

Guideline

for gas cylinders with compressed and liquefied gases

For cryogenic liquefied gases, please see separate document.



This guideline contains the most important regulatory, operational and internal provisions, in order to ensure safe working conditions with gas cylinders at the ETH Zurich.

Gas cylinders with compressed and liquefied gases are used very frequently in the laboratories and workshops of ETH Zurich. They pose significant risks due to their properties.

- **High pressure:** The pressure in gas cylinders with compressed gases can reach up to 300 bar. The risk of bursting is therefore great. The gas can escape suddenly if there is a leak (e.g. in the valve). A compressed gas bottle can travel approx. 800 meters in free flight and penetrate a concrete wall 20 cm thick. For liquefied gases the filling pressure corresponds to the vapor pressure of the respective compound. At rising temperatures the pressure increases rapidly according to the vapor pressure equation.
- **Type of gas:** The substances can be toxic, flammable, explosive or corrosive. Depending on the substance, the gases are heavier or lighter than air, and therefore can collect near the ground or at the top of a room.

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1. Legal Basis

The following documents form the legal basis for handling gases:

- Ordinance on Accident Prevention and Occupational Diseases (VUV)
- Federal Accident Insurance Act (UVG) under article 82
- Bundesgesetz über die Sicherheit von technischen Einrichtungen und Geräten (STEG) mit den Artikeln 1 und 3. Federal Law on the Safety of Technical Installations and Equipment (STEG) under articles 1 and 3
- Ordinance on use of pressurized devices (832.312.12)
- EKAS directive «Pressure Equipment» (No. 6516)
- SUVA publication «Gas Cylinders - Storage, Gas Networks, Gas Distribution Systems» (No. 66122)
- SUVA publication «Exposure Limits at the Workplace» (No:1903.d)
- SUVA publication «Explosion Prevention» (No. 2153)
- Fire prevention directives (VKF)
- Guideline to Ordinance 3 and 4 to the Employment Act

The gas cylinders must comply with the regulation on the transport of dangerous goods on the road (SDR) and the regulation on the transport of dangerous goods by rail (RSD).

The regulatory basis form the minimum requirements. According to specific situations, more strict operational provisions and additional safety measures may apply

2. Scope of Application

This guideline shall apply for all members of the ETH Zurich (employees, students, apprentices, scholars/fellows, academic guests), as well as for spin-offs and third-party companies working in the premises of the ETH Zurich. For any deviation from this guideline, a specific risk assessment has to be done, and they need written approval by SSHE [1].

For gases used as cooling agents (e.g. ammonia, CO₂), deviating or additional provisions might apply (the fact sheet for the use of ammonia as cooling agent can be obtained from sgu-safety@ethz.ch). SSHE has to be involved from the very beginning when the first planning steps are taken.

3. Glossary

connected gas cylinder

gas cylinder, which is directly connected to a device or to a gas network.

(pressurized) gas cylinder

transport container for a compressed or liquefied gas (single cylinders or bundles of cylinders). For containers for cryogenic liquids (cryotanks, Dewar containers), see separate guideline.

gas cabinet

safety cabinet for the storage of gas cylinders, according to SN EN 14470 (Type G90). Gas cabinets have to be connected to the lab exhaust system.

fastening device

device to secure gas cylinders against falling or rolling away. The fastening device has to be made of non-flammable material (e.g. metal chain, Kevlar strap). The gas cylinders have to be secured in the upper third of the cylinder body.

[1] https://www.ethz.ch/content/dam/ethz/associates/services/Service/sicherheit-gesundheit-umwelt/files/chemikalien_gase_gefahrstoffe/de/Gasflaschen_Antrag_Spezialbewilligung_form_public.pdf

gas network

connecting lines (incl. fittings and valves) between gas cylinder(s) or ramp(s) and a piece of equipment or extraction point(s).

storage area

area (place, room) in which non-connected gas cylinders are stored.

spare gas cylinder

non-connected gas cylinder, which is necessary for an undisturbed functioning of a device or of a local gas network.

ramp

fixed installed device for the connection of two or more gas cylinders.

centralized gas distribution

gas network for a whole building or large parts of a building.

