the supply of electricity. In that case, switch the device off and let it cool.

* The time interval is reduced to 3 or 6 years depending on the nature of the fluid contained (see the **table in section 5.2.1**).

FACTSHEET 4 • EXPERIMENTAL SETUP

The principles set out in this factsheet apply to the installation of devices and reactors with continuous or discontinuous operation for which:
• the properties of the products used (flammability, toxicity, corrosion, etc.)
• the nature of the reaction (for example, exothermal)
• experiment conditions (temperature, pressure, etc.)
require risk analysis at the design stage and before being put into service.

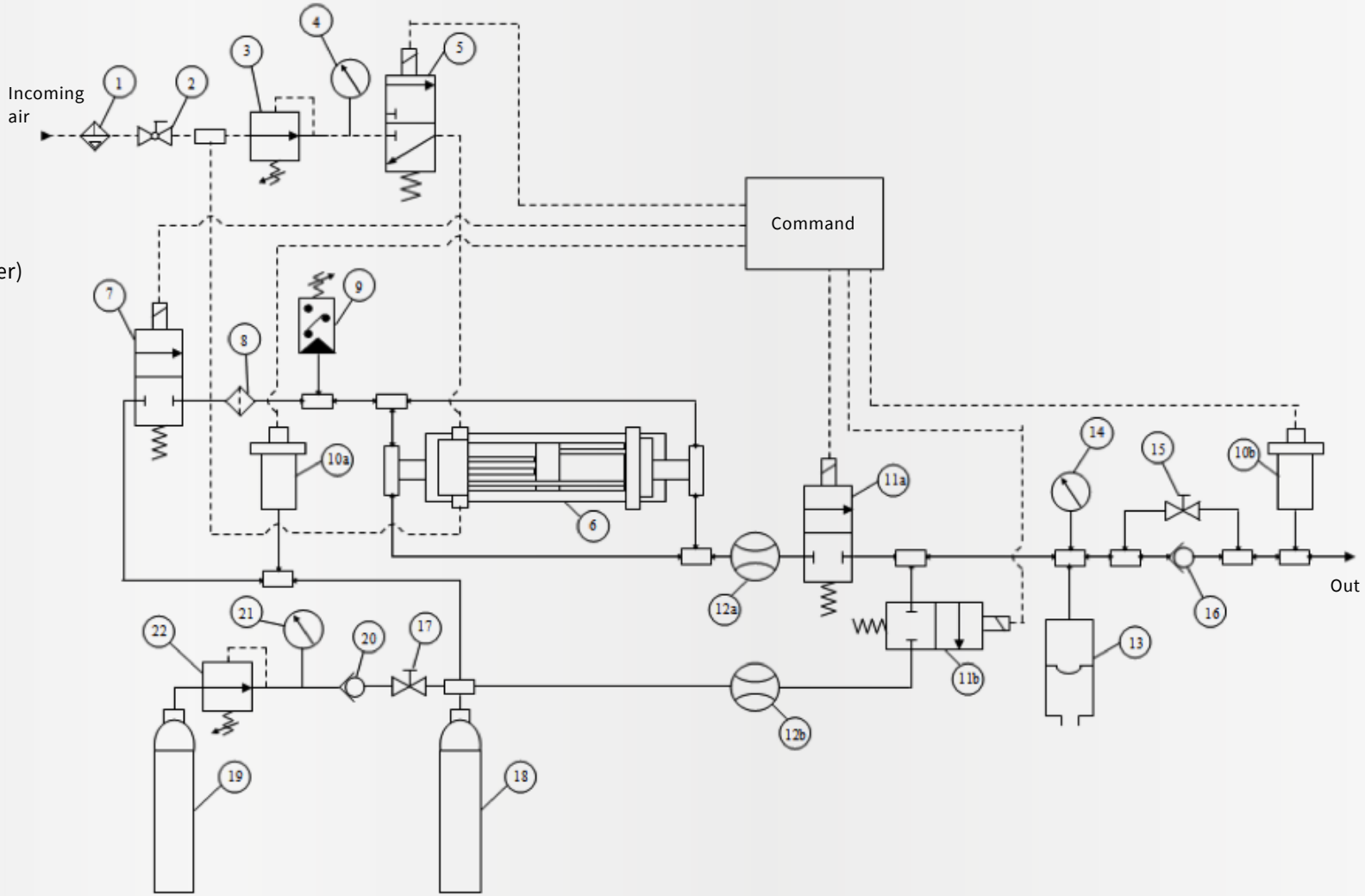
Installation
Depending on its characteristics (volume, pressure, nature of fluids), equipment must be installed in an isolated site or in a laboratory with adequate “rhinoband”-type protection (see photo at the end of this factsheet)

