STANDARD PROCEDURES FOR HYDROGEN SUPPLY SYSTEMS

Doc 250/24

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As part of a programme of harmonisation of industry standards, the European Industrial Gases Association, (EIGA) has published EIGA Doc 250, *Standard Procedures for Hydrogen Supply Systems*, jointly produced by members of the International Harmonisation Council and originally published by the Compressed Gas Association as CGA H-7, *Standard Procedures for Hydrogen Supply System*.

This publication is intended as an international harmonised standard for the worldwide use and application of all members of the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association, and Japan Industrial and Medical Gases Association (JIMGA). Each association's technical content is identical, except for regional regulatory requirements and minor changes in formatting and spelling.

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Table of Contents

1 Introduction

With the increased emphasis on renewable and clean energy, the hydrogen space is seeing tremendous growth both in activities and in entrants to the space. Much of that growth is taking place in near-consumer locations, such as gas stations and convenience stores, as opposed to the more traditional industrial settings historically associated with the use of hydrogen. Additionally, more personnel are becoming involved with the use of hydrogen.

It is important that these new entrants learn the best practices for working safely with and around hydrogen. The general public has concerns about the safety of hydrogen and must be comfortable with the work of those in the hydrogen space.

2 Scope

This publication provides recommended best practices and standardised procedures for personnel using hydrogen supply systems. The practices and procedures are limited to bulk gaseous and cryogenic liquid hydrogen and do not address nonbulk (cylinders) supply systems. This publication addresses processes for commissioning, filling, decommissioning, maintaining, and operating hydrogen supply systems.

This publication assumes that the hydrogen supply system has been designed and installed in accordance with the appropriate codes, standards, and local permits, as well as having an emergency preparedness plan in place. Users are encouraged to read the applicable codes and standards listed in Section 6 and Section 7 before undertaking any work on a hydrogen supply system. This publication does not replace the content found in those standards but is intended to supply best practices for working around hydrogen and with equipment in hydrogen service.

This publication contains general guidelines for any equipment that is storing, processing, or transporting hydrogen that otherwise has no procedural guidance. It is not intended to replace any system-specific standards or guidelines.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Authority having jurisdiction (AHJ)

Organisation, office, or individual responsible for enforcing the requirements of a code or standard or responsible for approving equipment, materials, installations, or procedures.

NOTE—There may be multiple AHJs with various levels of responsibility and authority.

3.2.2 Asphyxiant

Gas which can cause suffocation when inhaled by man or animals.

NOTE—Although most gases, with the exception of air, oxygen, and a few others, are asphyxiant, the term is mainly used for gases not connected with other hazards, flammability, toxicity, etc.

3.2.3 Bonding

Electrical connection between components to ensure the static electric discharge to earth ground.

3.2.4 Cryogenic

Temperatures less than –90 °C (–130 °F).

3.2.5 Flammability

Ability of a substance to ignite at some concentration in air.

3.2.6 Fire code

Code enforced by the authority having jurisdiction (AHJ). Typically, the model code is written by a national fire protection association (e.g., NFPA 1, *Fire Code®*) or by the International Code Council (i.e., *International Fire Code*) [1, 2]. [1]

3.2.7 Grounding

Practice of intentionally electrically connecting all exposed metallic items not designed to carry electricity in a room or building as protection from electric shock.

NOTE—grounding is also known as "earth grounding."

3.2.8 Inert gas

Nonreactive, nonflammable, noncorrosive gas such as argon, helium, krypton, neon, nitrogen, and xenon.

3.2.9 Process hazards analysis (PHA)

Set of organised and systematic assessments of the potential hazards associated with an industrial process.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

NOTE—A PHA provides information intended to assist in making decisions for improving safety and reducing the consequences of unwanted or unplanned releases of hazardous chemicals.

3.2.10 Purge

Elimination of an undesirable contaminant by displacement with another fluid.

4 General safety principles

The unique properties of hydrogen provide the reasoning for the safety practices described in this section. Section 5 provides specific examples of how these elements are put into practice.

4.1 Hydrogen properties

Global Harmonized System of Classification and Labelling of Chemicals (GHS) list hydrogen as "an extremely flammable gas." It is the lightest of all elements. It is naturally buoyant and lighter than air in gaseous form. However, hydrogen can migrate along the ground when in liquid or cryogenic gaseous form and is less buoyant than air. When warmed up, hydrogen can rise and become trapped under obstructions such as roofs or enclosures.

Hydrogen has a low ignition energy, high burning velocity, and a wide flammability range. Releases of hydrogen will create a flammable cloud that will ignite in the presence of an ignition source. Personnel who are involved with any activity within the hydrogen site shall be aware of the dangers caused by ordinary everyday items like cell phones, lighters, cigarettes, watches, or standard flashlights. Energy from these items can cause an explosion in hydrogen-enriched atmospheres. Additionally, static electricity can be an ignition source. All sources of ignition should be eliminated. Burning hydrogen can result in a flash fire and subsequent jet fire. A confined cloud can result in an explosion. Hydrogen burns with an almost invisible bluish flame. The flame is so pale in daylight that a person can feel heat or be burned by hydrogen that was accidentally ignited without having seen a flame.

Large volumes of hydrogen can displace air and serve as an asphyxiant. Since hydrogen is flammable at 4% in air, it is a flammability hazard well before it can act as an asphyxiant.

Liquid hydrogen has a temperature that can liquify air. Exposed bare piping will generate air condensation that can create both a cryogenic burn hazard and fire hazards from oxygen-enriched environments (i.e., a concentration greater than 23.5% by volume).

More detailed information can be found in EIGA Doc 23.07 [3].

4.2 Safe venting of hydrogen

Intentional hydrogen releases shall be directed to a vent stack that is designed to have sufficient height and separation from equipment, structures, and exposures to prevent expanding gas restrictions (confinement) and to ensure potential heat from hydrogen flames are not in the proximity of people and structures.

