This guideline contains the most important regulatory, operational and internal provisions for ensuring safe working conditions with gas cylinders at 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 cylinder might 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 floor or below the ceiling.
Table of Content

1. Legal Basis ................................................................................................................................. 3
2. Scope of Application ...................................................................................................................... 3
3. Glossary ......................................................................................................................................... 3
4. Risk Assessment – the S T O P Principle ...................................................................................... 4
5. Technical and Construction Requirements (T) ........................................................................... 5
  5.1. General Requirements for Rooms Containing Gas Cylinders ................................................. 5
  5.2. Requirements for Gas Networks ............................................................................................ 5
  5.2.2. Additional Requirements for Gas Networks for Flammable Gases ..................................... 5
  5.2.3. Additional Requirements for Gas Networks for Corrosive Gases ...................................... 6
  5.2.4. Additional Requirements for Gas Networks for Carbon Monoxide (CO) ......................... 6
  5.2.5. Additional Requirements for Gas Networks for Toxic Gases ........................................... 6
  5.3. Gas Monitoring ..................................................................................................................... 7
6. Organisational Requirements (O) ............................................................................................... 7
  6.1. Labeling ................................................................................................................................... 7
  6.2. Instruction ............................................................................................................................... 7
7. Personal Protective Equipment - PPE (P) .................................................................................... 8
8. Handling of Gas Cylinders / Working with Gases ....................................................................... 8
  8.1. General Rules ....................................................................................................................... 8
  8.2. Additional Requirements for Gas Networks and Ramps ......................................................... 9
  8.3. Additional Rules for Hazardous Gases .................................................................................. 9
  8.4. Defective Gas Cylinders / Defective Gas Installations ......................................................... 9
9. Purchasing and Acquiring of Gas Cylinders .............................................................................. 9
  9.1. General Rules ....................................................................................................................... 9
10. Storage of Gas Cylinders ........................................................................................................ 10
  10.1 General Requirements .......................................................................................................... 10
  10.2. Constructional Requirements for Storage Areas for Gas Cylinders .................................. 10
  10.3. Additional Requirements for Storage Rooms for Flammable Gases .................................. 10
  10.4. Additional Requirements for Storage Rooms for Toxic Gases .......................................... 10
11. Transport of Gas Cylinders ...................................................................................................... 10
12. Disposal of Gas Cylinders ........................................................................................................ 11
  12.1. General Rules .................................................................................................................... 11
  12.2. Additional Rules for Toxic / Corrosive Gases .................................................................... 11
  12.3. Lecture Bottles .................................................................................................................. 11
  12.4. Outdated Gas Cylinders .................................................................................................... 11
13. Audits / Checks ........................................................................................................................ 11
1. Legal Basis
The following documents form the legal foundations for handling gases:

- Ordinance on Accident Prevention and Occupational Diseases (VUV)
- Federal Accident Insurance Act (UVG), article 82
- Federal Law on the Safety of Technical Installations and Equipment (STEG), articles 1 and 3
- Ordinance on the 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 for Ordinance 3 and 4 of 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 legal foundations define the minimum requirements. Depending on the specific situation, more strict operational provisions and additional safety measures may apply.

2. Scope of Application
This guideline applies for all members of ETH Zurich (employees, students, apprentices, scholars/fellows, academic guests), as well as for spin-offs and third-party companies working in the premises of ETH Zurich. For any deviation from this guideline, a specific risk assessment has to be conducted and sent to SSHE for approval. [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 for securing 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 fastening device has to be fixed in the upper third of the cylinder body.

**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 unconnected 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**
permanently 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 conducted in a way that ensures the protection of people, property and the environment. The safety measures derive from the risk posed by the connected or stored gas cylinders. The location of the cylinders 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 at once.
- The gas spreads throughout the room.
- Artificial ventilation is not taken into account.

To minimise risks 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** Organisational 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 to use a different, less dangerous process. If this is not possible, the gas volume has to be 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 compartment). The following applies:

- **The risk of explosion must be virtually zero** (possible concentration below LEL (Lower Explosion Limit) or no ignition source in the room).
- **The health of persons must not be endangered.** In order to assess the health risk, the MAC value (maximum allowed workplace concentration) is taken.
- **The risk of suffocation of persons must be virtually zero.** Nonflammable inert gases per se are not dangerous. Exceptions are liquefied inert gases under pressure. For these gases, oxygen displacement must be taken into consideration. 18% Vol oxygen is defined as threshold value.
5. Technical and Construction Requirements (T)