Equipment
This must be fitted with protection systems to guard against the risk of overpressure (valves, bursting discs, pressure release, etc.). Depressurised fluids must discharge into an open conduit, in an isolated zone. Additional precautions (containment) must be taken in the case of dangerous gases.
Pressure release and rapid evacuation controls must be placed outside the protective enclosure, in a protected zone with permanent access. Equipment must be earthed.

Example : Overpressure group at 200 bar
(See figure of a typical experimental set up next page).

Figure of a typical experimental setup

① oil bath filter
② plug cock valve
③ regulator
④ pressure gauge
⑤ 3/2 distributor
⑥ booster pump (pressure exchanger)
⑦ 2/2 distributor
⑧ filter
⑨ pressure switch
⑩ sensor
⑪ 2/2 distributor
⑫ flow meter
⑬ bursting disc
⑭ regulator
⑮ throttle valve
⑯ check valve
⑰ valve
⑱ tank
⑲ gas cylinder
⑳ check valve
㉑ pressure gauge
㉒ pressure reducer



FACTSHEET 4 • EXPERIMENTAL SETUP

Use

All precautions must be taken and the necessary instructions provided to ensure that equipment use, maintenance and monitoring are adequate (periodic use and corrosion inspections for example).
Operations must be carried out remotely. In case of manual operation, this should be designed so as to avoid any projections towards the operator in case of accident.

Dismantling

- depressurise the assembly in a ventilated enclosure (fume hood, filterless hood) or using a vent pipe,
- dismantling should be easy, any resistance should raise concern,
- never tighten nor loosen a connector under pressure.

RECOMMENDATIONS

CYLINDERS
- always secure them (with straps or chains)
- use the appropriate connector (refer to the supplier) and check it is airtight

PIPES AND HOSES
- they are selected according to use pressure (refer to the supplier): for a given width, pressure is divided by two when diameter is multiplied by two;
- they are chained to a fixed point;
- it is essential to use a pipe-bending machine to form them and the bending radius depends on the diameter (bending radius >/ diameter x 5);
- bending them using a vice then heating them is prohibited.

VALVES AND PRESSURE GAUGES
- they are selected according to use pressure:
  - valve: service pressure +10%
  - pressure reducing gauge for filling an autoclave: maximum use pressure
- pipes are fixed onto a frame to avoid any risk of torsion,
- for very high pressure assemblies (several GPa), static pressure must always be under the needle valve, to avoid joint fatigue (Figure 3).

