THE LINDE GROUP

Safety Advice.
18 – Handling of gases under pressure.

Introduction

Industrial gases are normally filled, transported, stored and used under pressure. They are therefore called pressurised gases. The technical equipment for handling pressurised gases is gas systems.

Gas systems are designed so that the strength (bursting pressure) is greater than the test pressure. The latter is normally 1.5 times the maximum permissible operating pressure. This means that the gas system is reliably protected against bursting under normal operating conditions. However, if a gas system is incorrectly manufactured or operated, it can burst or parts of it can become detached and fly off.

To avoid these risks, the manufacture and operation of gas systems are regulated in different national and European rules. These Safety Advice are not intended to replace the above rules, merely to supplement them. They contain knowledge from damage cases which, if applied, can help prevent repetition.

Pressure hazards from compressed gases

Gases which cannot be condensed at normal temperatures (e.g. nitrogen, oxygen, hydrogen, argon, helium) are compressed in the gaseous form at pressures of up to 300 bar and are filled into cylinders. The pumps or compressors used for filling are made safe so that no bursting can be caused by overfilling. The maximum permissible filling pressure is defined so that even a possible pressure increase caused by intense sunlight cannot cause the cylinder to burst. However, this can occur if the filled gas cylinder is heated by an external fire. Gas cylinders must therefore be protected against fire.

The strength of gas cylinders can be impaired by corrosion. For example, if they contain water, oxygen cylinders can corrode to such an extent that they burst at the operating pressure. To avoid the ingress of contaminants into the the cylinder, it shall never be emptied below a few bar. Besides the cylinder valve shall be closed whenever possible.

Pressure warning

Hazards arises if a gas is allowed to enter a system designed for a lower pressure. The following safety measures must be observed:

- Compressed gases must be extracted from the storage vessel using pressure reducers. The back-pressure set at the pressure reducer must not be higher than the operating pressure of the downstream gas system. Since, in the event of a fault at the pressure reducer, the high admission pressure can extend into the back-pressure range, a suitable safety valve must be installed on the pressure reducer or immediately behind it.

- Connections between system sections with different operating pressures are only permissible if a pressure reducer is used. Shut-off valves or non-return valves alone do not provide sufficient safety.
- Gas cylinders with compressed gases must not, under normal circumstances, be connected to gas cylinders with liquefied gases, as their operating pressures are different. If this does occur in exceptional cases (e.g. to produce a mixture), a pressure reducer must be connected in between.

- Even if only empty gas cylinders are connected to a gas system correctly (e.g. for purging or evacuating the cylinders), the system must be protected by a safety valve because a full gas cylinder can also be accidentally connected.

- Pressure and leakage tests with compressed gases may only be carried out on system sections that are suitable for the intended test pressure. Connection to other system sections must be reliably interrupted, e.g. by a blind flange.

Pressure hazards from gases liquefied under pressure

Gases which can be liquefied by compression at normal temperature (e.g. propane, carbon dioxide, ammonia, nitrous oxide) are filled into cylinders at pressures up to 60 bar.

A vessel with pressure-liquefied gas can burst if it is either moderately overfilled and is slightly heated, or if it is normally filled and significantly heated. In both cases, the heating causes an expansion of the liquid until it completely fills the vessel and the pressure of the incompressible liquid bursts the vessel.

To prevent overfilling, the filling ratio stipulated for every gas (kg liquid per litre vessel volume) must be observed. The tare weight of the empty cylinders and the full weight of the full cylinders must be checked for this purpose by weighing. This also applies if liquefied gas is transferred

from a large cylinder to a small one (see the Linde Safety Advices 8 "(Re-)filling gases" and 14 "Handling Liquefied Petroleum Gas").

Cylinders with liquefied gases may only be heated up to max. 50°C to increase the vapour pressure, e.g. with warm water. Naked flames must never be used for this purpose under any circumstances.