Venting cryogenic gaseous hydrogen, which is not as buoyant as warm gaseous hydrogen, can create a flammable hydrogen cloud that will drift downwind. Cryogenic releases create visible water vapor clouds. These clouds should be observed to avoid flammable mixtures at or near grade by adjusting the vent rate.

Vented hydrogen is subject to ignition from static electricity and lightning. Some recommended practices for venting hydrogen in the presence of lightning are as follows:

- Avoid venting for 30 minutes after lightning has been seen. Reset the 30-minute no-vent time when new lightning has been seen; and
- During that 30-minute period, cease outdoor work.

The ignition of vented hydrogen at the stack exit is not uncommon. Properly engineered vent stacks take such fires into consideration. It is important to isolate the vented hydrogen, when possible, to minimize the stack fires duration.

Water shall not be sprayed onto a vent stack.

See EIGA Doc 211, for more details about venting and how to size a stack that releases hydrogen at a safe elevation [4].

4.3 Grounding of hydrogen supply systems

To reduce the chances of hydrogen ignition, ground all equipment in hydrogen service and all associated equipment for the hydrogen supply system. The ignition of hydrogen clouds can come from a wide range of sources, common to other flammable gases, but also includes static electric discharge from friction caused in transfers and venting. Electrical zone classifications outlined in NFPA 70, *National Electric Code®* and NFPA 2, *Hydrogen Technologies Code*, shall be followed [5, 6]. Some typical causes of ignition are arcs from electrical equipment and open flames. Other sources are sparks from working with tools or electrical devices. Careful attention to grounding of hydrogen equipment is critical.

Grounding electrodes shall have clean metal surfaces and be free of paint or other nonconductive materials. The grounding system shall have a resistance to ground of 25 ohms or less. See IEC 60079 [5] and EN 1127 [15]

Provisions in laws and regulations may vary by country. In this case, the jurisdictional laws and regulations shall take precedence.

EIGA Doc 6 provides details about grounding [7].

4.4 Personal protective equipment

Appropriate personal protective equipment (PPE) shall be worn when working on a bulk hydrogen supply system or within the separation distances outlined in EIGA Doc 15 [6] . The appropriate PPE includes the following:

- eye protection (glasses or shields);
- gloves (leather or cryogenic);
- hard hats;
- safety shoes;
- hearing protection (for noise from venting and equipment operation);
- flame retardant (FR) clothing; and
- on-person gas monitoring to test area continually for a flammable atmosphere.

EIGA Doc 136, provides further information about PPE [8].

NOTE—These PPE requirements do not apply to individuals who are dispensing hydrogen to a vehicle.

4.5 Purging equipment and piping

A key step in working on hydrogen supply systems is to purge the system with an inert gas, usually nitrogen, to remove air before hydrogen is added to the system, or to remove hydrogen before opening the system to the atmosphere. See Figure 1 and Figure 2 for purging systems into and out of service.

Hydrogen supply systems shall be purged into service for operation. Hydrogen supply systems shall be purged out of service for maintenance and repair and other procedures, which are considered to be out of normal operation. This section provides the overall considerations for purging.

Liquid hydrogen supply systems shall be free of gases other than hydrogen or helium prior to introduction of liquid hydrogen. Liquid hydrogen will freeze solid any gas except for hydrogen and helium.

Hydrogen shall be purged from the system with nitrogen before moving equipment from the supply system site.

Systems should be purged with inert gas before introducing gaseous hydrogen. The level of oxygen shall be less than 1.0% concentration as measured with a handheld or personal gas monitor.

When removing a liquid hydrogen supply system from service, liquid hydrogen shall be removed and the system allowed to warm up before purging with nitrogen.

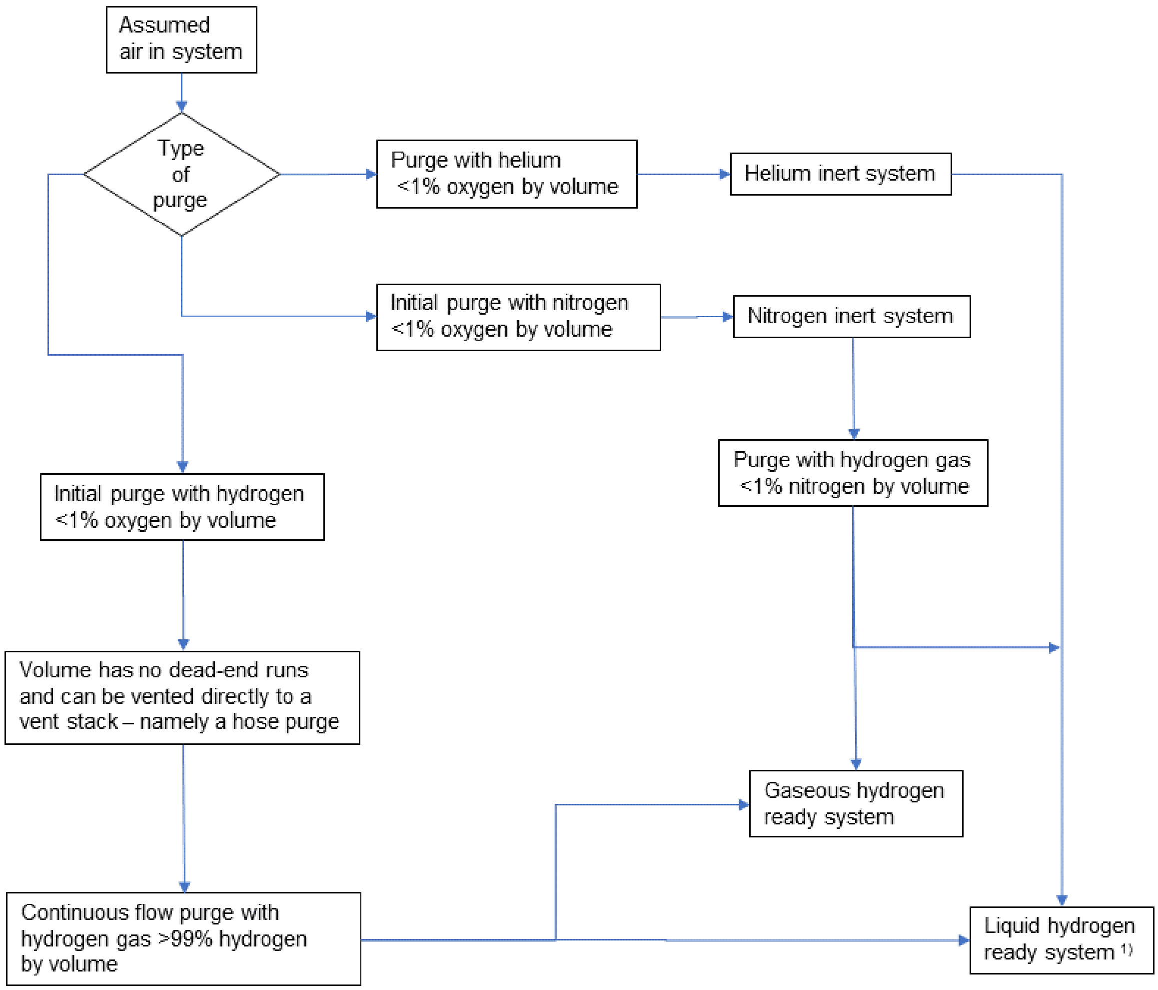
A continuous flow purge is acceptable when there are no branch connections. The minimum flow rate should be 10 volumes of the equipment storage.