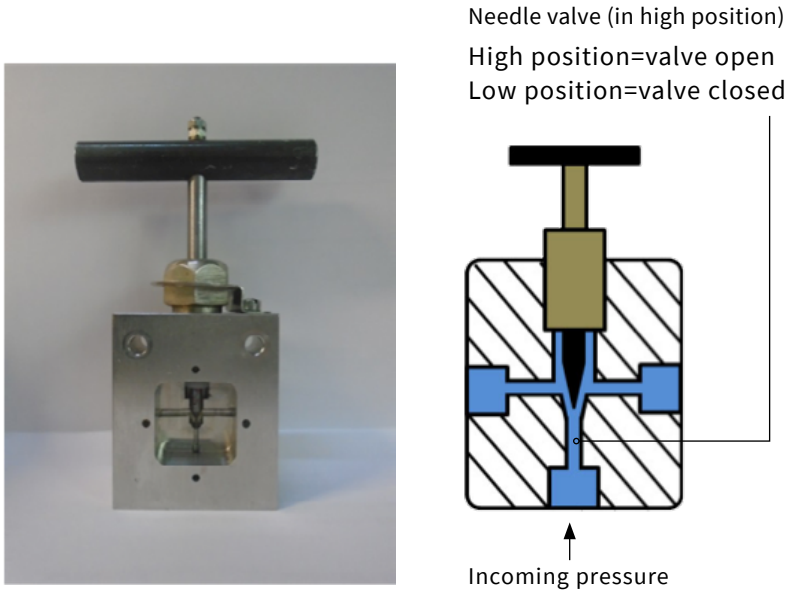


Figure 3 *Cross-section and figure of a valve*

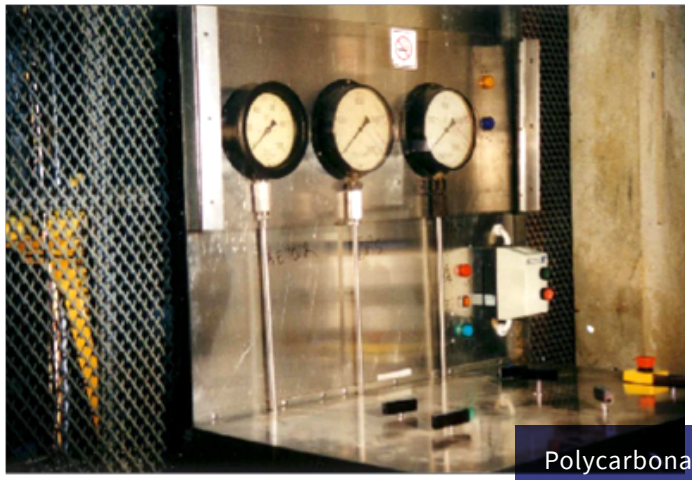
Collective protection
- Install appropriate “rhinoband”-type meshing; selecting the mesh, and manufacturing and assembling the meshing must be carried out by specialists,
- place polycarbonate (Lexan®, Makrolon®, Tuffak®) in front of pressure gauges fixed on a pressure vessel,
- leave space behind the pressure gauges (vent),
- pressure generators must be controlled by temperature,
- appropriate detectors should be available (temperature, gas, etc.)
- use valves and bursting discs appropriate for the service pressure and the physical-chemical properties of the gas used.

Discs have a bursting value of ± 10% of nominal value,
- never place valves and bursting discs at head height and direct them instead towards a vent.

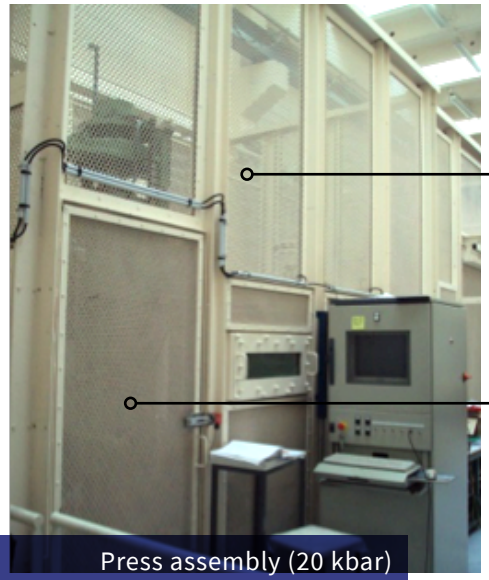
Priority must be given to bursting discs because in the event of overpressure, bursting causes the experiment to stop, prompting the investigator to find the reason for the problem.
In addition, certain fluids (CO_2, N_2O, etc.) may not be used, because they might freeze in the event of sudden pressure release.

Personal protection
- use polycarbonate face shields.

Instructions
- display instructions at the entrance of experiment rooms,
- do not leave the experiment unattended.