Propane cylinders are protected against the risk of bursting by a safety valve integrated in the cylinder valve. Most carbon dioxide cylinders, as well as nitrous oxide cylinders, have a rupture disk on the cylinder valve for the same purpose. These safety devices must not be modified in any way.

When combined with water ("carbonic acid"), carbon dioxide can corrode the cylinder material. This also sometimes causes CO_2 cylinders to burst. In the past, this happened mainly with CO_2 cylinders used in beverage dispensing systems and which were therefore "contaminated" with watery liquid. This fault can be prevented by a backflow preventer between the liquid vessel and the CO_2 cylinder. The penetration of rain water is prevented by CO_2 cylinders not being completely emptied

and by being stored and transported with the valve closed.

When the pressure is relieved to below 5.2 bar, liquid carbon dioxide goes partly back to the gaseous state and partly to its solid aggregate state ("carbon dioxide snow"). For example, if the pressure on a hose through which liquid carbon dioxide was transported is relieved, CO_2 snow can block the hose, thereby causing a pressure build-up. When the hose is disconnected from the gas system and the blockage is freed, the built-up pressure is relieved and the hose can whip around dangerously. The formation of such a blockage can be largely prevented by relieving the hose at the lowest point. The ends of the hoses should be secured with an arrester cable ("safety wire") which is not removed until after the hose coupling has been released and after pressure relief has been fully completed.

Pressure hazards from cryogenic gases

These include gases, which are liquefied under very low temperatures like oxygen (LOX), nitrogen (LIN), argon (LAR), helium (LHe), hydrogen (LH_2) and natural gas (LNG). They are stored in cryo-tanks. So that these tanks are not over-filled when a cryo-pump is used, they should have safety devices, which switch off the fill pump and shut off the fill line when the permissible filling pressure is reached.
Pressure hazards arise from cryogenic gases particularly in non-insulated system sections such as pipelines. This is where the liquid vaporises as a result of heat taken from the environment. If the system section is closed at both ends, an impermissible high pressure arises. To prevent bursting, non-insulated system sections must have the possibility of pressure release either inwards (e.g. into the tank) or outwards (safety valve, rupture disk).

The filling port of the cryo-tank is normally closed off with a dummy cap. This must have an open hole to safely relieve the pressure arising in the fill line as a result of vaporising liquid.
Pipelines for cryogenic gases are sometimes thermally insulated with a mineral wool jacket. If the pipeline leaks (e.g. at a flange connection), the escaping liquid causes a pressure build-up in the insulation jacket, with the result that the latter can burst. For this reason, on pipelines for cryogenic gases, preference should be given to insoluble connections, especially in inaccessible areas.
Cryogenic nitrogen is used, among other things, to make material brittle for deburring and grinding. The fine-grain product resulting from this can block up the opening through which the gaseous nitrogen should be relieved. If this possibility exists, there must be a safety valve to prevent hazardous pressure build-up.

Safety measures during work on gas systems

Relieving gas systems

Repairs to gas systems – for example repairing a leak or clearing a blockage, replacing a component – may only be carried out by suitably skilled persons and in the depressurised state. Before the start of repair work, it must be absolutely certain that the gas system is depressurised.
It is not permissible to rely here on pure assumption or unclear tests, as this could prove to be a fatal mistake.
To relieve the gas system, the following questions must be answered on the basis of the pipe-diagram and / or the installation:

- Where must the gas system be relieved?
- Where must valves be actuated, pipelines disconnected or blind flanges positioned to prevent pressurised gas penetrating into the relieved system?
- How can the depressurised state be monitored?

  (A reliable testing method is, for example, flushing the system: If pressurised gas is conducted to a point A from the outside and flows out at another point B, the section A – B is reliably depressurised.)
  The following characteristics give no reliable indication of whether the system is depressurised or not:

- An open relief valve or a partly detached component. (The valve or the pipeline can be blocked upstream of the component).
- A pressure gauge showing "zero". (The pressure gauge may be faulty or blocked, or its measuring range can be so great that a slight residual pressure is not indicated).
- A closed valve or a non-return valve which is supposed to shut off the relieved section of the system from the pressurised gas. (Valves and non-return valves can be faulty).