Where a flow purge is not possible, such as working on tanks, receivers, or other vessels, a pressure purge can be used with the following process, see Figure 1 and Figure 2:

- Pressurise to 200 kPa (30 psi); [2]
- Allow pressure to "soak" for 5 minutes;
- Soak time can start at first positive pressure;
- Vent to less than 7 kPa (1 psi);
- Repeat until vented gas is in specification; and
- Repeat no fewer than 7 times.

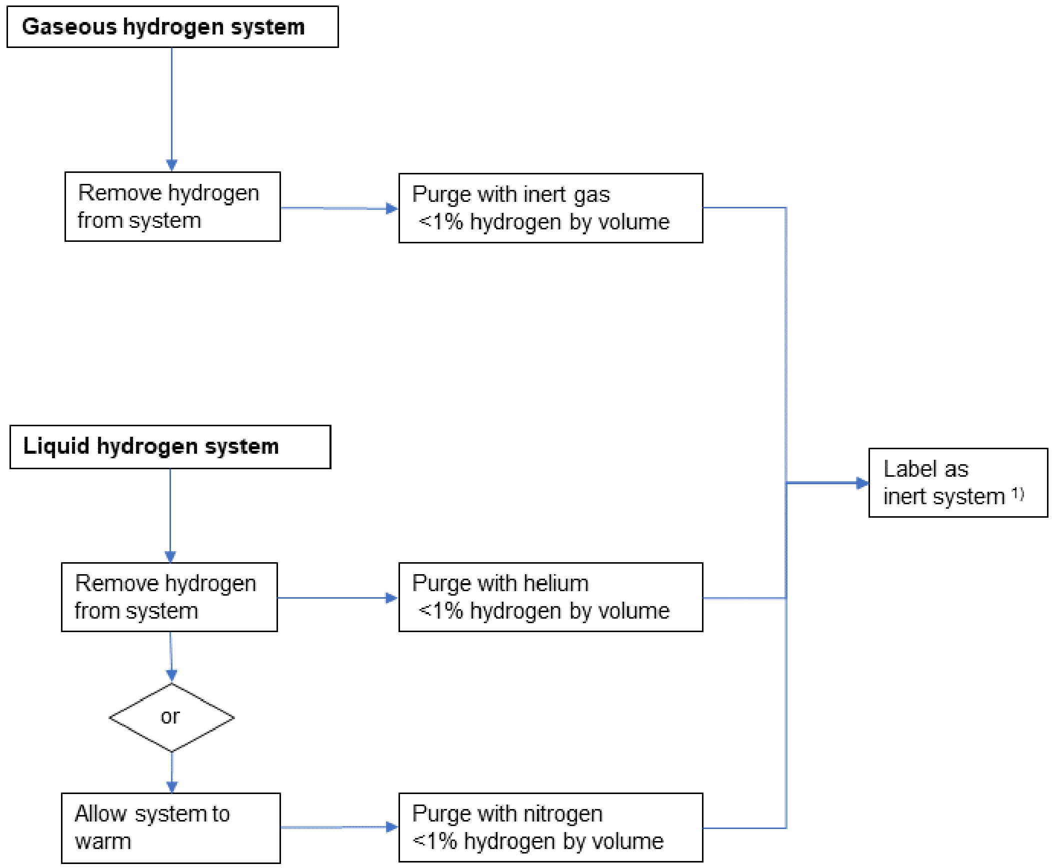
See EIGA Doc 6 and EIGA Doc 15 for more information about purging requirements [7, 6].

[2] psi, bar, and kPa shall indicate gauge pressure unless otherwise noted as (psia; bar, abs; and kPa, abs) for absolute pressure or (psid; bar, dif; and kPa, dif) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [9].



1) Only introduce liquid hydrogen to systems specifically designed for liquid hydrogen cryogenic service.

Figure 1 - Purging hydrogen supply systems into service



1) Label the date of inerting and the gas used.

Figure 2 - Purging hydrogen supply systems out of service

4.6 Safety planning

Documented safety planning is critical to consistent execution as well as a means to capture best practices. The following subsections outline specific elements of safety planning that shall be considered but does not constitute an exhaustive list of elements of a safety plan.

These procedures shall be posted with a site plot plan that provides a visual image of the route to follow to exit the site and proceed to the assembly area. In some facilities more than one set of procedures and plot plan are necessary to assure this information is readily available to personnel. For more information, see [6, 10].

