Department of the Air Force
HQ AEDC (AFMC)
Arnold AFB, TN 37389

Safety, Health, and Environmental Standard

Title: **GASEOUS HYDROGEN**

Standard No.: E3

Effective Date: 11/30/2010

The provisions and requirements of this standard are mandatory for use by all personnel engaged in work tasks necessary to fulfill the AEDC mission. Please contact your safety, industrial health and/or environmental representative for clarification or questions regarding this standard.

Approved:

Contractor/ATA Director
Safety and Health Group

Air Force Functional Chief

Record of Review/Revision

Date/POC	Description
11/04/2010 Roosa	Two-year review, updated to new format; added Section 5.0 Training and 6.0 Inspections and Audits; verified references, no changes were required as of the time of this review.
05/26/09 Roosa	Annual review; no changes required.
05/06/08 Roosa	Annual review; no changes required.
06/11/07 Roosa	Annual review; no changes required.
06/01/06 Roosa	Annual review; no changes required.
06/14/05 Roosa	Annual review; no change required.
02/18/04 Roosa	Verified referenced standards for consistency and accuracy and made minor technical and formatting changes throughout; added "uncontrolled copy" statement.
08/27/02	Reformatted entire standard according to COI 91-5. Added definitions and reference to the text *Fundamentals of Industrial Hygiene*, 4 Ed., by the National Safety Council.

Safety, Health, and Environmental Standard

GASEOUS HYDROGEN (GH_2)

1.0 INTRODUCTION/SCOPE/APPLICATION

1.1 Introduction – This standard provides information on the properties and hazards of gaseous hydrogen (GH_2).

1.2 Scope – Establishes controls for safe use of GH_2 at AEDC. If there are any conflicts noted between this standard and industry or national codes, standards or regulatory requirements, the operating contractor shall notify the government.

1.3 Application - Departments and divisions develop and apply procedures and work methods using the content herein as minimum guidelines for all phases of gaseous hydrogen work. Properties of gaseous hydrogen are listed in the annex to this standard. Supplementary material is provided in the sources listed under "References."

2.0 BASIC HAZARDS/HUMAN FACTORS

2.1 Health

2.1.1 Gaseous hydrogen is a colorless, odorless gas and is not detectable by the other senses.

2.1.2 Gaseous hydrogen will react violently with strong oxidizers; it ignites easily with oxygen and spontaneously with fluorine and chlorine tri-fluoride.

2.1.3 Gaseous hydrogen is not toxic but can cause asphyxiation by displacement of oxygen in confined spaces; therefore, good ventilation is essential. Gaseous hydrogen is lighter than air at normal temperatures and tends to rise. Below -418°F, immediately after evaporation from liquid, it is heavier than normal ambient air and tends to fall. The cold hydrogen gas displaces warmer air, thus producing an oxygen deficient atmosphere. Unless confined, gaseous hydrogen dissipates rapidly. Forced ventilation expedites dissipation.

2.2 Fire

2.2.1 Gaseous hydrogen may form a flammable mixture when mixed with air. As seen by the properties listed in the annex, the flammable range is wide. Ignition may occur with a very low energy input (one tenth that of a gasoline-air mixture). Ignition of hydrogen/air mixtures can be initiated by heat, spark or an open flame.

2.2.2 A temperature in excess of 1,000°F is required for ignition at atmospheric pressure. However, at less than atmospheric pressure, i.e., at 0.2 to 0.5 atmospheres, ignition occurs at temperatures as low as 650°F if maintained long enough. At pressures less than 0.066 (0.9702 psi) atmospheres, hydrogen/air mixtures do not ignite.

2.2.3 Hydrogen flames are colorless. Unless viewed through an infrared viewer, any visibility is caused by impurities/contaminants present when burned.

2.2.4 The primary method for extinguishing a hydrogen fire is shutting off the hydrogen supply. A water spray can be used to cool adjacent equipment. Steam and CO_2 may also used to extinguish hydrogen fires.

2.3 Explosion of Hydrogen-Air Mixture

2.3.1 Hydrogen gas can burn in two modes. The primary mode of burning is called deflagration, in which the flame front travels through the mixture at subsonic speeds. Under these conditions, the flame speed may travel from 10 to several hundred feet per second. The rapid expansion of hot gases causes a pressure front capable of damaging nearby structures.