4. Risk Assessment – the S T O P Principle

Installation and handling of gas cylinders, ramps and gas networks must be done in a way that ensures the protection of people, values and the environment. The safety measures have to be implemented according to the risk posed by the connected or stored gas cylinders. The location, as well as the specific properties of the gases have to be taken into account.

To evaluate risks in the use and storage of gases, the following worst-case scenario is assumed:

- The content of the largest container of each gas is released.
- All gas is released immediately
- The gas spreads throughout the room.
- Artificial ventilation is not taken into account.

To eliminate dangers effectively, i.e. to minimize residual risk, irrespective of whether it is a gas or not, the S T O P principle is applied. The effectiveness of the measures decreases from top to bottom:

S	Substitution	1st priority
T	Technical measures	2nd priority
O	Organizational measures	3rd priority
P	Personal measures	4th priority

Accordingly, the most effective method is always to substitute a hazardous gas with a nonhazardous gas or use a different, less dangerous process. If this is not possible, the gas volume is reduced.

Events (e.g. fire) in the lab cannot be completely ruled out without unreasonable effort, which is why the consequences must be minimized and limited to a lab (fire zone). The following applies:

- **The risk of explosion must be virtually zero.** Possible concentration under LEL (Lower Explosion Limit) or there may be no ignition source in the room.
- **Poisoning of persons is not tolerated.** As a measure of toxicity, the MAC value (maximum allowed workplace concentration) is taken.
- **Suffocation of persons is not tolerated.** Nonflammable inert gases are generally not dangerous. Exceptions are liquefied inert gases under pressure. For these gases, oxygen displacement must be taken into consideration. 18%Vol oxygen are defined as threshold value.

5. Technical and Construction Requirements (T)

- Gas cylinders, ramps and gas networks should not be installed in the basement floors of a building. If they have to be installed below ground level, special protective measures have to be implemented in order to ensure safety.
- Gas cylinders must not be installed at a place where leaking gas could spread in an uncontrolled way and could pose hazard due to accumulation (for gases heavier than air, basement rooms, cavities, pits, rooms on a lower level etc. could be problematic).
- Storage areas, ramps and gas networks, incl. valves and fittings have to be placed in a way that allows easy access for handling, control and revision work, as well as for cooling in case of a fire.

5.1. General Requirements for Rooms Containing Gas Cylinders

- Rooms, in which gas cylinders are connected or stored, have to be sufficiently ventilated.
 - **natural ventilation:** Either volume of the room $> 4000 \text{ m}^3$, or rooms above ground level equipped with two separate, non-closable openings against the outside of the building, of min 20 cm^2 per m^2 room surface. These openings have to be placed in a suitable way with respect of the density of the gases.
 - **artificial ventilation:** at least 3-5fold air exchange per hour, connection to the chemical exhaust system of the building, exhaust ducts placed below the ceiling or bottom exhaust ducts, according to the density of the gases.
- For rooms below ground level, an artificial ventilation is mandatory.
- Gas cylinders have to be protected against heat, mechanical damage and falling. Fastening devices have to be installed in the room.
- If the total volume of the gas cylinders is 200 L or more, they have to be stored outdoor, or in a separated fire zone without any additional fire loads, or inside a gas cabinet.
- Gas cylinders must not be placed in any escape route.

5.2. Requirements for Gas Networks

Gas networks have to be installed by qualified personnel. Do-it-yourself gas networks with plastic tubes are prohibited. For the installation of a gas network, a work order has to be placed (<https://gmis.ethz.ch/>).