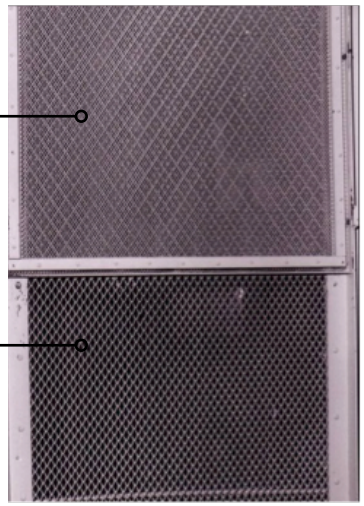


Polycarbonate protection



Press assembly (20 kbar) protected by rhinoband

Rhinoband - large mesh size



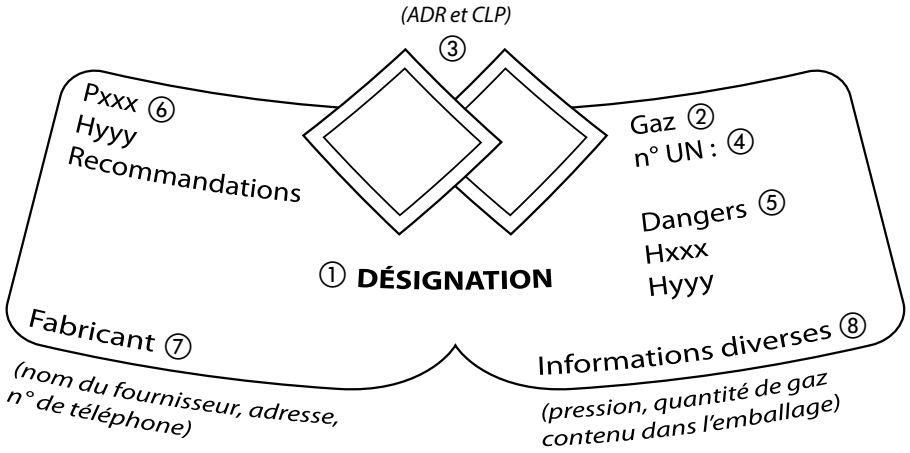
Rhinoband - small mesh size

FACTSHEET 5 • HAZARD SYMBOLS

	Oxidising gases, cat.1 Oxidising liquids, cat. 1, 2, 3 Oxidising solids, cat 1, 2, 3
	Flammable gases, cat. 1 Flammable aerosols, cat. 1, 2 Flammable liquids, cat. 1, 2, 3 Flammable solids, cat. 1, 2 Self-reactive substances and mixtures, type B, C, D, E, F Pyrophoric liquids, cat. 1 Pyrophoric solids, cat. 1 Self-heating substances and mixtures, cat. 1, 2 Substances and mixtures which, in contact with water, emit flammable gases, cat.1, 2, 3 Organic peroxides, type B, C, D, E, F
	Acute toxicity (via ingestion, skin contact or inhalation), cat. 1, 2, 3
	Compressed gases Liquefied gases Refrigerated liquid gases Dissolved gases
	Corrosive to metals, cat. 1 Skin corrosion, cat. 1A, 1B, 1C Serious eye damage, cat. 1
	Risk of asphyxia
	Contains cryogenic fluid

Labels
They are affixed on each cylinder and provide all the necessary information on the gas contained:

① Name of gas
② Nature and chemical composition
③ Hazard symbol(s)
④ UN transport code
⑤ Danger and warning signal words (H XXXX)
⑥ Precautionary statements (P XXX)
⑦ Supplier name and address 8 Miscellaneous information
⑧ Miscellaneous information



Examples of labels affixed to an argon gas cylinder and to a hydrogen gas cylinder

FACTSHEET 6.1 • GAS CYLINDERS – IDENTIFICATION

Gas cylinder shoulder colour code

Provisions of the NF-EN 1089-3 standard:
This standard sets out the colour code for gas cylinders. The general rule is one colour per hazard.

The code is linked to the physical-chemical and toxicological properties of the gas. There are four major hazards:

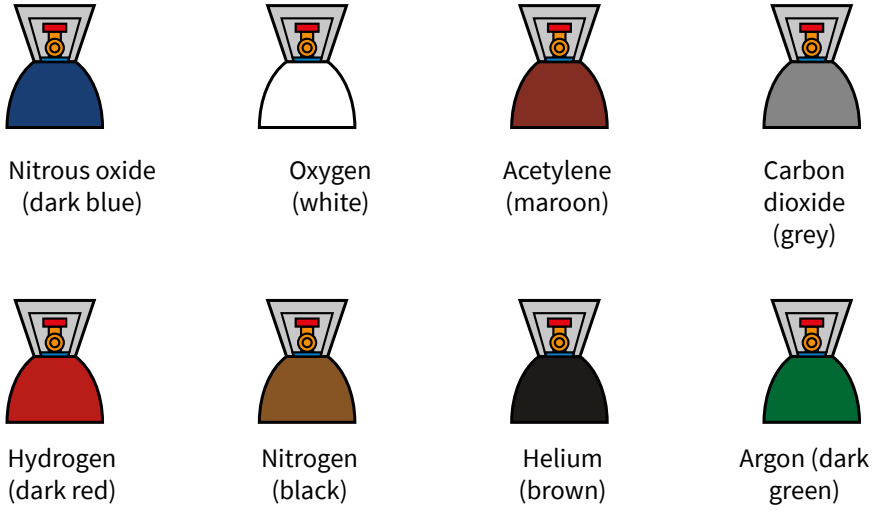
YELLOW	toxic
RED	flammable
LIGHT BLUE	oxidising
BRIGHT GREEN	inert