2.3.2 In the other mode of burning, detonation, the flame front and resultant shock wave travel through the mixture at speeds greater than the speed of sound within the medium. Detonation typically occurs only when the mixture has been shocked into detonation by another detonation (blasting cap, primary explosion) or when confined by at least 3 sides.

2.4 Diffusion

2.4.1 Hydrogen diffuses approximately 3.8 times faster than air. A spill on the ground of 500 gallons of liquid hydrogen diffuses to a non-explosive mixture after approximately one minute.

2.4.2 Air turbulence increases the rate of hydrogen diffusion.

2.5 Leakage

2.5.1 Hydrogen gas is particularly subject to leakage because of its low viscosity and low molecular weight. Leakage is inversely proportional to viscosity.

2.5.2 When an accumulation of hydrogen is discovered, personnel must evacuate the area. Personnel entry is permitted only after it has been determined that a non-flammable atmosphere exists.

3.0 DEFINITIONS

Asphyxiation – Impairment or death caused by human exposure to an oxygen-deficient atmosphere without other means of obtaining breathable air, such as supplied air respirator or self contained breathing apparatus.

Deflagration – Burning in which the flame front travels through a mixture at subsonic speeds.

Detonation – Burning in which the flame front creates a shockwave that travels through the mixture at supersonic speed.

Flammable mixture – A combination of flammable substance and air that will burn (at normal concentrations of air).

4.0 REQUIREMENTS/RESPONSIBILITIES

4.1 Detection of Flammable Mixtures

4.1.1 Lower explosive limit (LEL) meters/detection systems should be used for detecting the presence of free hydrogen in areas where hazardous accumulations may exist.

4.1.2 To be effective, LEL detection equipment must have sufficient response to avoid hazardous accumulations. Detection pickups should be critically located to minimize sampling time.

4.1.3 Fixed LEL detection systems should automatically effect shut-off, start area ventilating systems, and actuate a warning alarm when a prescribed limit is exceeded.

4.1.4 Only LEL systems validated for hydrogen-air atmospheres should be used.

4.2 Building Construction

4.2.1 Hydrogen operations should be conducted out-of-doors where leaks are easily diffused and diluted to non-flammable mixtures.

4.2.2 If protection from the weather is required, the order of preference for buildings made of noncombustible materials is as follows:

4.2.2.1 Roof without peaks and open sides

4.2.2.2 Well-ventilated roof and removable sides

4.2.2.3 Well ventilated expendable building

4.2.2.4 Well ventilated permanent building with explosion relief areas in sides

4.2.3 Explosion relief areas of 10 square feet should be provided for each 30 standard cubic feet of hydrogen gas present.

4.2.4 Ceiling areas must be constructed to eliminate/minimize accumulations of hydrogen gas or potential collection areas must be well ventilated.

4.2.5 Permanently enclosed buildings containing hydrogen should be equipped with a continuous hydrogen gas detection system with an audible alarm.

4.3 Electrical Equipment

4.3.1 Electrical equipment installed in hydrogen use areas must meet the requirements in Article 500 of the National Electric Code.

4.3.2 In lieu of the above, electrical devices can be totally enclosed and purged with an inert gas, provided the purge system is alarmed in the event of loss of flow.

4.3.3 Electrical equipment that does not meet either of the above two requirements can not be used during operations and must be de-energized when hydrogen is present.

4.3.4 In areas where flammable mixtures of hydrogen gas may accumulate, lines and equipment, fixed or movable, must be grounded to prevent accumulation of static electricity.

4.4 Metals

4.4.1 Many metals lose some of their strength properties because of hydrogen embrittlement. Generally, nickel monel, inconel, austenitic steels (types 304, 304L, 308, 316, and 321), brass, bronze, aluminum, and copper possess satisfactory properties for use in gaseous hydrogen systems. However, pressure and temperature limitations are to be considered when selecting these metals. Carbon steel must be avoided.

4.4.2 Stainless steel type 347 has limited use in hydrogen systems because it is difficult to weld. It should not be used in AEDC piping systems unless approved by the Metallurgical Lab.

4.4.3 Use of the stabilized 18-8 (18 Cr and 8 Ni) series stainless steels is preferred.

4.4.4 The Metallurgical Lab should be contacted concerning the selection of the material for hydrogen service.

4.5 Piping and Tubing

4.5.1 Piping must be installed in accordance with AEDC Engineering Standard T2, Pressure Piping, and Safety Standard D2, Pressure Vessels and Systems. Cast iron pipe and fittings must not be used.