5.2.1. General Requirements for Gas Networks

- Gas installations must be laid out so that they correspond to the properties of the gas used. Suitable materials must be used for the regulating valve, gas module and gas lines. (All gas installation components incl. regulator unit require a material compatibility certificate from the manufacturer.)
- Gas networks have to be planned and installed according to the maximum working pressure.
- Tubes and lines from gas networks have to be labeled with the name of the gas as well as with the direction of flow. This takes in particular for passages, junctions, branches or valves.
- Gas installations and lines must be clearly marked; avoid using unspecific labels such as “mix corrosive”.
- For gas mixtures, the modules of the media columns have to be labeled in a clear way, also indicating with which gas cabinet they are connected.
- The valves at the media columns have to be labeled with the same color as the shoulder of the gas cylinder (specific for each gas).
- Coupled fixtures must always be easily accessible and protected against damage.

5.2.2. Additional Requirements for Gas Networks for Flammable Gases

- gas cylinder size max. 10 L.
- gas cylinders with more than 10 L volume require a written approval by SSHE.[1]
- All gas cylinders must be installed in a ventilated gas cabinet. For 10 L gas bottles, this requirement may be omitted under certain conditions (all conditions must apply):

- a. The bottle is not located in the vicinity of heat sources, such as ovens, hot plates, radiators.
 - b. The room is well-ventilated (connection to the chemical exhaust duct with 3-5fold air exchange rate per hour, exhaust ducts under the ceiling or bottom exhaust according to the density of the gas).
 - c. the LEL is not reached if the entire content escapes (room volume must be at least 5 m³ larger than the volume at which the LEL is reached).
 - d. there are no ignition sources in the vicinity of the gas bottle.
- The gas cylinders must be installed in a ventilated gas cylinder cabinet.
 - The gas cylinders must be fastened in the gas cabinet according to regulations.
 - Maximum gas flow of the regulating valves and gas connections is reduced.
 - All gas purging must be disposed of via an exhaust air duct.
 - Local manual gas shutoff valves required.

5.2.3. Additional Requirements for Gas Networks for Corrosive Gases

- Lecture Bottles or small gas cylinders (max. 2 L) should be used, which are installed in the fume hood and connected directly to the point of use. Such installations may only be made by experienced and qualified specialists. Self-made designs or workshop orders are not allowed.
- gas cylinders with more than 2 L, or gas installations of corrosive gases outside of a fume hood volume require a written approval by SSHE.[1]
- Passivation regulations for the respective gas must be observed.
- The primary side of the high-pressure side of the regulator unit has to be equipped with inert gas purging.
- All the components which come into contact with the corrosive gas on the high-pressure side, incl. screw joints, fittings or seals are made of material suitable for the gas being used.
- The gas outlet on the low-pressure side is connected with a direct line to the point of use. Lines, screw joints, fittings are constructed of materials that are suitable for the gas being used.
- Prior to initial operation, a leak test with helium has to be performed by the manufacturer (written certificate of leak test).
- As the pressure reducing valves are directly connected to the gas cylinders, they have to be protected against damage.

5.2.4. Additional Requirements for Gas Networks for Carbon Monoxide (CO)

- Gas cylinder size max. 10 L.
- Gas cylinders with more than 10 L volume require a written approval by SSHE.[1]
- The gas cylinders must be installed in a ventilated gas cylinder cabinet.
- The gas cylinders must be fastened in the gas cabinet according to regulations.
- Maximum gas flow of the regulating valves and gas connections is reduced
- All gas purging must be disposed of via an exhaust air duct
- Local manual gas shutoff valve is required.

5.2.5. Additional Requirements for Gas Networks for Toxic Gases

- Lecture Bottles or small gas cylinders (max. 2 L) should be used, which are installed in the fume hood and connected directly to the point of use. Such installations may only be made by experienced and qualified specialists. Self-made designs or workshop orders are not allowed.
- gas cylinders with more than 2 L, or gas installations of toxic gases outside of a fume hood volume require a written approval by SSHE.[1]
- Prior to initial operation, a leak test with helium has to be performed by the manufacturer (written certificate of leak test).
- All gas purging must be disposed of via an exhaust air duct

- As the pressure reducing valves are directly connected to the gas cylinders, they have to be protected against damage.