4.6.1 Developing a process hazard analysis

The first step in developing a safety plan is to prepare and document a process hazard analysis (PHA). A PHA can come in various forms, for example, a hazard identification (HAZID), hazard and operability analysis (HAZOP), failure mode and effects analysis (FMEA), What-If, etc. An example of a HAZOP can be found in Seveso II Directive [11]. The PHA should be documented and used to develop the safety plan.

The safety plan should include standard operating procedures (SOPs), emergency procedures, and reference to the PHA.

Management of change (MOC) should be used to update the safety plan. See EIGA Doc 186, for more information about the MOC process [12].

The SOPs incorporated in the safety plan should be specific to the hydrogen supply system. The emergency procedures portion of the safety plan can be more broadly applied. The following sections outline the emergency procedures portion of the safety plan.

4.6.2 Emergency procedures

Emergency procedures document the required behaviors of operators during an emergency. They are noted below in three categories based on the level of training.

See Appendix A4 for best practices in the event of a hydrogen spill.

4.6.2.1 Emergency procedures for personnel

Each site shall prepare emergency procedures that address the following to ensure that personnel are removed from danger during an emergency:

- recognising emergency situations and alarms;
- evacuating and assemble; and
- re-entering the facility.

If a site has existing emergency procedures, these items shall be incorporated into those procedures.

4.6.2.2 Special roles for trained operating personnel

The following responsibilities require special training and shall be considered in preparation for an emergency:

- emergency coordination;
- contact with professional emergency responders;
- hydrogen supply system shutdown;
- site security;
- first aid; and
- taking attendance at point of assembly.

These roles, among others, also require alternate personnel who can ensure that these duties are fulfilled at all times.

4.6.2.3 Emergency responders

Responding directly to a hydrogen release requires specialised training. Community resources (i.e., fire department) that are anticipated to respond to emergencies, including the hydrogen system, should be made aware of system details and associated hazards. Detailed instructions for dealing with emergencies at hydrogen storage (stationary) systems and transportation (mobile) equipment can be found in the following resources:

- for stationary equipment—safety data sheets (SDSs) from hydrogen suppliers; or
- for mobile equipment— ADR, Agreement concerning the International Carriage of Dangerous Goods by Road [13].

Additionally, emergency responders shall be familiar with the following:

- establishment of an exclusion zone;

- fire response;
- equipment safety systems;
- hazardous materials storage and use, and associated mitigation equipment; and
- rescue of personnel from the evacuated area.

4.6.3 Site map

For the purpose of documenting the site for the safety plan, it is important to create the map that identifies critical locations. Those locations include, but are not limited to:

- emergency resources (water);
- fire extinguishers and hoses;
- points of egress;
- gas and/or flame detectors;
- areas requiring PPE;
- emergency vehicle access;
- hazardous materials storage and use;
- classified areas;
- electrical zones and high voltage areas; and
- points of anticipated venting.

4.6.4 Personnel training

Personnel training is necessary and required by regulations to ensure safety when working on hydrogen equipment. The training program shall include but not be limited to instruction on the elements of the safety planning. The program shall define the personnel who are trained. Periodic retraining is recommended to ensure that the personnel skill level remains current. Satisfactory completion of training/retraining shall be documented and maintained.

Additional training sessions can be scheduled when necessary.

Training shall be in accordance with national/regional regulations, such as EU-OSHA, DOT, and Fire Code [10, 14, 1, 2].

See EIGA Doc 186 for more information about training and documentation [12].

4.7 Additional procedures

Additional procedures and processes can be found in Appendices A and B:

- See Appendix A1 for details on lockout/tagout methodology;
- See Appendix A2 for details on hot work;
- See Appendix A3 for details on contract work; and
- See Appendix B for details on marking and labeling.

5 Examples of implementing general safety practices

The following subsections provide an outline of how the general safety practices are applied and the special exceptions that are considered. These examples are intended to be general in nature and not comprehensive as compared to an operation procedure.

There are existing standards and guidelines for the design principles for the various components of a hydrogen supply system, which include:

- EIGA Doc 6 for details about bulk hydrogen supply systems [7];
- CGA G-5.4, *Standard for Hydrogen Piping Systems at User Locations*, for details about hydrogen piping systems [16]
- EIGA Doc 23.07 for general information about hydrogen [3]; and
- EIGA Doc 211 for details about hydrogen vent systems [4].

5.1 Commissioning and initial fill

An overall inspection of the hydrogen supply system, including verification of completeness, correct operation, and function of safety systems, is necessary prior to commissioning. Equipment might have been purged with an inert gas before commissioning begins, but this condition shall be verified before putting the system into hydrogen service. For commissioning of liquid or gaseous supply systems, begin by purging the system into service (see 4.5 and Figure 1). See Appendix A6 for best practices of leak checking.

Commissioning a tank requires permits, some of which can vary by jurisdiction. Prior to commissioning, the required permits shall be in place.

5.1.1 Venting

Commissioning and initial filling requires more venting than normal operation. Some of that venting will be removal of air and purge gases.

If commissioning and performing an initial fill of a cryogenic system, there will also be venting of cold gas, which can lead to a more substantial volume of gas and will require venting for a longer period of time. Observing the vent gases at initial fill of a cryogenic system is useful to assess whether the equipment has achieved its operating temperature. When such equipment is warm, the vent gases will exit warm. As the equipment cools down, the vent gases will cool down and frost will be visible on the vent stack. The presence of frosting and water vapor clouds from the vent indicate that the tank is approaching operating temperature.

5.1.2 Grounding

Ensure equipment is grounded as intended by design. Verify grounding resistance to not exceed 25 ohms. Stationary system vent stacks shall be independently grounded. Electrical bonding clamps should be provided for grounding of delivery equipment.

Provisions in laws and regulations may vary by country. In this case, the jurisdictional laws and regulations shall take precedence.

5.1.3 Personal protective equipment

At the start of commissioning, hydrogen is likely not present on the site and the requirements for PPE can be different. It is recommended that the PPE requirements outlined in 4.4 are implemented during the commissioning process. Increased numbers of personnel are often present to support commissioning activities.