4.5.2 High-pressure piping should be installed with sufficient flexibility to prevent thermal expansion or contraction from causing excessive stresses in the system material.

4.5.3 Threaded joints are acceptable for use in gaseous hydrogen systems, provided they meet the requirements specified in AEDC Engineering Standard T2.

4.5.4 High-pressure gaseous hydrogen lines should be constructed of welded pipe whenever practicable.

4.5.5 Piping and tubing systems must be identified in accordance with Safety Standard D3, Identification of Piping Systems.

4.5.6 Piping and tubing systems must be tested in accordance with AEDC Engineering Standard T2 and Safety Standard D2.

4.6 Valves

Criteria, such as system application, operating pressure, temperature data, environmental requirements, and service fluid, must be determined and considered before valve selection is made.

4.7 Gauges

4.7.1 Gauges must comply with the provisions of Safety Standard D2.

4.7.2 Gauges must be made of stabilized stainless steel (e.g., types 316, 321, and 347), phosphor bronze, and beryllium-copper alloy for bourdon tubes in hydrogen service.

4.8 Pressure-Relief Devices

4.8.1 Hydrogen piping/tubing systems and storage vessels must be equipped with pressure-relieving devices in accordance with the ASME Code and Safety Standard D2.

4.8.2 Relief device discharges must be directed away from normal walkways or areas where personnel are working.

4.9 Venting of Flammable Hydrogen Concentrations

4.9.1 Hydrogen must be discharged to the atmosphere at a minimum height of 15 feet above roof level.

4.9.2 Vent discharge openings will be located so that hydrogen is not drawn into the building ventilation system.

4.9.3 Vent lines must have a check valve installed near the atmospheric discharge to prevent a backflow of air.

4.9.4 Vent stacks greater than one inch in diameter must be purged with an inert gas before and after hydrogen venting.

4.9.5 Flaring (burning dimly) of vented hydrogen is permissible.

4.9.6 When hydrogen lines enter buildings, two valves must be installed in the line with an atmospheric discharge between them (double block and bleed), all positioned external to the building.

4.10 Storage

4.10.1 Warning signs must be permanently erected around the storage areas as follows: "HYDROGEN-FLAMMABLE GAS - NO SMOKING OR OPEN FLAMES."

4.10.2 Fire-fighting equipment must be provided. The Fire Department should be consulted on this requirement.

4.10.3 Hydrogen storage vessels should be located outdoors, if possible.

4.10.4 Compressed gas cylinders containing gaseous hydrogen should be stored according to CFR 1910.103 and be separated from oxidizers by at least 20 feet or by a fire-resistant barrier.

4.11 Compatibility Data

The materials selected for use in gaseous hydrogen systems must be compatible.

5.0 TRAINING

5.1 Employees who work with gaseous hydrogen shall be trained in proper use and handling.

6.0 INSPECTION/AUDITS N/A

7.0 REFERENCES

7.1 AEDC Safety, Health and Environmental Standards
D2, Pressure Vessels and Systems
D3, Identification of Piping Systems

7.2 AEDC Engineering Standards
T-1, Pressure Vessels
T-2, Pressure Piping
T-3, Engineering Design and Drafting Practices

7.3 Code of Federal Regulations (CFR)
CFR OSHA Standard 1910.103, Hydrogen

8.0 ANNEX

Properties of Gaseous Hydrogen

ANNEX

PROPERTIES OF GASEOUS HYDROGEN

Molecular Weight..2.016
Specific Gravity - Vapor Density...0.07 (Air = 1.00)
Density of Gas at Boiling Point..0.081 lb_m/ft^3 (1.3 g/1)
Boiling Point ....-423.13^{o}F (-252.85^{o}C)
Freezing Point ....-434.45^{o}F (-259.14^{o}C)
Density of Gas at Room Temperature..0.051 lb_m/ft^3 (0.82 g/1)
Upper Flammable Limit...75%
Lower Flammable Limit...4%
Auto-ignition Temperature in Air ....1065^{o}F (574^{o}C)
Heat of Vaporization...191.7 BTU/lb_m (106.5 cal/g)
Heat of Combustion ....57.8 kcal/mole
Liquid to Gas Expansion Ratio 865
Temperature Range at Which Gas is Heavier than Air ....-423.13^{o}F to –418^{o}F