Detaching components on the relieved gas system

- When detaching a component from a gas system, you should stand to the side of the direction in which the component might fly off.
- When detaching a screwed-down flange cover on a gas system, the screws may

at first only be loosened, so that the cover is still held safely in place. The flange cover must then be lifted off the sealing surface on a testing basis. Only when no gas escapes when the cover is lifted may the screws be completely undone.

- This test can be unreliable if, for example, a slide valve is being removed which is closed and on which pressure is still present on one side. Valves may therefore only be detached if the gas system has been proved to be depressurised on both sides of the valve.

- When loosening a threaded connection, undo it only by a few turns at first. Then, by moving the loosened component, determine that no gas is escaping. The component can then be completely detached.

- A detached component may only be removed from the system manually or with the aid of a tool. On no account may the component be pressed off "pneumatically" (meaning with gas pressure or air pressure).

- Do not use force during disassembly work on gas systems. Do not hit with a hammer.

Components of gas systems

In a gas system, only components may be fitted for which it is known for certain that their nominal pressure is at least as great as the expected operating pressure. Evidence of the nominal pressure can be furnished by a manufacturer's certificate, identification on the component, calculation or a pressure test.

Provisional measures or compromises when installing a component in a gas system can be potentially fatal.

- Pressure gauges have proven sometimes to be weak points in gas systems. Pressure gauges must therefore be connected or arranged in such a way that nobody can be injured if the pressure gauge leaks or bursts. Safety pressure gauges must normally be used.

- When replacing a pressure gauge, ensure that the instrument is suitable for the gas in question (for oxygen and acetylene there are specially identified pressure gauges). In addition, the correct measuring range must be selected. The units of measurement "bar" and "mbar" must not be mixed up. Pressure gauges with an unknown unit of measurement or on which the unit of measurement is not shown or is no longer identifiable must not be used.

Hoses in gas systems

Installation conditions:

- Hoses must be marked with the nominal pressure and may only be used if this is at least as great as the intended operating pressure. Hoses which do not show the nominal pressure should also not be used if they seem from other characteristics (shape of the connecting thread, colour) to be assigned to a particular nominal pressure.

- Hoses must be reliably attached to the gas system e.g. with a hose screw connection or plug-in connector. Adapters may only be used if their nominal pressure is at least as great as the intended operating pressure. A hose attached to a pipe socket piece must be secured with hose clamps.

- Hoses must not be bent when connected. Metal hoses in particular can tear open when subjected to bending stress.

- Hoses must not leak and must not have any recognisable external damage.

Operation:

- A hose may only have pressure applied to it if it is reliably connected to the gas system at both ends.

- As long as the hose is connected to a gas system on one side only, the free end of the hose should be screwed onto a dummy connection or should be closed off with a dummy cap. This prevents the dangerous whip effect if the hose is accidentally pressurised.

- A hose may only be disconnected from the gas system if it is relieved and if the pressure is shut off.

Safety valves in gas systems

Safety valves should relieve gas systems in good time in the event of an impermissible pressure increase. Safety valves are type-tested and normally operate reliably. In exceptional cases however, their function may be faulty, e.g.:

- The blow-out line can be blocked by "nature" (birds' nests, insect nests) or by ice.

- The movement of the moving parts of a safety valve can be hindered by rust, foreign bodies, ice or excessive friction.

To identify and remedy such problems in good time, safety valves must be inspected regularly, e.g. during the course of scheduled maintenance.

Final observations

The setting up and operation of gas systems requires experience, skill and care. If these conditions are fulfilled, the pressurised gases perform their function and the pressure will not make itself apparent in a negative way. Our gas specialists will be able to tell you how to achieve this aim.

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