5.1.4 Purging

Allow sufficient time to purge the system. The purging process can potentially span more than one day. Ensure the availability of the inerting gas is sufficient to purge the equipment. Ensure that the necessary purge gas metering equipment is present.

5.1.5 Safety planning

Ensure training of personnel has been completed and safety plan is in place prior to receiving hydrogen onsite. If special processes (e.g., handling of inert gases) contain additional specific hazards, they should be included in the safety plan. All required placarding and signage shall be appropriately displayed prior to commissioning the system. Ensure that first responders have been notified that the hydrogen supply system is being commissioned.

Commissioning activities result in elevated noise levels. It might be necessary to inform outside parties of the noise level during commissioning.

5.2 Transferring hydrogen and routine deliveries

Prior to transfer operations, the delivery personnel should conduct an inspection of the equipment to ensure that it is safe to accept hydrogen.

5.2.1 Venting

Venting during transfer operations is focused on hose purges and fill circuit. Venting for any reason should be directed to a vent stack. A hose drain or vent should be used to depressurise the hose prior to disconnection.

Cryogenic trailers used for deliveries might also need to vent prior to departing from the site.

5.2.2 Grounding

Verify that grounding connections (bonding clamps) are in good working condition and are in place prior to transfer. The user should not rely solely on the bonding capability of the transfer hose.

5.2.3 Personal protective equipment

See 4.4.

5.2.4 Purging

Within normal purging, a sweep purge can be considered (potentially in combination with pressure swings). Particularly for liquid transfers, it is preferable to purge the vented gases from the customer system to the trailer vent, to avoid impurities migrating into the customer tank.

5.2.5 Safety planning

See 4.6.

5.3 Maintenance

The potential for accidents increases during maintenance procedures, as compared to normal operations, due to the need to disassemble and reassemble system components. Increased diligence to the general safety practices is important to mitigate these risks.

Hydrogen supply systems shall be maintained to remain in safe working order by developing and implementing a preventative maintenance program. The components of each hydrogen supply system should be identified in the preventative maintenance program and assessed for when and how they should be repaired or replaced.

For the purposes of this publication, the user should consider any maintenance activities on a system containing hydrogen as hot work due to the low ignition energy of hydrogen (see Appendix A2 for more information about hot work).

5.3.1 Venting

Before disassembling the system, residual hydrogen shall be vented to a safe location, preferably through a vent stack. If venting to a stack is not possible, the area and the method in which the residual hydrogen is vented shall be safely controlled considering the volume, pressure, and duration of the released hydrogen. A procedure to remove pressure and residual hydrogen, and to control potential low temperature exposures shall be developed and implemented (e.g., a residual energy deactivation procedure as defined in the EU-OSHA (USA 29 CFR 1910.147), [10]

5.3.2 Grounding

Maintenance can potentially interrupt the contiguous grounding of the system. Under these circumstances, the user should restore the electrical bonding as necessary.

5.3.3 Personal protective equipment

In addition to the general PPE specified in section 4.4, specific maintenance activities could require additional PPE.

5.3.4 Purging

Purging shall be done to ensure no exposures of personnel to flammable mixtures. Similarly, purging into service shall be done to ensure no exposures of personnel to flammable mixtures or residual contaminations. The user should consider pre-purging components before reinstallation to simplify final purging operations.

5.3.5 Safety planning

See 4.6. Additionally, for the safety considerations that are unique to maintenance and an example list of periodic inspections, see Appendix A5.

5.4 Decommissioning

Prior to executing a decommissioning effort, the AHJ shall be notified of the intent to decommission the system and a decommissioning plan shall be developed and may be required for review by the AHJ. It might be necessary to perform some inspection and maintenance activities to ensure the ability to safely perform decommissioning, see 5.3. This includes ensuring that valves operate properly, that all piping is present and intact, and that there is no encroachment of incompatible materials or processes, as expected in the decommissioning plan.

5.4.1 Venting

If de-inventorying the system of hydrogen that is to be recovered, the user should observe the guidance provided for transfer operations (see 5.2.1). If the receiving tank is new, the user should observe the guidance provided for commissioning activities (see 5.1.1). If venting to atmosphere through a vent stack, the user should consider the consequences (e.g., physical hazards and noise) of venting for an extended duration.

5.4.2 Grounding

Ensure equipment remains grounded as intended by design. Verify grounding resistance to not exceed 25 ohms. Stationary system vent stacks shall be independently grounded.

If hydrogen inventory is to be recovered and transferred to a receiving container, ensure bonding clamps are provided for the container.

5.4.3 Personal protective equipment

At completion of decommissioning, hydrogen might not be present on the site and the demands for PPE can be different. It is recommended that the PPE requirements outlined in 4.4 continue to be implemented during the decommissioning process. Increased numbers of personnel are often present to support decommissioning activities and all need PPE.

5.4.4 Purging

For decommissioning of liquid or gaseous supply systems, begin by purging the system out of service, see 4.5 and Figure 2.

Allow sufficient time to purge the system. The purging process can potentially span more than one day. Ensure the availability of the inerting gas is sufficient to purge the equipment. Ensure that the necessary inert gas metering equipment is present.

5.4.5 Safety planning

Ensure training of personnel has been completed and decommissioning plan is in place prior to de-inventorying hydrogen from the system. If special processes (e.g., handling of inert gases) contain additional specific hazards, they should be included in the decommissioning plan. All required placarding and signage shall be removed or covered when the system has been decommissioned. Ensure that first responders have been notified that the hydrogen supply system has been decommissioned.

Decommissioning activities result in elevated noise levels. It might be necessary to inform customer personnel and others on site of the noise level during decommissioning.

