Safety Human Factors Information

Prepared by WG-16 Safety Info HF - 14/24

Organisation

Human Factors in Hydrogen Applications

Hydrogen: Hydrogen is a unique gas that behaves in a different way to other flammable gases. People working with or near hydrogen installations need to understand and take extra care for these reasons.

Target Audience: Any professional organisation dealing with hydrogen and related installations including designers and suppliers.

Learning more about Hydrogen

If the answer to any of the questions below is 'no', then you need to take action

1.	Are personnel trained in the properties of hydrogen, e.g. flammability range, explosion limits, low ignition energy, lowest molecular weight, high diffusion speed, heating effect of expansion, that are relevant to their work?	☐
2.	Are personnel aware of the implications of hydrogen's very low viscosity (leaks/permeates very easily)?	☐
3.	Do all personnel understand the unique aspects of hydrogen fire and actions to be taken in an emergency? (e.g. almost invisible flame,…)	☐
4.	Do employees and contractors understand the actions to take in the event of a hydrogen gas leak?	☐
5.	Do employees and contractors understand the actions to take in the event of a fire involving hydrogen?	☐
6.	Do employees and contractors understand the actions to take in the event of a liquid hydrogen leak or spill?	☐
7.	Are personnel aware of the potential cross sensitivity of some (e.g. carbon monoxide) sensors in gas monitors to hydrogen?	☐
8.	Has the need for a hydrogen personal gas monitor been defined for each role?	☐

EUROPEAN INDUSTRIAL GASES ASSOCIATION *AISBL*
AVENUE DES ARTS 3 – 5 ♦ B-1210 BRUSSELS
PHONE +32 2 217 70 98 ♦ FAX + 32 2 219 85 14 ♦ E-mail : info@eiga.eu - www.eiga.eu

9.	Do people understand that the vapour above an evaporating liquid hydrogen pool has approximately the same density as air?	☐
10.	Are all hydrogen scenarios included in the site emergency plan?	☐
11.	Is the limited compatibility of materials with hydrogen understood and applied in the selection or specification of equipment?	☐
12.	Are ATEX zones defined around hydrogen equipment?	☐
13.	Are all people in the vicinity of the installations made aware of the extent and shape of the ATEX zones?	☐
14.	Is all fixed, transportable or portable equipment taken into the zone ATEX compliant?	☐
15.	Do people entering the hydrogen ATEX zone wear appropriate PPE (e.g. antistatic, flash fire protective clothing and partially conductive safety footwear)?	☐
16.	Are the specific properties of hydrogen considered in the process hazard review for the installation?	☐
17.	Is the location and direction of all hydrogen vents assessed in the facility siting review?	☐
18.	Are the specific properties of hydrogen considered in all task risk assessments?	☐
19.	Do your design standards have hydrogen specific criteria for equipment selection?	☐
20.	Do your energy isolation procedures (LOTO) define specific isolation requirements for hydrogen or flammable gases?	☐
21.	Do you have a documented maintenance plan for your hydrogen installations?	☐
22.	Are earthing continuity requirements documented and periodically checked?	☐
23.	Are there documented purging/venting procedures that include clear definitions of safe level of residual oxygen before hydrogen is (re-)introduced?	☐
24.	Has the site inventory been evaluated to understand whether it is subject to Seveso Directives?	☐
25.	If yes are the Seveso obligations for sites which include hydrogen installations properly understood?	☐
26.	Do personnel understand that liquid hydrogen transfer hoses are cold enough to liquify air on the outside, creating a local oxygen enriched atmosphere?	☐

What can we do about it?

Management responsibility:

The factors that can lead to incidents and accidents in hydrogen installations and tasks are often related to the unique properties of hydrogen.

To avoid such incidents and accidents and improve the safety of people on hydrogen installations, it is important that management should, as a minimum, ensure that:

EUROPEAN INDUSTRIAL GASES ASSOCIATION *AISBL*
AVENUE DE L'ASTRONOMIE 30 ♦ B-1210 BRUSSELS
PHONE +32 2 217 70 98 ♦ E-mail : info@eiga.eu - www.eiga.eu

- People are trained and competent to perform tasks associated with hydrogen equipment (including those people involved in design, specification and procurement). [1]
- Detailed training material (including relevant information from the safety data sheet) about the specific properties of hydrogen is available, understood and used.
- There are structured processes to identify, assess and address human error potential during tasks on hydrogen installations as part of the task risk assessment. [2]
- Clear work instructions for all foreseeable tasks on hydrogen installations are available. [3]
- Precise energy isolation procedures are in place and lockout equipment is available.
- Activities requiring work permit are defined.
- Clear procedures for working alone exist, are understood and followed.
- Legally required Explosion Protection Documents including hazardous zone drawings are available, and that the limits of all zones are clearly identified. [4]
- Documented hazard and risk reviews identifying foreseeable accident scenarios and emergency actions to be taken exist. [5]
- An effective change management process is in place for equipment, people and procedures involved in hydrogen installations. [6], [7]
- Criteria for reporting, investigating and addressing leaks and other incidents are defined.
- The safety culture around work on hydrogen installations focusses on improvements and not for example normalizing reports of small leaks.
- Supplies of the correct spares and consumables for use with hydrogen are available.