If a gas or gas mixture present several hazards, the colour of the cylinder shoulder is in accordance with the primary, most important hazard.

PLEASE NOTE

When the NF-EN1089-3 standard came into force, the gas and gas mixture cylinders whose shoulder colour identification changed, compared to the old standard, had to be marked with two diametrically opposed “Ns”. Since then, these cylinders have had a five-year or ten-year check and they have been repainted in accordance with the standard. It is therefore no longer necessary to mark them with N.

In addition, a specific colour has been attributed to certain gases in special cases:



Nitrous oxide (dark blue) | Oxygen (white) | Acetylene (maroon) | Carbon dioxide (grey)

Hydrogen (dark red) | Nitrogen (black) | Helium (brown) | Argon (dark green)

General points
- Close the valves, even if the cylinders are empty.
- Do not drop cylinders heavily on the floor.
- Cylinders must always have their safety cap (tulip) screwed on.
- Never transport cylinders with their accessories attached (pressure gauge, torch, etc.): take them apart after closing the cylinders.
- Do not smoke.
- Avoid any sparks.
- Wear personal protective equipment: goggles, gloves, safety shoes.

Manual transport
- Do not drag or lift large cylinders by their cap.
- Only pivot cylinders on a smooth surface and over a short distance, otherwise use an appropriate cylinder trolley.

Transport in a vehicle

Regulations on the transport of dangerous goods by road, known as ADR (European Agreement concerning the International Carriage of Dangerous Goods by Road) apply to all industrial gases.

The obligations set out in the ADR may be limited in certain conditions (nature of the gas and volume to be transported).

Volume of gas transportable with restricted obligations[1]

These depend on the types of gas being transported. They break down in three transport categories:
- Category 1: toxic gases (T, TC, TF, TOC, TFC), except anhydrous ammonia (UN1005) and chlorine (UN1017) whose overall maximum weight by transport unit is 50 kg.
- Category 2: flammable gases (F)
- Category 3: asphyxiating (A) and oxidising (O) gases

Symbols	
T	Toxic
C	Corrosive
F	Flammable
O	Oxidising
A	Asphyxiating

If gas cylinders transported in the transport unit belong to the same category, to keep within regulatory thresholds, the total quantity of cylinders by transport unit is the following:
- Category 1: 20
- Category 2: 333
- Category 3: 1,000

given that "maximum quantity by transport unit" means:
- for liquefied, refrigerated and dissolved gases, the net mass in kilogrammes;
- for compressed gases, the nominal capacity[2] of the vessel in litres.

EXAMPLES
- Propane, butane (F, liquefied gas), Acetylene (F, dissolved gas): 333 kilogrammes
- Hydrogen (F, compressed gas): 333 litres
- Argon, nitrogen, oxygen, helium (A or O, compressed gas): 1,000 litres

[1] In accordance with article 1.1.3.6 of the ADR.

[2] "Nominal capacity of the container": nominal volume, expressed in litres, of the dangerous substance contained in the vessel. For compressed gas cylinders, the nominal capacity is the water volume of the cylinder.

FACTSHEET 6.2 • GAS CYLINDERS – TRANSPORT

If gas cylinders transported in the transport unit belong to several categories, the sum of the quantity of matter (Q), calculated with the following formula, must not exceed 1,000:

[(Q Category 1) . 50] + [(Q UN1005 and UN1017) . 20] + [Q Category 2) . 3] + [Q Category 3] < 1,000

The ADR considers that an empty container is as dangerous as a full one.