6 References

[1] Not applicable to Europe: NFPA 1, *Fire Code®*, National Fire Protection Association. www.nfpa.org

[2] *International Fire Code®*, International Code Council Headquarters. www.iccsafe.org

[3] EIGA Doc 23.07, *Safety Training Leaflet Hydrogen.* www.eiga.eu

[4] EIGA Doc 211, *Hydrogen Vent Systems for Customer Applications.* www.eiga.eu

[5] IEC 60079, *Explosive Atmospheres, International Electrotechnical Commission*. www.iecex.com

[6] EIGA Doc 15, *Gaseous Hydrogen Installations*, www.eiga.eu

[7] EIGA Doc 6, *Safety in Storage, Handling and Distribution of Liquid Hydrogen,*. www.eiga.eu

[8] EIGA Doc 136, *Selection of Personal Protective Equipment*, www.eiga.eu

NOTE—This publication is part of an international harmonisation programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonised regional references.

[9] Not applicable to Europe: CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry*, Compressed Gas Association, Inc. www.cganet.com

[10] EU-OSHA, www.osha.europa.eu/en/about-eu-osha

[11] Seveso II Directive 96/82/EC, *Control of Major-Accident Hazards Involving Dangerous Substances*, www.eur-lex.europa.eu/legal-content/EN\

[12] EIGA Doc 186, *Guideline for Process Safety Management*, www.eiga.eu

NOTE—This publication is part of an international harmonisation programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonised regional references.

[13] ADR , Agreement concerning the International Carriage of Dangerous Goods by Road www.unece.org/transport

[14] Not applicable to Europe: *Code of Federal Regulations*, Title 49 (Transportation) Parts 100-180, U.S. Government Printing Office. www.gpo.gov

[15] EN 1127, *Explosives Atmospheres. Explosion Prevention and Protection. Basic Concepts and Methodology*, www.cencenelec.eu

[16] EIGA Doc 121, *Hydrogen Pipeline Systems*, www.eiga.eu

[17] Directive 1999/92/EC, *Minimum Requirements for Improving the Safety and Health Protection of Workers Potentially at Risk from Explosive Atmospheres*, www.eur-lex.europa.eu/legal-content/EN

[18] Pressure Equipment Directive. www.eur-lex.europa.eu/legal-content/EN

[19] Seveso III 2012/18/UE. www.eur-lex.europa.eu/legal-content/EN

7 Additional References

CGA G-5.3, *Commodity Specification for Hydrogen*, Compressed Gas Association, Inc. www.cganet.com

EIGA Doc 172, *Combustion Safety for Steam Reformer Operation*, www.eiga.eu

EIGA Doc 185, *Safe Startup and Shutdown Practices for Steam Reformers*, www.eiga.eu

EIGA Doc 202, *Mechanical Integrity of Syngas Outlet Systems*, www.eiga.eu

EIGA Doc 210, *Hydrogen Pressure Swing Adsorber (PSA) Mechanical Integrity Requirements*, www.eiga.eu

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

EIGA Doc 230, *Safe Catalyst Handling in HYCO Plants*, www.eiga.eu

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

CGA P-12, *Guideline for Safe Handling of Cryogenic and Refrigerated Liquids*, www.cganet.com

CGA PS-31, *Position Statement on Cleanliness for Proton Exchange Membranes Hydrogen Piping/Components*, Compressed Gas Association, Inc. www.cganet.com

CGA PS-33, *Position Statement on Use of LPG or Propane Tank as Compressed Hydrogen Storage Buffers*, Compressed Gas Association, Inc. www.cganet.com

CGA PS-46, *Position Statement on Roofs Over Hydrogen Storage Systems*, Compressed Gas Association, Inc. www.cganet.com

CGA PS-48, *Position Statement on Clarification of Existing Hydrogen Setback Distances and Development of New Hydrogen Setback Distances in NFPA 55*, Compressed Gas Association, Inc. www.cganet.com

CGA P-74, *Standard for Tube Trailer Supply Systems at Customer Sites*, Compressed Gas Association, Inc. www.eiga.eu

EIGA Doc 244, *Reciprocating Cryogenic Pumps and Pump Installations for Hydrogen and Liquefied Natural Gas*, www.eiga.eu

CGA PS-69, *Position Statement on Liquid Hydrogen Supply Systems Separation Distances*, Compressed Gas Association, Inc. www.cganet.com

Appendix A—Additional Requirements
(Normative)

A1 Lockout/tagout methodology

EU-OSHA, (USA 29 CFR 1910.147), *Control of Hazardous Energy*, requires that hazardous energy sources be identified and controlled when performing maintenance work on equipment [10]. Sources of energy can be any of the following:

- electrical;
- mechanical;
- hydraulic;
- thermal;
- pneumatic;
- chemical; or
- residual.

EU-OSHA requires the use of locks and tags and other hardware necessary to effectively control access to equipment isolation devices that can energise equipment or release energy while active work is being performed [12]. It also requires residual energy be controlled, such as inerting piping or pressure depletion that can be harmful during the maintenance work. Each employer is required to identify all of the energy sources associated with the hazardous work they perform, and to prepare work instructions for the maintenance tasks. They are also required to provide training to personnel who are authorised to perform the maintenance work, and all affected by such work.

Lockout/tagout is the process used to contain energy. Lockout means to place a lock on a device that prevents energy release. Tagout means to place a tag on a switch or other shut off device that warns not to start that piece of equipment.

A2 Hot work

Performing maintenance on a system that contains hydrogen, or within the vicinity of a system containing hydrogen, has unique risks. According to EU-OSHA, hot work means riveting, welding, flame cutting, or other fire or spark-producing operations [10].

Tools and instrumentations shall be rated for electrically classified areas if used permanently installed and/or left unattended.

Tools and instruments not rated for electrically classified areas may only be used if the area of use is declassified. This includes cell phone use.

Hot work areas are declassified when the following activities have been performed:

- area is monitored by local gas detectors;
- precautions are taken to minimise the likelihood of potential venting;
- area has at least two trained and authorised personnel on site; and
- potential hydrogen sources have been isolated.

See reference [17] , for more information regarding the use of non-sparking tools.