5.3. Gas Monitoring

All rooms at ETH containing gas networks, or rooms in which gas cylinders or cryogenic liquids are stored or handled, have to be equipped with a gas monitoring system, if – in case of a leak – a risk for people or animals may occur. This might be the case in labs, workshops, rooms with filling lines for liquid nitrogen, storage rooms for cryogenic liquids, animal facilities, refrigeration plants. In special rooms, in which large quantities of flammable liquids are handled (e.g. tank depot for solvents, disposal facilities for solvents, filling stations for solvents), a gas detection system might also be necessary.

To evaluate risks in the use and storage of gases, the following worst-case scenario is assumed:

- The content of the largest container of each gas is released.
- All gas is released immediately
- The gas spreads throughout the room.
- Artificial ventilation is not taken into account (exception: redundant exhaust system also available during an electric power-cut).

For each gas used in the room, the following considerations have to be made:

- Might there be an explosive mixture with the air?
benchmark: Lower Explosion Limit (LEL)
- Is there any health risk for people or animals?
benchmark: MAC value
- Might the oxygen content in the room fall below 18% Vol?

If at least for one of these three questions, the answer is “Yes”, a gas monitoring system is necessary for this gas. At ETH, usually fixed mounted gas monitoring systems are installed (<https://gmis.ethz.ch/>). Any exemption of this rule has to be permitted by SSHE beforehand.

An overview on the construction requirements for gas monitoring systems, alarm transmission and threshold values are compiled in the factsheet [Merkblatt «Gasüberwachung»](#)[2] (only available in German). This factsheet also contains information regarding responsibilities, necessary instruction of the users, as well as maintenance of these systems.

6. Organisational Requirements (O)

6.1. Labeling

Rooms in which gas cylinders are stored must be indicated accordingly (yellow triangular symbol “gas cylinder”). If there is danger of suffocation in a room with gas cylinders, this must also be indicated. Gas cabinets are also marked with the respective warning sign (e.g. flammable, toxic). Labels can be obtained from SSHE (email: stickers@ethz.ch).

6.2. Instruction

Before the start of their activity, all people handling gases have to be instructed about the hazards related to this work and about the necessary precautionary measures. This instruction has to be refreshed regularly. The supervisors are responsible for the instruction (for students in practical courses: the head of the practical course). The instruction has to be documented.

[2] https://www.ethz.ch/content/dam/ethz/associates/services/Service/sicherheit-gesundheit-umwelt/files/chemikalien_gase_gefahrstoffe/de/Gasueberwachung_MB.pdf

Rules for the instruction regarding gas monitoring systems are available in the [factsheet \[2\]](#).

6.3. User Manuals / SOPs

All organizational units in which gas cylinders are stored or handled, or which use gas networks or centralized gas distributions, have to ensure that the necessary safety measures are respected. The user manuals, SPOs and checklists have to be available locally.

6.4. Commissioning, Maintenance and Repair

Prior to the first use, after a modification or a repair work, all gas installation have to undergo a leak-testing (above the maximum working pressure) according to the rules of technology. The test have to be documented.

All installations have to be maintained according to the supplier' specifications. The maintenance has to be done by specialized personnel. The instructions for the maintenance have to be available locally. All maintenance work has to be documented.

Inoperable installations have to be secured against unintended use, and have to be labeled as such.

