IMPACT OF HYDROGEN ON WORKS IN CONFINED SPACES

TECHNICAL NOTE

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ABOUT MARCOGAZ

Founded in 1968, MARCOGAZ represents 28 member organisations from 20 countries. Its mission encompasses monitoring and policy advisory activities related to European technical regulation, standardisation and certification with respect to safety and integrity of gas systems and equipment, rational use of energy as well as environment, health and safety issues. It is registered in Brussels under number BE0877 785 464.

DISCLAIMER

Contents

Tables

Figures

1. Introduction

The objective of this report is to analyse the risks of gaseous hydrogen when working in confined spaces and to provide appropriate mitigating measures.

Entering a confined space must be the last option after having considered work practises which would not require an entry, e.g. removing parts or machines and conducting repair or maintenance works outside of a confined space.

This document deals with the dangers of hydrogen in confined spaces and is not intended to replace international and national regulations for working in confined spaces, but merely to raise awareness of the subject.

It is concluded that accumulation of hydrogen in the top of a confined space is an added risk compared to natural gas. This is caused by the low density of hydrogen.

The health risks of hydrogen are comparable with natural gas. No known significant effects of critical hazards have been identified.

There may be national occupational health and safety regulations in force that contain detailed requirements with respect to the issues addressed here. These national regulations generally take precedence over the information provided in this document.

Hydrogen

Hydrogen is the most abundant element in the Universe, which under normal conditions is in a gaseous state, but is not free on Earth. It is not a primary source of energy, it is a fuel that has to be produced through transformation processes and can be easily stored.

The application of hydrogen contributes to reductions in greenhouse gas emissions.

Hydrogen can be converted from electricity (e.g. renewable energy sources) through electrolysers and injected into the existing natural gas grid for storage and subsequent use in a range of different applications (power generation, heat supply, transport applications such as fuelled urban gas buses or passenger cars).

Hydrogen can be injected into gas networks to further promote renewable energy sources, decarbonise the gas grid and provide long-term energy storage.

Many industries use hydrogen in its liquid and gaseous forms in manufacturing processes to produce chemicals, food and electronic devices.

2. Hydrogen risks according to the Safety Data Sheet (SDS)

Pressurised gases should only be handled by experienced and properly trained persons. Care must be taken since hydrogen is a gas, odourless and colourless in the event of a leak.

Hydrogen (CAS number: 1333-74-0) is classified according to the Regulation (EC) No. 1272/2008 as:

- Hazard statements

H220	*An extremely flammable gas*	
H280	*Gases under pressure, danger of explosion if heated.*	

- Precautionary statements

P210	*Keep away from heat, hot surfaces, sparks, open flames and all other sources of ignition. Do not smoke.*
P377	*In case of leakage of burning gas do not extinguish, unless the leak can be stopped without danger.*
P403	*Store in a well ventilated place.*

The risks of hydrogen compared to methane follow from their properties:

Property	**Methane (CH_4)**	**Hydrogen (H_2)**
Minimum Ignition Energy (mJ)	0,28	0,017
Auto-ignition temperature (°C)	537	560
LEL-UEL[1] (vol %)	4,4 - 17	4 - 77
Molecular weight (g/mol)	16	2
Relative density	0,55	0,07

Table 1: Methane and hydrogen properties

[1] LEL – UEL: Lower Explosive Limit – Upper Explosive Limit

3. Confined spaces

Containers and confined spaces are areas surrounded on all sides or predominantly by solid walls in which, due to their spatial confinement, insufficient air exchange or the substances, mixtures, impurities or facilities contained or introduced into them, particular hazards exist or can arise that can be caused by the potential danger usually prevailing in the workplace. Areas that are only partially surrounded by solid walls, but in which, due to the local conditions or the construction, hazardous substances can accumulate, or a lack of oxygen can arise, are narrow spaces within the meaning of this technical note. A confined space is also any space with limited entry and exit openings and unfavourable natural ventilation, in which toxic or flammable pollutants may accumulate, or have an oxygen-deficient atmosphere, and which is not designed for continuous occupation by the worker.

The risks in these spaces are multiple, since in addition to the accumulation of toxic or flammable substances and lack of oxygen, there are also those caused by the narrowness, discomfort of working positions, limited lighting, etc.

- Confined spaces that are open at the top and are so deep that they are difficult to ventilate naturally such as ditches.
- Confined spaces that are closed at the top with a small entrance and exit opening such as storage tanks / gasometers, compressors, gas treatment facilities like dehydrators or desulfurization towers, vaporizers, underground technical rooms, tunnels / service galleries, sewers, …

Figure 1: Work in a confined space

4. General risks of confined spaces.

The following risks, apart from the dangerous nature of the indoor atmosphere, are due to the poor material conditions of the space as a workplace:

- Fire or explosion hazard
- Loss of consciousness due to the accumulation of hazardous gases,
- Mechanical risks, sharp and protruding elements
- Trapping,
- Collisions and blows,
- Risks of electrocution due to contact with live metal parts,
- Falls to different levels and at the same level,
- Falling objects inside while working,
- Bad postures,
- Thermal risks due to extreme heat or cold environments,
- Noise,
- Vibrations,
- Poor lighting,
- Risk of biological infections

Figure 2: Control of the atmosphere before entering in a confined space

5. Specific risks of hydrogen in confined spaces

Specific risks related to hydrogen in confined spaces are caused by the special conditions in which this type of work is carried out, which can give rise to the risks of asphyxiation, fire or explosion and intoxication.