IMPORTANT

Transport by a tank truck company should always be preferred, especially in the case of toxic gases.

Vehicle features
- appropriate system for securing cylinders,
- vehicle is open, covered by a tarpaulin or equipped with permanent ventilation,
- airproof separation between driver and cylinders, with natural or forced ventilation essential,
- powder extinguisher with a minimum capacity of 2 kilogrammes,
- anti-explosion lamp.

Staff training
The people tasked with this type of transport must be trained to meet the requirements set out by the ADR[3].

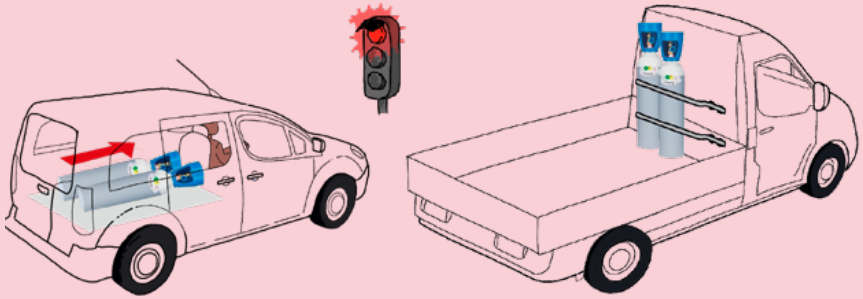
Recommendations
- Check the cylinders before loading.
- Secure the cylinders so that they cannot roll off or fall from the vehicle.

BEWARE of collisions

In the event of a forward collision or the vehicle rolling, a cylinder may become a dangerous projectile, even if it has been laid down in the back of a vehicle.

Action to be taken

Secure cylinders solidly.



- Store cylinders vertically.
- Separate empty from full cylinders and oxygen from flammable gases.
- Balance the load.
- Do not leave the cylinders in a vehicle without a valid reason.
- Protect cylinders from strong sunlight.
- In the event of a leak, park the vehicle, close the valves and alert the supplier.
- In the event of fire, do not draw near, do not let bystanders near and alert or have someone alert emergency services.

[3] In accordance with article 1.3 of the ADR.

Storage premises (design and management)

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- Ideally, the storage area should be outdoors to enable permanent natural ventilation. Otherwise, equip premises with mechanical ventilation.
- Secure access.
- Ensure easy access and that the floor is in a perfect state.
- Maintain a temperature that is compatible with the nature of the gas stored. The installation of an awning is recommended to protect against sunlight and precipitations.
- Mark out the storage area depending on the hazard.
- Display instructions with the detailed measures to be taken in the event of an accident.
- If storing flammable gas, follow mandatory rules on explosive atmospheres (ATEX).
- If necessary and especially if the storage area is not outdoors, equip premises with ventilated enclosures for toxic and corrosive gases.
- Limit the quantity of gas stored. Rental agreements provide better management of gas cylinders in terms of safety and cost.

The specific case of hydrogen: where possible, prefer the use of a hydrogen generator to gas cylinders.

- Sort gas cylinders by hazard group.
- Do not store unused cylinders in labs, workshops and so on.

Handling

- Use an appropriate cylinder trolley.
- Secure cylinders to a fixed point, at two thirds of their height, using a chain.
- Do not use a lift or goods lift at the same as cylinders.
- Wear appropriate personal protective equipment (such as safety shoes and handling gloves).
- Never move a cylinder without its safety cap (tulip or valve protection cap)
- Never try to catch a falling cylinder.
- Bend your legs and keep your back straight when lifting a cylinder.

Tulip cap

Valve protection cap

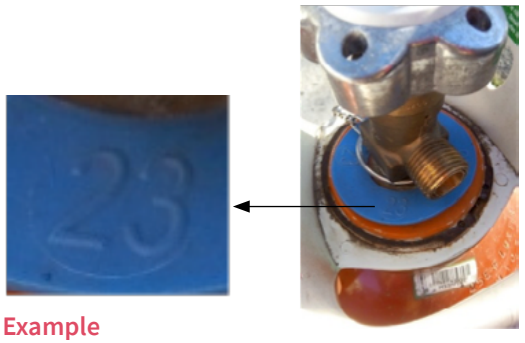
FACTSHEET 6.3 • GAS CYLINDERS – PRECAUTIONS FOR USE