7. Personal Protective Equipment - PPE (P)

All people handling gases have to be equipped with the appropriate Personal Protective Equipment (PPE) by the employer (professor, institute, etc.), e.g. protective clothes, safety shoes, respiration protection, safety glasses or protective gloves. The use of the PPE has to be stipulated and controlled by the supervisor (for students in practical courses: by the head of the practical course)

8. Handling of Gas Cylinders / Working with Gases

8.1. General Rules

- At the point of use (e.g. in laboratories or workshops) only pressurized cylinders that are required for operation may be present (no storage). This also hold true for empty bottles.
- The gas cylinders should be positioned so that the mounted fittings are always easily accessible and protected against damage.
- Gas cylinders must always be secured to prevent them from falling over or rolling away. The fire-proof safety mechanism (chain, cable, commercially available straps) must be placed at a height of about 2/3 of the bottle. Never secure a gas cylinder around the bottle neck. The cylinder fastening must be anchored solidly (to a wall, immovable piece of furniture, etc.). Each bottle should have its own fastening device.
- Pressurized gas cylinders may never be placed near a heat source (radiator, heating bath, oven,...). No part of a gas cylinder may be exposed to temperatures exceeding 40°C (liquefied gases) or 60°C (compressed gases).
- Only the regulating valve approved for the respective gas may be used, the use of adaptors is prohibited. For pure oxygen use only fittings which are absolutely free of oil and grease and which are equipped with non-flammable seals (approved by Swiss Association for Welding Technology).
- For flexible connections (metal corrugated hose), a safety cord should be used at an operating pressure over 40 bar so that the hose cannot injure anyone should the connection burst. Such a safety cord is also recommended for other high-pressure hoses.
- The cylinder valve must always be opened carefully and completely (open all the way and turn back ¼ revolution).
- For longer interruptions in gas use, the cylinder valves must be closed.
- If a gas cylinder is not being used, the regulating valve should be dismantled and the protective cap screwed back on.

- Empty gas cylinders have to be labeled as such. The cylinder valve has to be closed and the protective cap screwed on.
- Before changing a gas cylinder, the main valve of the cylinder, as well as the valve of the connecting line, have to be closed.
- Damaged, brittle or fissured gas tubes have to be replaced.
- Connecting gas cylinders to a gas network or a ramp may only be done according to the respective checklists in order to avoid incorrect handling by the user. The checklists must be posted clearly visible by the gas cylinder cabinets. Before filling the gas network or ramp, the main valves have to be closed. All valves then have to be opened slowly and carefully.
- When working with gas cylinders, personal protective equipment must always be worn.
- The material safety data sheets (MSDS) of all the gases used must be stored safely and the guidelines contained therein carefully.
- (Re-)filling of gas cylinders by the users is prohibited. Exceptions require a written approval by SSHE.[1]

8.2. Additional Requirements for Gas Networks and Ramps

- when a gas network or ramp is not in use for a longer period of time, the pressure has to be released. When releasing the pressure, the gas has to be sucked away without posing a risk (i.e. via the lab exhaust system)
- Non-used connections of a gas network have to be removed (work order <https://gmis.ethz.ch/>) or have to be sealed tightly against unwanted gas release (e.g. screw cap). Only closing the valve does not count as tight sealing.
- At a collecting line of a ramp, only cylinders of the same gas and with the same maximum pressure are allowed.

8.3. Additional Rules for Hazardous Gases

- The cylinder valve should be frequently opened and closed with corrosive gases in order to prevent blockages. The regulating valve should not be left too long on the bottle with these gases, unless they are used a lot. The regulating valve should be flushed thoroughly with compressed air or nitrogen after each use.
- Experiments with hazardous gases are only allowed during the opening hours of the building.
- Working alone is prohibited when handling hazardous gases.

8.4. Defective Gas Cylinders / Defective Gas Installations

Do not use defective gas cylinders or gas installations. They must be marked as “defective” and have to be blocked against further use. Defective gas cylinders must be stored in a safe, well-ventilated place until picked up by the supplier.

If a flammable, corrosive or toxic gas leaks from a gas cylinder or a gas installation, immediately contact the ETH Emergency Desk (phone 888).

9. Purchasing and Acquiring of Gas Cylinders

9.1. General Rules

Gas cylinders may only be procured in the smallest possible size. A centralized and coordinated ordering procedure (by building or by organizational unit) for non-toxic and non-corrosive gases is recommended.