5.1. Asphyxiation

The air contains 21% oxygen in normal conditions. If this is reduced, symptoms of asphyxiation occur and become more severe as this percentage decreases.

Asphyxiation is a consequence of the lack of oxygen and is basically caused by the consumption of oxygen or its displacement by other gases. Hydrogen has the potential to produce oxygen deficiency, especially in the top of the confined space because of its low density (See Table 1). If hydrogen is accumulated in a confined space in sufficient concentrations, it is an asphyxiant (like any other gas except oxygen). At high concentrations in the air, hydrogen produces a decrease in oxygen which can cause suffocation, loss of consciousness or mobility and respiratory arrest.

5.2. Fire and explosion

In a confined space, an explosive atmosphere can be created with extraordinary ease. Hydrogen is flammable in concentrations between [LEL, in vol %] 4% and [UEL, in vol %] 77% in air, which is a very wide range compared to other common fuels like methane (4,4% – 17%). In addition, only a very low ignition energy is required to cause hydrogen to explode (See Table 1). The concentration of hydrogen can easily reach the lower explosion limit (LEL = 4%) if there is a leak in a confined space without ventilation. A leak in the open air would simply rise rapidly and spread. Hydrogen ignites more easily than methane as stated in the Table 1. Hydrogen flames are difficult to see in daylight unless they contain impurities and their radiant heat is low, so you cannot feel the presence of a flame until you are very close to it. If an unintended hydrogen release finds an ignition source then a fire or explosion occurs.

In the case of a high pressure release the fire burns back to source and a jet fire is generated. Therefore, when considering fires in enclosed spaces, the influences of surfaces and barriers should be borne in mind alongside the phenomenon associated with free jet fires. If the hydrogen is stored at high pressure it will generally ignite after release, producing a ‘jet fire’.

Beyond overpressure associated with the stored gas, flammable gases like hydrogen can burn or combust. The hydrogen accumulates in the upper parts forming clouds whose complete combustion takes place very fast. If a cloud of gas is ignited, the rapid combustion of hydrogen can create an overpressure. This is the common perception of an 'explosion'.

The primary measure of explosion protection is to avoid the occurrence of dangerous explosive atmospheres by taking measures. The formation of an explosive atmosphere is considered to be prevented if it is permanently ensured that the concentration of the gases, vapours, mists or dusts mixed with air is far below LEL, f.i. 30% or 50% of the LEL.

5.3. Toxicity

As mentioned above, hydrogen is an element that is not toxic. No known significant effects of critical hazards have been identified for inhalation.

6. Preventive measures for work in confined spaces.

Generally speaking, the strategy for making a hydrogen facility safe, in terms of risks of fire and explosion, should follow the following hierarchy:

- First, take steps to ensure that a flammable atmosphere does not develop;
- Second, avoid any source of ignition around where a flammable atmosphere can form;
- Third, use segregation, suppression, containment, and other mitigation techniques to reduce any exposure to the effects of fires and explosions.

Before entering into a confined space, the risks associated with all hazards must be examined (risk assessment) and appropriate measures taken. All hazards must be determined and all necessary protective measures defined. Due to the high risk potential, it must always be checked whether working in containers, silos and confined spaces can be avoided. The concerns of working in containers, silos and confined spaces must be taken into account when planning and setting up the systems. When designing the accesses, not only the relevant standards must be taken into account, but above all the planned access and rescue procedures as well as the personal protective equipment to be used:

- Flame-retardant anti-electrostatic clothing
- Safety glasses and gloves
- In case of emergency breathing apparatus.

When hydrogen might occur in confined spaces, ventilation must be ensured and controlled. It is one of the most efficient and usual safety measure in order to avoid the formation of a dangerous explosive atmosphere. Ventilation can be used to control an explosive atmosphere (resulting from a leak) in different ways, such as:

- To avoid the accumulation of gas by extracting the combustible gas thus avoiding the formation of an explosive atmosphere;
- To reduce the volume of the explosive atmosphere (dilution effect);
- To keep the presence of possible explosive gases as low and as short as possible.

Other measures are:

- Odorization of gas;
- Escape routes;
- Education and training of personnel;
- Historical records and previous risk analysis experience;
- Systematic methods such as a Job Safety Analysis (JSA) should be used in preparation of the work.

Regarding hydrogen no additional personal protective equipment (PPE) is required compared with natural gas.

7. Conclusion

Specific risks for hydrogen in confined spaces are accumulated in the upper parts of confined spaces, a very wide concentration range in which hydrogen is flammable and explosive, a very low ignition energy and asphyxiation. These risks can be mitigated by ventilation and measurements.

Those who issue work permits and those who work in the confined spaces need to be trained on these specific risks related to hydrogen.

The health risks of hydrogen are comparable with those of natural gas. No known significant effects of critical hazards have been identified.

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8. References

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