Installation and use

- Prefer having gas distributed by gas plants outside the site.
- Constantly ventilate premises that contain gas cylinders (opening doors and windows does not constitute ventilation).
- Adapt quantities used (in cylinder capacity and number) to the needs of the experiment.
- Keep a storage register of gas cylinders and their recertification date.
- Prefer connectors to rigid piping. If flexible piping is used, fix it to a pipe hanger (whatever the use pressure of the gas).
- Identify rigid piping according to the gas cylinder colour code and name where possible.
- Use appropriate connectors, valves and regulators.
- Never lubricate valves.
- Operate a valve by hand, without forcing it.
- Open valves slowly.
- Never put a makeshift valve together and never attempt to repair a faulty one.
- A cap may only be removed if the cylinder's design allows it.
- Tighten hoses and fix them to avoid whiplash (use a choker cable or chain to the wall).
- Do not connect hoses together
- Check that hoses are appropriate for the nature and pressure of the gas.
- Reduce hose length as much as possible.
- Make a regular check of cable sleeving, connectors, joints and threads and do not exceed their replacement date. Never ignore any leak.
- Have personal protective equipment close at hand.
- Install appropriate gas detectors for the nature of the gas. Link them to an audible and visual alarm. Depending on the hazard, predefined detection thresholds trigger the shutting off of gas supply and the potential activation of forced ventilation.
- Avoid any source of ignition in the presence of a flammable gas.
- Never pour the contents of one cylinder into another.
- Store empty cylinders in the same way as full ones.
- Always keep gas cylinders vertical.
- Return to the supplier any faulty or damaged cylinder (dented, misshapen following a collision) or any cylinder whose recertification period (10 years) has expired.
- Obtain the technical data sheet for the gas from the supplier.
- Mark out area where the gas is used, depending on the hazard.
- Display instructions with the detailed measures to be taken in the event of an accident.

PLEASE NOTE

The next recertification date features on a plastic disc around the valve.



Example

Cylinder needs to be recertified in 2023.

The blast effect is the damage caused by a shock wave after an explosion. It leads to variable projections (victims and debris), damage, injury and thermal effect (burns).

Most common injuries

- Ears: eardrum affected, with hearing loss or deafness, tinnitus, possible bleeding.
- Digestion: organs containing air expand (stomach and intestines) leading to local or abundant bleeding (the victim is pale and has abdominal pains) and secondary infections. These signs may appear several hours after the explosion.
- Upper respiratory tract: nosebleed, acute respiratory problems may occur, evidenced by cyanosis (bluish skin colour).
- Skin and mucous: more or less severe burns.
- The displacement of a mass of air many lead to many injuries – such as arms and legs being broken, wounded or torn – because of more or less heavy projectiles.

Measures to be taken

Because assessing the extent of injury is not easy, the following must be done before emergency services arrive:

- lay the victim down (unless they insist on staying seated – breathing difficulties).
- assess vital signs (enlist the help of a first aider or equivalent where possible) and start cardiac resuscitation if necessary.
- address acute injuries (apply pressure to bleeding, treat burns, etc.).
- reassure the victim and watch them until a medical team takes over.
- cover them where appropriate.

A 24- or 48- hour hospital stay is usually required for monitoring purposes.

MEDICAL ADVICE REQUIRED

Never let anyone, even apparently unhurt, leave an explosion area before they have been examined by a physician.

Autoclaves used to carry out very high pressure reactions. Autoclaves are fitted with a bursting disc which can be likened to a fuse under pressure, to prevent any risk of explosion. Chemistry developed in the Laboratoire Hétérochimie Fondamentale et Appliquée (LHFA) combines cutting-edge fundamental research (unusual chemical structures, unique bonding patterns, new chemical transformations) with applications in high-profile fields such as catalysis and nanochemistry.

CNRS
COORDINATION NATIONALE DE PRÉVENTION ET DE SÉCURITÉ
1, place Aristide-Briand - 92195 Meudon Cedex
01 45 07 54 88
cnps@cnrs.fr

Graphic design Dircom - Coconut graphics +33 299457339
Produced by Ifsem, printed document team
Translation: Hélène Wilkinson • https://helene.wilkinson.fr/