A3 Checking for leaks

For the transfer equipment (site equipment used to transfer product to either customer storage or mobile storage), ensuring the sealing integrity of a piping system is critical to ensuring a system can operate safely.

Systems shall be checked for leaks:

- initially when the system is commissioned into service;
- annually as part of a preventive maintenance plan; and
- whenever leaks are suspected to exist in the system.

Initially, when the system is commissioned into service, the system shall be leak tested as part of a pneumatic pressure test using an inert gas. It is recommended to use a "small molecule" leak test using helium or at least a 5% helium/balance nitrogen mixture for larger volumes.

Annually, a transfill system should be leak tested as part of the annual inspection of the system. This leak check is not intended to check the piping system at the system design pressure, rather, the system shall be bubble-leak tested at its operating pressure. Any resulting leaks shall be repaired.

When new piping systems are installed or changes are made to existing systems, pneumatic pressure testing of the piping system shall be conducted to ensure the structural integrity and leak tightness of a piping system. For hydrogen supply systems, the pneumatic leak test procedure in ASME B31.12, *Hydrogen Piping and Pipelines*, shall be carried out [18]. It is critical to perform this test with an inert gas, preferably helium or a 5% helium/balance nitrogen mix, prior to placing the system in hydrogen service.

Management of any pneumatic pressure testing shall be carried out by trained individuals.

The maximum allowable working pressure (MAWP) of all components in the system shall be verified and confirmed to meet the design pressure of the system prior to commencing any pressure testing.

All non-destructive testing (NDT) and quality control (QC) testing of welds shall be carried out prior to performing the pressure test. All mechanical joints (threaded, compression fittings, flanges) shall be checked for proper installation as an initial visual inspection prior to pressure testing.

CAUTION: *Pneumatic pressure testing is a hazardous activity due to possible release of energy stored in compressed gas. All personnel involved shall exercise extreme caution.*

Appendix B—Marking and labeling (Normative)

Marking and labeling are required by regulations, under ADR (DOT) and EU-OSHA, and emergency response codes adopted by state and local regulation. All container units shall be marked and labeled in accordance with requirements prescribed by the applicable authorities, as follows:

- in transportation, under ADR [13] (DOT's *Hazardous Materials Regulations* [14]);
- in the workplace under EU-OSHA's *Hazard Communication Standard* [10];
- as a stationary tank and hazardous material storage area under the local fire code.

B1 In transportation

Each liquid and gaseous hydrogen bulk unit in transportation shall be placarded, and in proximity marked with a proper shipping name and UN identification number. Placement shall be located on each side of the container.

For liquid and gaseous hydrogen, the placards and associated markings are illustrated in Figure B-1.

Hydrogen, refrigerated liquid **Hydrogen, compressed**

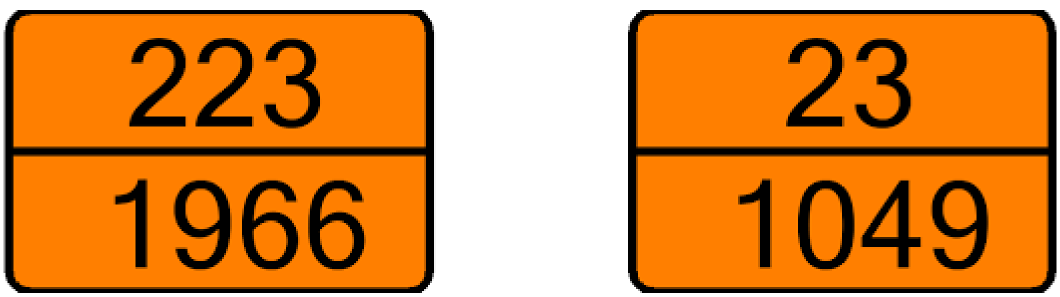


Figure B-1 - Hydrogen placards

B2 In the workplace

Liquid and gaseous hydrogen bulk hydrogen supply systems shall be labeled with hazard symbols, a signal word, hazard statements, precautionary wording for storage and use, first aid information, business name, address, and telephone number. Placement for trailers should be located on the inside of the valve control box door. For stationary containers, they shall be located where they are likely to be read by affected personnel, such as on the container at eye level.

For liquid and gaseous hydrogen, workplace typical markings are illustrated in Figure B-2 and Figure B-3.