9.2. Additional Rules for Toxic/ Corrosive Gases

Toxic / corrosive gases and gas mixtures are ordered and managed directly by the work groups themselves. The supplier of toxic / corrosive gases must arrange a binding delivery date with the work group (also for returns). Delivery must always be accepted personally; if this is not the case, the for-

warder shall take the full gas cylinders back with him. Agreements, by which the forwarder deposits the gas cylinders in front of the lab or office door, are not allowed. When receiving a gas cylinder, always check that the name of the gas given coincides with the color code of the cylinder. If there is any discrepancy, the cylinder should immediately be returned to the supplier. It is strictly prohibited to draw off gas to determine the actual content.

10. Storage of Gas Cylinders

10.1 General Requirements

- Storing gas cylinders together with flammable or self-igniting materials (paper / cardboard boxes, solvents, etc.) is prohibited.
- Gas cylinders are not to be kept in escape routes.
- Gas cylinders have to be stored standing upright.
- In storage areas, the full gas cylinders have to be grouped by the different gases, empty gas cylinders have to be stored separately.

10.2. Constructional Requirements for Storage Areas for Gas Cylinders

- Storage areas have to be ventilated sufficiently (requirements according to chapter 5.1).
- Storage rooms and rooms with gas cylinders for centralized gas distributions, have to be built as separate fire zones (EI 90, doors EI30). All doors have to be equipped with a mechanical closing system.
- Escape routes from storage rooms have to be kept clear and labeled as such.
- Outdoor storage areas have to be protected against unauthorized access (e.g. cage construction, fence).
- All gas cylinders in the storage areas have to be secured with an appropriate fastening device, and they have to be protected from extreme heat.

10.3. Additional Requirements for Storage Rooms for Flammable Gases

In storage rooms for flammable gases, EX protection measures have to be taken. When planning such storage rooms, it is mandatory to contact SSHE beforehand.

10.4. Additional Requirements for Storage Rooms for Toxic Gases

Toxic gases must always be stored inside a gas cabinet.

11. Transport of Gas Cylinders

The internal transport of gas cylinders is only allowed on special cylinder carts. The cylinder valve must always have a protective cap; bottles with a mounted regulating valve may not be transported. Never roll gas cylinders in a lying position or drag or haul them across the floor. When transporting them on a cylinder cart, the gas bottles must always be secured with a chain.

For transporting gas cylinders, only the freight elevators are allowed to be used. Simultaneous transport of people and gas cylinders in an elevator is prohibited.

For external transport (public street), please observe the ADR/SDR guidelines ([Request for Transport of Hazardous Goods](#)).[3]

12. Disposal of Gas Cylinders

12.1. General Rules

Never completely empty gas cylinders, but always leave a small residual pressure in the bottle when it is returned. When returning the cylinder, the cylinder valve should be closed and the protective cap screwed on. The gas cylinder must be returned to the supplier before expiration date.

12.2. Additional Rules for Toxic / Corrosive Gases

The supplier of toxic / corrosive gases must arrange a binding delivery date with the work group (also for returns). The hand-over must always be accepted personally. Agreements, by which the forwarder picks up the empty gas cylinders in front of the lab or office door, are not allowed.

12.3. Lecture Bottles

Lecture Bottles (small non-reusable cylinders) have to be returned to the supplier after use. They must not be disposed of as scrap metal or scrap aluminum.

12.4. Outdated Gas Cylinders

If gas cylinders, which have exceeded their date of periodic mandatory check, have to be disposed of, SSHE has to be contacted beforehand, in order to define a suitable way of disposal.

13. Audits / Checks

The SSHE can conduct (announced or unannounced) inspections of the individual institutes and work groups to check adherence to the safety guidelines on a random basis.

[3] https://www.ethz.ch/content/dam/ethz/associates/services/Service/sicherheit-gesundheit-umwelt/files/gefahrgut/en/Auftrag_Gefahrguttransport_EN_form_public.pdf

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