- Gas cylinders, ramps and gas networks should not be installed in the basement floor 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 in places where leaking gas could spread in an uncontrolled way or pose hazard due to accumulation (for gases heavier than air, basement rooms, cavities, pits, 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 the volume of the room has to be above 4000 m³, or the room has to be above ground level and equipped with two separate, non-closable openings against the outside of the building, with a size of at least 20 cm² per m² room surface. These openings have to be placed in a suitable way with respect to the density of the gases.
  - **Artificial ventilation:** At least 3–5 fold air exchange per hour, connection to the chemical exhaust system of the building, exhaust ducts placed below the ceiling or bottom exhaust ducts, depending on the density of the gases.
- For rooms below ground level, 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 outdoors, or in a separate fire compartment without any additional fire load, or inside a gas cabinet.
- Gas cylinders must never be placed in an 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 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 labelled with the name of the gas as well as with the flow direction. This applies 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 labelled in a clear way, also indicating to which gas cabinet they are connected.
- The valves at the media columns have to be labelled with the same colour 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 cylinders, this requirement may be omitted under the following conditions (all conditions must apply):
  - The cylinder 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 cannot be 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 cylinder.

- 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 are required.

5.2.3. Additional Requirements for Gas Networks for Corrosive Gases

- Lecture bottles (small non-reusable cylinders) or small gas cylinders (max. 2 L), which are installed in the fume hood and connected directly to the point of use, should be used. Such installations may only be made by qualified personnel. Self-made designs or workshop orders are not allowed.
- Gas cylinders with more than 2 L, or installations of corrosive gases outside a fume hood require written approval by SSHE.[1]
- Passivation regulations for the respective gases 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 resistant to 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.
- A local manual gas shutoff valve is required.

5.2.5. Additional Requirements for Gas Networks for Toxic Gases

- Lecture bottles (small non-reusable cylinders) or small gas cylinders (max. 2 L), which are installed in the fume hood and connected directly to the workstation, should be used. Such installations may only be made by qualified personnel. 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, and 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 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 at once.
- 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:

- In the event of a leak, can an explosive mixture develop with ambient 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 for only 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 (work order: https://gmis.ethz.ch/). Any exemption of this rule has to be permitted by SSHE beforehand.

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

6. Organisational Requirements (O)

6.1. Labeling
Rooms in which gas cylinders are stored must be labelled accordingly (yellow triangular symbol “gas cylinder”). If there is danger of suffocation in a room with gas cylinders, this must be indicated, too. 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 repeated periodically. The supervisors are responsible for the instruction (for students in practical courses: the head of the practical course). The instruction has to be documented.

Rules for the instruction regarding gas monitoring systems are available in the factsheet "Gasüberwachung".

### 6.3. User Manuals / SOPs

All organisational units which store/handle gas cylinders, use gas networks or centralized gas distribution systems, have to ensure that the necessary safety measures are observed. The user manuals, SPOs and checklists have to be available in situ.

### 6.4. Commissioning, Maintenance and Repair

Prior to first use, after a modification or a repair work, all gas installations have to undergo a leak test (above the maximum working pressure). The test has to be documented.

All installations have to be maintained according to the manufacturer's specifications. The maintenance has to be executed by specialized personnel. The instructions for the maintenance have to be available in situ. All maintenance work has to be documented.

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

### 7. Personal Protective Equipment – PPE (P)

All people handling gases have to be equipped with the appropriate PPE by the employer (professor, institute, etc.), e.g. protective clothes, safety shoes, respiration protection, safety glasses or protective gloves. The use of 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 workplace (e.g. in laboratories or workshops), only pressurized cylinders required for operation may be installed (no storage). The same holds true for empty cylinders.
- 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 cylinder. Never secure a gas cylinder around the cylinder neck. The cylinder fastening must be anchored solidly (to a wall, immovable piece of furniture, etc.). Each cylinder 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 SWISSMEM).
- For flexible connections (corrugated metal hose), a safety cord should be used when operating at a 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 rotation).
- 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 dismounted and the protective cap screwed back on.
• Empty gas cylinders have to be labelled 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 have to be opened slowly and carefully.
• When working with gas cylinders, always wear PPE.
• The material safety data sheets (MSDS) of all the gases used must be kept available and the regulations contained therein observed.
• (Re-)filling of gas cylinders by the users is prohibited. Exceptions require a written approval by SSHE.

8.2. Additional Requirements for Gas Networks and Ramps
• When a gas network or ramp has not been 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 in a safe way (i.e. via the lab exhaust system).
• Unused 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 valves of cylinders containing corrosive gases should be frequently opened and closed in order to prevent blockages. The regulating valve should not be left on the cylinder for too long with these gases, unless they are used frequently. The regulating valve should be flushed thoroughly with compressed air or nitrogen after each use.
• Experiments with hazardous gases are only allowed during working hours.
• 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 Emergency Desk (phone no. internal 888, external 044 342 11 88).

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
Safety, Security, Health and Environment

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 according to the gas type, 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; cylinders 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 cylinders 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 empty gas cylinders completely, but always leave a small residual pressure in the cylinder 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 supplier 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 aluminium.

12.4. Outdated Gas Cylinders
If gas cylinders, which have exceeded the date of their 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
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.