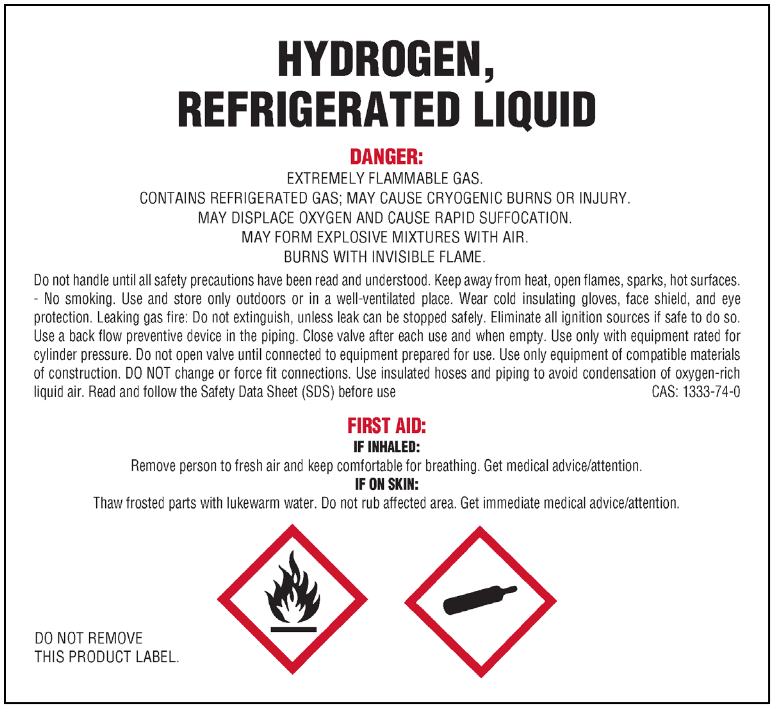


Figure B-2 - Liquid hydrogen workplace label

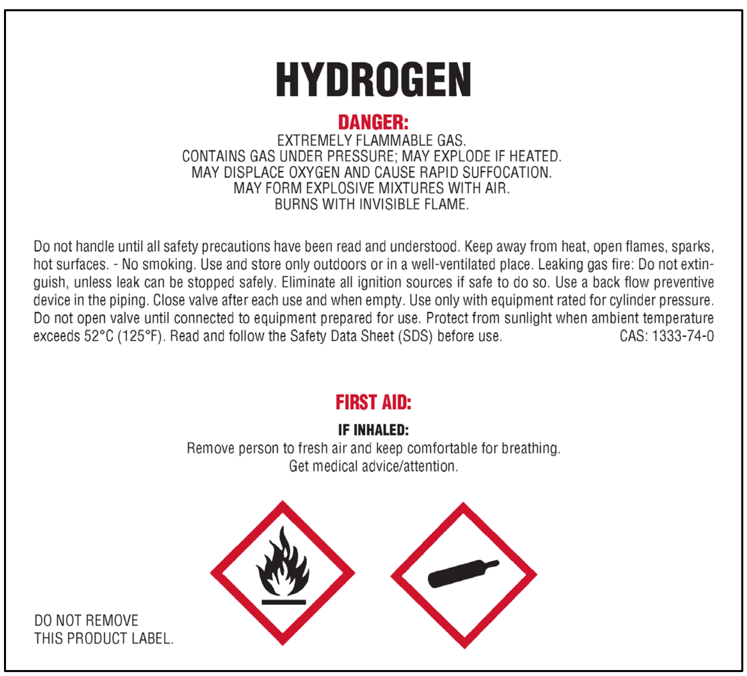


Figure B-3 - Gaseous hydrogen workplace label

B3 State and local hazard identification signs for emergency response

Stationary tanks shall also be marked with hazard identification signs in accordance with national/regional regulation [19]. The marking shall be located on the tank, so it is visible from the approach by emergency responders. Also, many local jurisdictions may require these signs on gates, storage areas, and building doors, so they are visible upon entry. Typical hazard identification signs for liquid and gaseous hydrogen are illustrated in Figure B-4.

NOTE—Hazard identification signs shall not be applied to containers in transportation.

Figure B-4 - Hazard identification signs for liquid hydrogen and gaseous hydrogen

Appendix C—Additional Information
(Informative)

C1 Contract work

Contract work performed around hydrogen installations and associated maintenance activities should be performed under the supervision of the facility or terminal management. Contract work such as grass cutting, fence construction, or pavement repair, among others, can create a hazard to a hydrogen installation, as well as personnel performing such work; this includes facility employees and bystanders. The scope of the work to be performed, and the associated hazards, should be assessed and understood by all parties before commencing work. Collaboration should occur between the facility management and contractor personnel to assure hazards are identified, rules and procedures are in place and understood, and affected personnel are informed and trained as necessary.

C2 Practices in the event of a hydrogen spill

Some general principles and best practices to follow in the event of a fire or a liquid hydrogen spill are listed below but do not replace the material in the SDSs and regulations (e.g. ADR or DOT):

- Isolate the area by 100 m (330 ft) in all directions;
- Cordon off the area or provide other methods to keep unauthorised personnel away from the site;
- Isolate the source of hydrogen if remote shut-offs are available;
- Allow the fire to burn out rather than trying to extinguish the fire;
- Move undamaged tube trailers and cylinders, if safe to do so;
- Shut off all ignition sources within the 100 m (330 ft) radius area;
- Direct water spray onto equipment near the fire to keep it cool;
- Do not direct water to hydrogen spills, pressure relief devices, or vent stacks;
- Do not allow emergency responders to use water to extinguish hydrogen fires. Water can only be used to cool the trailer or surrounding equipment. Do not allow emergency responders to use water near the vent stack or valves. This can lead to water ice freezing the vent stack closed, leading to an inability to release internal tank pressure through the safety relief valve systems; and
- Never attempt to extinguish a hydrogen fire with a fire extinguisher. Trailer mounted fire extinguishers are to be used only to combat external fires such as tire fires. Carbon dioxide fire extinguishers shall not be used around hydrogen installations. The dry ice formed by the extinguisher can create extremely high static electrical charges that could cause fires or explosions. Fire extinguishers shall be used only in fighting tire or other fires that do not involve hydrogen.

C3 Example periodic inspection list

In order to maintain a cryogenic vessel in good operating condition, certain system components should be inspected on a periodic basis. The following are recommended inspection intervals for system components:

- Weekly—Inspect the fill hoses during a fill event. Monitor fill bayonet connector seals for excessive leaks during a fill event. Replace the seals as necessary. Ensure area public utility drains (sewer) are closed. Check for leaks and malfunctions in the valves, piping, and tank. Repair as necessary;
- Monthly—Inspect the liquid hydrogen storage tank for signs of corrosion. Make sure the fire extinguishers are charged and functional. Perform a functional check of all valves. Inspect the line safeties, pump line manifold jacket safeties, and tank safety valves. Replace as necessary. Trees should not be allowed to overhang on hydrogen equipment. Leaves, branches, and other debris should not be allowed to accumulate on the site;

- Quarterly—Recharge the fire extinguishers;
- Annually—Inspect the inner vessel safety heads and secondary rupture disk. Replace as necessary. Inspect the tank jacket lift safety heads to ensure it has not been altered. Check the vacuum in the storage tank annular space and in the vacuum-jacketed piping. Repair/pump down as necessary per tank manufacturer's procedures;
- Every 3-5 years—Test the pressure relief devices (PRDs); and
- Every 5 years—Replace the rupture disks.

Important maintenance actions and inspections for liquid hydrogen storage tanks, both scheduled and unscheduled, should be recorded in a facility maintenance system. Be sure to note any adjustments, alterations, and parts replacements.