Defences against incidents at hydrogen installations:

Defences are in this context any technical or organizational measures intended to prevent or reduce the likelihood of human errors and to mitigate the consequences of accidents. Management is responsible for implementing effective defences. However, accident reports often show that management decisions contributed to breakdown of these defences.

	Incident Example	**Human Cause**	**Organizational Defence**
	Incorrect o-ring used during maintenance resulting in leak and fire	Correct o-ring type not available at site.	Management are responsible to ensure that supplies of the correct spares and consumables for use with hydrogen are available. Technicians should be adequately trained to select the right components for maintenance.

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AVENUE DE L'ASTRONOMIE 30 • B-1210 BRUSSELS
PHONE +32 2 217 70 98 • E-mail : info@eiga.eu - www.eiga.eu

	Incident Example	Human Cause	Organizational Defence
	Ignition of hydrogen at a relieve device tail pipe.	Earthing of tail pipe not done. Missed in design, hazard review and commissioning of the installation.	Management needs to ensure that design standards for hydrogen installations include clear earthing requirements. Designers need to be sufficiently trained in the unique properties/hazards of hydrogen.
	Driver running towards a leaking trailer connection was burnt by the invisible hydrogen flame. He did not survive.	Incorrect action taken when the fill connection leaked. Improper response to a leak/emergency scenario.	Personnel must understand the unique aspects of hydrogen fire and actions to be taken emergencies (e.g. almost invisible flame,…).
	Hoses procured for hydrogen filling developed bubbles under the outer wall. No leak or injury	Incorrect hose material specification for use with hydrogen.	Management must ensure that design standards include hydrogen compatibility specification of “soft” materials (such as hoses, O-rings, valve seats) as well as metals. Procurement as well as those specifying equipment must be sufficiently trained in the unique properties/hazards of hydrogen.
	An operator purged pipework with oxygen by mistake. Realising the error, he then purged out the oxygen however a residual amount remained in the piping, which ignited when hydrogen was introduced causing an explosion and fire. First degree burns to operator’s forearms. The fire was fed for 10 minutes.	Error adding oxygen as purge gas. Residual oxygen level too high after initial purge There was no emergency shutoff valve	Ensure optimal design and thorough risk assessments. Requirement for and location emergency shutoffs must be included in early design hazard review for hydrogen installation. Note: location of manual emergency shut-off buttons should consider direction and distance of foreseeable release or flame.
	An analyser cabinet exploded after hydrogen leaked from instrument tubing within the cabinet.	Teflon wrapped screw connection was not sufficiently tightened. The cabinet had insufficient ventilation.	Ensure optimal design and thorough risk assessments. Pre-startup inspection should be documented and completed. Personnel must understand the ATEX aspects of hydrogen installations.

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AVENUE DE L’ASTRONOMIE 30 ♦ B-1210 BRUSSELS
PHONE +32 2 217 70 98 ♦ E-mail : info@eiga.eu - www.eiga.eu

Useful Reference Information

Unless otherwise specified, the latest edition shall apply.

[1] HF 02, *Individual – "Training and Competence"* www.eiga.eu

[2] HF 13, *Organisation – "Human Reliability"* www.eiga.eu

[3] HF 04, *Task – "Design and Effectiveness of Procedures"* www.eiga.eu

[4] Directive 2014/34/EU, "*relating to equipment and protective systems intended for use in potentially explosive atmospheres"* https://eur-lex.europa.eu/

[5] HF 06, *Organisation – "Site Emergency Response"* www.eiga.eu

[6] DOC 51, *Management of Change* www.eiga.eu

[7] HF 10, *Organisation – "Managing Organisational Change"* www.eiga.eu

Further Useful Information

Hydrogen Basic Information Hydrogen Fuel Basics | Department of Energy

DOC 06*, Safety in Storage, Handling and Distribution of Liquid Hydrogen* www.eiga.eu

DOC 211, *Hydrogen Vent Systems for Customer Applications* www.eiga.eu

DOC 242, *Safety of Hydrogen, HyCO production and Carbon Capture* www.eiga.eu

TB 42, *Welded Gaseous Storage Vessels and Hydrogen Compatibility* www.eiga.eu

DOC 15, *Gaseous Hydrogen Installations* www.eiga.eu

DOC 121, *Hydrogen Pipeline Systems* www.eiga.eu

DOC 100, *Hydrogen Cylinders and Transport Vessels* www.eiga.eu

DOC 102.07, *Safety Audit / Assessment Tool – Hydrogen Compression, Purification and Cylinder Filling*

DOC 235, *Industrial Gas Pipeline Integrity Management* www.eiga.eu

DOC 215, *HYCO Plant Gas Leak Detection and Response Practices* www.eiga.eu

DOC 185, *Safe Start Up and Shutdown Practices for Steam Reformers* www.eiga.eu

DOC 23.07, *Safety Training Leaflet Hydrogen* www.eiga.eu

DOC 171*, Storage of hydrogen in systems located underground* www.eiga.eu

DOC 246*, Guideline for Small Scale Hydrogen Production* www.eiga.eu

Directive 1999/92/EC *on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres* https://eur-lex.europa.eu/

Directive 2012/18/EU *Control of major-accident hazards involving dangerous substances ("Seveso")* https://eur-lex.europa.eu/

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